

[001] METHOD AND APPARATUS FOR UTILIZING A DIRECTIONAL
BEAM ANTENNA IN A WIRELESS TRANSMIT/RECEIVE UNIT

[002] FIELD OF INVENTION

[003] The present invention is related to a wireless communication system. More particularly, the present invention is a method and apparatus for utilizing a switched beam directional antenna in a wireless transmit/receive unit (WTRU) operating in a cellular network. The present invention is applicable to any wireless communication system including, but not limited to, Global System For Mobile Communications (GSM), General Packet Radio System (GPRS), and Enhanced Data Rates For GSM Evolution (EDGE).

[004] BACKGROUND

[005] One of the most important areas in cellular technology development is the exploration of ways to improve the capacity of the system. Spectral efficiency and power consumption in mobile systems are forcing wireless communications designers to explore new areas in the technology that will offer capacity relief. One of these new areas being explored is the use of directional beam antennas to improve the link margin of the forward and reverse links between a base station and a WTRU. The increased gain of the directional antenna over the typical omni-directional antenna provides increased received signal level at the WTRU receiver allowing the base station to transmit at a lower power level. This allows more users to be simultaneously active, (i.e., more capacity), and lowers the interference seen by WTRUs in adjacent cells.

[006] Directivity of the antenna in a WTRU can also provide a reduction in the interference level from signals received from adjacent base stations. The reverse link from the WTRU to the base station enjoys the same link margin improvement, thereby allowing the WTRU to transmit at lower power level. This reduces the interference seen at base stations of adjacent cells and can lengthen the battery life at the WTRU.

[007] The use of a directional antenna at a WTRU requires decisive reference to the signal level measurements on each of the directional beams in

order to select the best directional mode of the antenna. In a mobile communication network, the WTRU must continually monitor the received signal level in each of the directional modes and periodically reselect the best directional mode to accommodate environment changes and movement of the WTRU. In a GSM network where a TDMA scheme is employed to accommodate multiple users, inactive timeslots, (i.e., where the WTRU is not required to transmit or receive), can be used to make these measurements. However, the signal level received at the WTRU constantly changes due to multi-path propagation. Thus, measuring a higher received signal level in one direction versus another at a given time may not result in the best directional beam selection.

[008]

SUMMARY

[009]

The present invention is a method and apparatus for steering a switched beam directional antenna employed at a WTRU operating in a wireless system, including, but not limited to, GSM/GPRS/EDGE type cellular systems. The WTRU measures the received signal from the serving base station in each of the directional modes of the switched beam antenna and selects the direction having the best signal. The measurements are made during inactive timeslots where the WTRU is not required to transmit or receive. Typically, the WTRU is assigned one timeslot to transmit and one timeslot to receive of the eight TDMA slots available in the GSM system, leaving six inactive timeslots.

[010]

The signal measurement in each directional mode can be formed from the total received signal power averaged over the timeslot, (hereafter called the received signal strength indication or RSSI), received on the BOCH from the serving base station. It can also be formed from an average over a portion of the timeslot. This allows multiple beams to be measured within the same timeslot, thereby reducing the time required to develop a beam selection decision.

[011]

Alternatively, the signal quality or carrier-to-interference ratio (CIR) of the signal received from different directional modes of the antenna may be measured using the midamble of the GSM burst waveform. This technique

would be applicable when measuring traffic channel slots that can also contain interference from adjacent base stations. The midamble contains a known data sequence used to discriminate between the desired signal, (i.e., the serving base station), and interfering signals received from other base stations.

[012] In general, the beam selection decision does not rely on a single set of measurements because of signal level fluctuations due to multi-path fading. Averaging the measurements from each direction prior to selecting the best direction is an effective technique. Alternately, when measuring several beams within the same timeslot, the signal level differences seen timeslot-by-timeslot can be used to form the beam selection decision.

[013] When performing received power measurements of neighbor cells for handoff decisions, the WTRU would be restricted to the omni-directional antenna. This provides consistent relative signal strength measurements of neighboring cells that may appear at different angles of arrival. However, if the WTRU has spare processing power to collect multi-beam measurements on neighbor cells, handoff to a directional beam may be considered.

[014] BRIEF DESCRIPTION OF THE DRAWINGS

[015] A more detailed understanding of the invention may be had from the following description of a preferred embodiment, given by way of example and to be understood in conjunction with the accompanying drawings wherein:

[016] Figure 1 is a diagram of a wireless communication system operating in accordance with the present invention;

[017] Figure 2 is a flow diagram of a process for utilizing a directional beam antenna in a WTRU of the system of Figure 1;

[018] Figure 3 is an exemplary directional beam pattern generated by the WTRU of the system of Figure 1;

[019] Figure 4 is a block diagram of a WTRU configured to utilize a directional beam antenna in the system of Figure 1;

[020] Figures 5 and 6 are time masks for normal duration bursts at GMSK modulation and 8-PSK modulation, respectively;

[021] Figure 7 is an example of three measurement intervals within a single timeslot in accordance with the present invention;

[022] Figure 8 is a diagram of GMSK normal burst bit structure;

[023] Figure 9 is a GSM multi-frame with occurrences of neighbor cell measurements (FN) and serving cell measurements (FS), wherein each frame type is exploded to detail the activities in the eight timeslots of the frame;

[024] Figure 10 is a TDMA time frame; and

[025] Figures 11-14 are flow diagrams of processes for selecting an active beam in accordance with the present invention.

[026] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[027] Hereafter, the terminology "WTRU" includes but is not limited to a user equipment, a mobile station, a fixed or mobile subscriber unit, a pager, or any other type of device capable of operating in a wireless environment. When referred to hereafter, the terminology "base station" includes but is not limited to a Node-B, a site controller, an access point, or any other type of interfacing device in a wireless environment.

[028] The features of the present invention may be incorporated into an integrated circuit (IC) or be configured in a circuit comprising a multitude of interconnecting components.

[029] The steering algorithm in accordance with the present invention provides an approach for steering a directional antenna (Subscriber Based Smart Antenna - SBSA) in a GSM/GPRS/EDGE handset for communicating with the network. This approach can be accomplished within the current GSM/GPRS/EDGE standards and deployed in existing networks, although the present invention is not limited to those standards.

[030] The present invention comes into operation after a handset has registered with the network and is using a specific serving cell ARFCN (Absolute Radio Frequency Channel Number). The omni-directional mode of the antenna would be typically used prior to registration, although this is not required. The technique for steering the antenna may be performed while the handset is in an

idle mode or during an active call/data transfer. During an antenna scan, the steering algorithm cycles through the antenna positions and uses an inactive timeslot to monitor signal strength of the serving cell broadcast common control channel (BCCH), since it is always active and is transmitted at a constant power. The antenna position is selected based on the strongest signal level monitored.

[031] Steering the antenna requires periodic measurements of the available directional modes to maintain the best pointing direction when the WTRU is moving. These signal strength measurements are preferably performed during "inactive" timeslots where the WTRU is not required to demodulate data. This eliminates any loss of data due to mis-pointing the antenna. Further, the antenna measurements are performed in timeslots where the serving cell is known to be transmitting.

[032] The signal strength of two antenna modes can be measured during the midamble of the GSM timeslot. The first half of the midamble containing a known data sequence would be received in one directional mode and the second half of the midamble would be received in another directional mode. A comparison of these two signal strength measurements serves to determine which mode is providing a better signal level. On a spare BCCH time slot, signal strength measurement of some number of antenna modes can be performed, limited by the transition requirements of the measurement and antenna switching unit(s).

[033] When performing received power measurements of neighbor cells for handoff decisions, the WTRU may be restricted to the omni-directional antenna. This provides consistent relative signal strength measurements of neighboring cells that may appear at different angles of arrival.

[034] Figure 1 is a diagram of a wireless communication system 100 operating in accordance with the present invention. The wireless communication system 100 includes a plurality of WTRUs 102_{a-c} and base stations 104_{a-c}. A coverage region of the wireless communication system 100 is divided into a plurality of cells 106_{a-c}. Each cell 106_{a-c} is covered by a respective base station

104_{a-c}. A WTRU 102_{a-c} transmits messages to, and receives messages from, a base station 104_{a-c} in a respective serving cell 106_{a-c}.

[035] The WTRU 102_{a-c} is configured to generate a narrow directional beam which radiates signals only in a particular direction, and preferably may also generate an omni-directional beam which radiates signals in all directions at the same power level. The WTRU 102_{a-c} preferably uses an omni-directional beam before the WTRU 102_{a-c} is registered with a wireless communication network. However, the WTRU 102_{a-c} may also use a directional beam before registration. Upon registration, the WTRU 102_{a-c} is assigned a channel to be used for communication with the base station 104_{a-c}.

[036] In accordance with the present invention, each WTRU 102_{a-c} uses a directional beam for the transmission and receipt of signals to and from the serving base station 104_{a-c} within the respective cell 106_{a-c}. As the WTRU 102_{a-c} moves, the WTRU 102_{a-c} needs to constantly adjust the direction of the directional beam. The WTRU 102_{a-c} is configured to switch the direction of the directional beam among a plurality of positions in order to maintain the best signal quality from the serving cell 106_{a-c}. In order to maintain the best direction for radiating signals, the WTRU 102_{a-c} must perform periodic measurements of the signal quality in each position of the beam pattern.

[037] Figure 2 is a flow diagram including method steps of a process 200 for utilizing a directional beam antenna in a WTRU, for example WTRU 102_a. In step 202, the WTRU 102_a registers with the wireless communication system 100. In order to perform physical measurements, the WTRU 102_a preferably receives and processes messages transmitted from a base station 104_a in a serving cell 106_a via a pilot channel or a broadcast channel, such as broadcast common control channel (BCCH) (step 204). The messages transmitted via the pilot channel or broadcast channel are always available and are transmitted at a known transmission power level. Therefore, the WTRU 102_a utilizes the messages to measure signal quality in each of a plurality of directions (step 206).

[038] In step 208, the WTRU 102_a selects a beam from the direction having the best signal quality. In selecting the best directional beam, the WTRU

may base its decision on the average or differences of some number of signal quality measurements made for each directional beams. In step 210, the WTRU 102_a communicates with the serving cell 106_a steering a directional beam in the selected direction. Since it is assumed that the WTRU 102_a constantly moves, the beam direction is constantly adjusted to maintain the best direction.

[039] In step 212, the WTRU 102_a periodically monitors the signal quality of the messages received from a pilot channel, a broadcast channel, or a traffic channel in the current beam direction. The frequency of measurements should be high enough to accommodate the movement of the WTRU 102_a.

[040] The WTRU 102_a may monitor signal quality only in an idle time slot in order to save processing power. If, as determined in step 214, the signal quality on the current beam direction drops below a predetermined threshold, the process 200 returns to step 206 to perform the measurements again in all other directions, in turn, and selects and switches to the beam direction having the best quality. If the signal quality on the current beam direction does not fall below the predetermined threshold, the WTRU 102 maintains the current beam direction (step 216) and continues to monitor the quality of the current beam direction, and the process returns to step 210. The threshold can be a predetermined signal quality, signal strength, or time period. The signal quality is preferably measured using a received signal strength indicator (RSSI) or a carrier-to-interference ratio (CIR). It should be noted that other parameters may be utilized alternatively or in combination to measure signal quality. Alternatively, the WTRU may rescan the antenna modes periodically instead of rescanning in accordance with the result of comparison with the threshold. A threshold scheme is more useful in a WLAN application where a multipath environment is more stationary.

[041] Figure 3 shows an example of a directional beam pattern generated by the WTRU 102_a. In this example, the WTRU 102_a establishes the beam pattern by switching the beam direction among eight predetermined positions and performs physical measurements in each of the eight positions or directions. Of course, those with skill in the art would realize that although there are eight

pre-determined positions shown in Figure 3, greater or fewer positions may be utilized.

[042] Figure 4 is a block diagram of a WTRU, for example WTRU 102_a. The WTRU 102_a includes a switched beam directional antenna 402, a receiver/transmitter 404, a beam steering unit 406, a baseband processor 408, and a controller 410.

[043] A received signal is fed from the receiver/transmitter 404 into the baseband processor 408 and the controller 410. The baseband processor 408 measures the signal quality of the received signal.

[044] The beam direction is switched among a plurality of predetermined positions, in turn, and in each direction, the signal quality is measured. The controller 410 compares the measurement results and selects a direction having the highest signal quality. It should be noted that the measurements need not be made on different positions in a particular order, (e.g., such as clockwise or counter-clockwise). For example, the measurements may begin in the direction of the previous "best signal" and then the two positions on either side of the position having the previous best signal may be selected for measurement, and so on. A random scheme may also be applied.

[045] A communication between the WTRU 102_a and the serving cell 106_a is performed after steering an antenna to the selected direction. During the communication, the controller 410 constantly monitors the signal quality on the current beam direction, and determines whether the signal quality has dropped below a predetermined threshold.

[046] The signal quality of two directions may be measured and compared using a midamble. The first half of the midamble containing a known data sequence is received in one direction and the second half of the midamble is received in another direction. Signal quality is then compared in the two directions, and the comparison determines which direction provides a better signal quality.

[047] A WTRU 102_a may also be configured to generate an omni-directional beam. The WTRU 102_a may utilize the omni-directional beam at the

initial registration with the network and for handover between cells. For handover, the WTRU 102_a has to measure signal quality of neighbor cells. An omni-directional beam provides consistent relative signal strength measurements of neighboring cells that may appear at different angles of arrival.

[048] Since each cell transmits on a different RF channel, (i.e., a different frequency), prior to measuring the quality of any channel, the WTRU must tune its receive frequency to the carrier frequency used by this cell. It takes about 250 microseconds to tune to each new carrier frequency, while measuring the channel quality itself takes perhaps 25 microseconds. Hence, the time required to tune the receive carrier frequency is a substantial part of the total time needed to measure the quality of each channel.

[049] As shown in Figures 5 and 6, the GSM/GPRS/EDGE system applies a constant power (commanded power) time mask for a fixed 542.8 μ s (useful part) of a burst transmission in the TDMA frame. In accordance with the present invention, the receiver signal measurements are averaged over a fixed period after the transient part of the curve as shown in Figure 7.

[050] The SBSA measurements for each beam are to be performed preferably only in the useful part of the burst transmission time period. The 542.8 μ s period is divided into a plurality of parts for measurements. For example, if three beams, (a right beam, a left beam and an omni-directional beam), are used, the 542.8 μ s period in one time slot is divided into three parts for measurement as shown in Figure 7. During each phase there are two stages. The first stage is the hardware preparation for measurement, followed by the actual measurement window as shown in Figure 7 except for the last part where last 4-bits (nu) are not taken into average to avoid a possible 10% transient as in Figure 6.

[051] In the foregoing example of Figure 7, assuming that it takes 150 μ s for measurement preparation, each beam measurement is averaged over 23.5 μ s (6.4 bits) as shown in calculation below.

Left.beam.average period = $(173.5 - 150) * 13 / 48 = 6.4$ bits, i.e., (e40 ~ e46, see Figure 8).

Omni-directional beam average period = $(173.5 - 150) * 13 / 48 = 6.4$ bits, i.e., (e58 + e64).

Right beam average period = $(195.7 - 150 - 577 * 10\% + 34.2) * 13 / 48 = 6$ bits, i.e., (e105 ~ e110).

[052] Alternatively, individual SBSA beams can also be measured on a per time slot basis. In this way, the SBSA beam measurement shall be scheduled alternately on consecutive radio frames of the measured channel. This prolongs the SBSA beam selection period and reduces the response time to environment change by threefold in the foregoing example.

[053] An SBSA-equipped WTRU operating within the communication network must perform channel quality measurements for selection of the active beam, and the WTRU must also perform all the functions normally performed by a prior art GSM/GPRS/EDGE mobile unit. The present invention provides a method for channel quality measurements for SBSA such that the interference with the normal functions of the GSM/GPRS/EDGE WTRU is minimized.

[054] Hereafter, the present invention will be explained with reference to an example WTRU configured to generate three beams; a right beam, a left beam, and an omni-directional beam. However, it should be noted that this is provided only as an example. The WTRU may generate any number of beams and the teachings of the present invention shall not be construed to be limited to any particular number of beams.

[055] Abbreviations used in the following descriptions are as follows:

[056] 1) Neighbor Carriers (NC) - This is a list of the BCCH carriers of the neighboring cells that the WTRU obtains from reading the BCCH channel of its serving cell. It is assumed that there are N carriers in this list denoted by: NC = {f1, f2, ..., fN}.

[057] 2) Ordered Neighbor Carriers (ONC) - This list is constructed by ordering the elements in NC list according to the signal level (i.e., carrier power) of each neighboring carrier measured on the omni-directional beam. This list has N members, and will be denoted by ONC list.

[058] 3) Neighbor Carriers/Beams (NCB) - Each member of this list is a unique combination of one of the carriers in the neighbor list and an SBSA beam (left, right, or omni-directional). This list has $3N$ elements and is denoted by: $NCB = \{f1O, f1L, f1R, f2O, f2L, f2R, \dots, fNO, fNL, fNR\}$.

[059] 4) Ordered Neighbor Carriers/Beams (ONCB) - This list is constructed by ordering the elements in the NCB list according to the signal level of each carrier/beam pair. This list has $3N$ elements and is denoted by ONCB. For example, the second element of ONCB is the neighbor cell/beam with the second highest signal level.

[060] 5) Serving Carrier/Beams (SCB) - Each member of this cell is a unique combination of the BCCH carrier of the serving cell and an SBSA beam (left, right, or omni-directional). This set has three elements and is denoted by: $SCB = \{f0O, f0L, f0R\}$.

[061] 6) Time T1 - The decrementing timer T1 is used to avoid a ping-pong effect in switching the active beam. Each time the active beam is switched, this timer is initialized to T1_MAX. After the active beam is switched, it takes T1_MAX seconds before the timer T1 gets to zero. The active beam can only be changed when T1 is zero.

[062] 7) Subsets of frames in the slow associated control channel (SACCH) block (104 frames) - The measurement procedures repeat at the start of each SACCH block. Each SACCH block consists of 104 consecutive TDMA frames as shown in Figure 9 (only 52 frames are shown in Figure 9 since the other 52 frames are same). Measurement procedures repeat every 104 frames. Four of these 104 frames must be devoted to decoding base station identity codes (BSICs). Therefore, 100 frames are available for measuring signal level of various BCCH carriers/beams. The 104 frames are divided into three subsets (FB, FS, and FN) as shown in Figure 9, and one TDMA frame structure is depicted in Figure 10.

[063] The FB subset is the set of four TDMA frames devoted to decoding BSICs. Typically, the WTRU attempts to decode the BSIC of six strongest carriers in the neighbor list (in a round robin fashion).

[064] The FS subset is a subset of the 100 TDMA frames during which the WTRU measures the signal level on the BCCH carrier of the serving cell.

[065] The FN subset is the subset of the 100 TDMA frames during which the WTRU measures the signal level on the BCCH carrier of the neighbor cells.

[066] The combined total number of elements in FS and FN is always 100. However, the exact number of elements in FS and FN is a design parameter. Making the FS list larger results in more frequent measurements of the BCCH of the serving cell. Making the FS subset smaller results in more frequent measurements of the BCCH of the neighbor cells. R denotes the ratio of the size of FS divided by the size of FN.

[067] The enumeration ranges from 1 to LISTSIZE, where LISTSIZE is the number of the elements in the foregoing lists. For each list, this enumeration is a one-to-one mapping between $\{1, \dots, \text{LISTSIZE}\}$ and the members of the list. For each list, the index can take values from 1 to LISTSIZE. Each embodiment defines the actions the WTRU should take during each of these 104 frames.

[068] In a first embodiment for active beam selection, the SBSA procedure repeats every SACCH block (104 TDMA frames). The WTRU measures signal strength on all three beams both for the serving cell and for the neighbor cells, and the WTRU is required to decode the BSIC on the new candidate active beam on the BCCH of the serving cell before the active beam is changed. Since the WTRU knows the timing of frames on the serving cell, the WTRU only attempts to decode the BSIC on those idle frames on its traffic channel that coincide with the synchronization frame on the BCCH channel, (i.e., frames (103, 337, 623, 857, 1143)). In this way, the decoding of BSIC for SBSA only uses 10% of the idle frames, (i.e., the impact of decoding BSIC for SBSA on the rest of the system is quite small).

[069] Figure 11 is a flow diagram of a process 1100 for selecting an active beam in accordance with a first embodiment of the present invention. The WTRU obtains the number of the current frame (step 1102). If the frame belongs to FS, the process 1100 proceeds to step 1104 and signals from the serving cell are measured. If the frame belongs to FN, the process 1100 proceeds to step

1110, and signals from the neighbor cell are measured. If the frame belongs to FB, the process 1100 proceeds to step 1116 and the WTRU decodes the BSIC of the new neighbor cell or the serving cell.

[070] If the frame belongs to FS, and it is determined that there is a dormant time slot at step 1104, the signal level of all elements of SCB is measured (step 1106). Then, the running average of the signal level is updated (step 1108). The process returns to step 1104 to determine whether there is another dormant timeslot available. If there is no dormant time slot available, the process 1100 proceeds to step 1126 to determine whether there is another available frame. If so, go to the next frame and the process 1100 returns to step 1102.

[071] Two of the dormant timeslots in each TDMA frame must be used for stabilizing the local oscillator for transmission and reception of data; hence, these two dormant timeslots are not available for above signal level measurement.

[072] If the frame belongs to FN, and it is determined that there is a dormant time slot at step 1110, signal level of all elements of ONCB is measured (step 1112). Then, the running average of the signal level is updated (step 1114). The process returns to step 1110 to determine whether there is another dormant timeslot available. If there is no dormant time slot available, the process 1100 proceeds to step 1126 to determine whether there is another available frame. If so, go to the next frame and the process 1100 returns to step 1102.

[073] Two of the dormant timeslots in each TDMA frame must be used for stabilizing the local oscillator for transmission and reception of data; hence, these two dormant timeslots are not available for above signal level measurement.

[074] If the frame belongs to FB, elements of NCB having the six highest averaged signal levels are determined (step 1116). If it is determined at step 1118 that there are new elements of NCB in the list of elements having the six highest averaged signal levels, the BSIC of the new elements is decoded at step 1120 starting from the strongest element. In decoding the new elements of NCB, if decoding succeeded on the last trial, or the number of attempts to decode on the current trial has exceeded three times, the next element in ONCB is tried. If the

strongest element of SCB is different from the previous one, and if the current frame number (modulo 1326) belongs to the set {103, 337, 623, 857, 1143}, then the BSIC of the new strongest element is decoded (steps 1122, 1124). If the decoding of the BSIC of the new strongest element of SCB succeeded, and the decrementing timer T1 has reached zero, the active beam is set to the new SCB element, and T1 is reset to T1_MAX (step 1130).

[075] In GSM voice, using the SACCH multiframe (which occurs once in every 104 TDMA frames), the WTRU reports to the network the BSICs of the carriers in the neighbor list with the highest six signal levels. In GPRS, the WTRU must report this information to the network anytime the network requests this information.

[076] In a second embodiment for active beam selection, the SBSA procedure repeats every SACCH multiframe (104 TDMA frames). The WTRU measures signal strength on all three beams both for the serving cell and for the neighbor cells, but is not required to decode the BSIC on the strongest active beam prior to switching.

[077] Figure 12 is a flow diagram of a process 1200 for selecting an active beam in accordance with a second embodiment. The WTRU obtains the number of the current frame (step 1202). If the frame belongs to FS, the process 1200 proceeds to step 1204 and signals from the serving cell are measured. If the frame belongs to FN, the process 1200 proceeds to step 1214, and signals from the neighbor cell are measured. If the frame belongs to FB, the process 1200 proceeds to step 1220 and the WTRU decodes the BSIC of new neighbor cell or the serving cell.

[078] If the frame belongs to FS, and it is determined that there is a dormant time slot at step 1204, the signal level of all elements of SCB is measured (step 1206). Then, the running average of the signal level is updated (step 1208). If a new strongest element of SCB is found in step 1210, and timer T1 is zero, the active beam is set to this strongest element of SCB, and the decrementing timer T1 is reset to T1_MAX (step 1212). The process returns to step 1204 to determine whether there is another dormant timeslot available. If

there is no dormant time slot available, the process 1200 proceeds to step 1226 to determine whether there is another available frame. If so, go to the next frame (step 1228) and the process 1200 returns to step 1202.

[079] Two of the dormant timeslots in each TDMA frame must be used for stabilizing the local oscillator for transmission and reception of data. Hence, these two dormant timeslots are not available for above signal level measurement.

[080] If the frame belongs to FN, and it is determined that there is a dormant time slot at step 1214, the signal level of all elements of ONCB is measured (step 1216). Then, the running average of the signal level is updated (step 1218). The process returns to step 1214 to determine whether there is another dormant timeslot available. If there is no dormant time slot available, the process 1200 proceeds to step 1226 to determine whether there is another available frame. If so, go to the next frame (step 1228) and the process 1200 proceeds to step 1202.

[081] Two of the dormant timeslots in each TDMA frame must be used for stabilizing the local oscillator for transmission and reception of data. Hence, these two dormant timeslots are not available for above signal level measurement.

[082] If the frame belongs to FB, elements of NCB having the six highest averaged signal levels are determined (step 1220). If it is determined at step 1222 that there are new elements of NCB in the list of elements having the six highest averaged signal levels, the BSIC of the new elements is decoded at step 1224 starting from the strongest element. In decoding the new elements of NCB, if decoding succeeded on the last trial, or the number of attempts to decode on the current trial has exceeded three times, the next element in ONCB is tried.

[083] In GSM voice, using the SACCH multiframe (which occurs once in every 104 TDMA frames), the WTRU reports to the network the BSICs of the carriers in the neighbor list with the highest six signal levels. In GPRS, the WTRU must report this information to the network anytime the network requests this information.

[084] In a third embodiment for active beam selection, the WTRU measures signal strength on all three beams for the serving cell and on the omnidirectional beam for the neighbor cells. The WTRU is required to successfully decode the BSIC on the new candidate active beam before the active beam is changed. Since the WTRU knows the timing of frames on the serving cell, the WTRU only attempts to decode the BSIC on those idle frames on its traffic channel that coincide with the synchronization frame on the BCCH channel (i.e., frames {103, 337, 623, 857, 1143}). In this way, the decoding of BSIC for SBSA uses only 10% of the idle frames (i.e., the impact of decoding BSIC for SBSA on the rest of the system is quite small).

[085] Figure 13 is a flow diagram of a process 1300 for selecting an active beam in accordance with a third embodiment. The WTRU obtains the number of the current frame (step 1302). If the frame belongs to FS, the process 1300 proceeds to step 1304 and signals from the serving cell are measured. If the frame belongs to FN, the process 1300 proceeds to step 1310, and signals from the neighbor cell are measured. If the frame belongs to FB, the process 1300 proceeds to step 1316 and the WTRU decodes the BSIC of the new neighbor cell or the serving cell.

[086] If the frame belongs to FS, and it is determined that there is a dormant time slot at step 1304, the signal level of all elements of SCB is measured (step 1306). Then, the running average of the signal level is updated (step 1308). The process returns to step 1304 to determine whether there is another dormant timeslot available. If there is no dormant time slot available, the process 1300 proceeds to step 1326 to determine whether there is another available frame. If so, go to the next frame (step 1328) and the process 1300 returns to step 1302.

[087] Two of the dormant timeslots in each TDMA frame must be used for stabilizing the local oscillator for transmission and reception of data; hence, these two dormant timeslots are not available for above signal level measurement.

[088] If the frame belongs to FN, and it is determined that there is a dormant time slot at step 1310, the signal level of all elements of ONC is

measured (step 1312). Then, the running average of the signal level is updated (step 1314). The process returns to step 1310 to determine whether there is another dormant timeslot available. If there is no dormant time slot available, the process 1300 proceeds to step 1326 to determine whether there is another available frame. If so, go to the next frame (step 1328) and the process 1300 proceeds to step 1302.

[089] Two of the dormant timeslots in each TDMA frame must be used for stabilizing the local oscillator for transmission and reception of data; hence, these two dormant timeslots are not available for above signal level measurement.

[090] If the frame belongs to FB, elements of NC having the six highest averaged signal levels are determined (step 1316). If it is determined at step 1318 that there are new elements of NC in the list of elements having the six highest averaged signal levels, the BSIC of the new elements is decoded at step 1320 starting from the strongest element. In decoding the new elements of NCB, if decoding succeeded on the last trial, or the number of attempts to decode on the current trial has exceeded three times, the next element in ONC is tried. If the strongest element of SCB is different from the previous one, and if the current frame number (modulo 1326) belongs to the set {103, 337, 623, 857, 1143}, then the BSIC of the new strongest element is decoded (steps 1322, 1324). If the decoding of BSIC of new strongest element of SCB succeeded, and the decrementing timer T1 has reached zero, the active beam is set to the new SCB element, and T1 is reset to T1_MAX (step 1330).

[091] In a fourth embodiment for active beam selection, the SBSA procedure repeats every SACCH multiframe (104 TDMA frames). The WTRU measures signal strength on all three beams for the serving cell and on omnidirectional beam for the neighbor cell, but is not required to decode the BSIC on the strongest active beam prior to switching.

[092] Figure 14 is a flow diagram of a process 1400 for selecting an active beam in accordance with a fourth embodiment. The WTRU obtains the number of the current frame (step 1402). If the frame belongs to FS, the process 1400 proceeds to step 1404 and signals from the serving cell are measured. If the

frame belongs to FN, the process 1400 proceeds to step 1414, and signals from the neighbor cell are measured. If the frame belongs to FB, the process 1400 proceeds to step 1420 and the WTRU decodes the BSIC of the new neighbor cell or the serving cell.

[093] If the frame belongs to FS, and it is determined that there is a dormant time slot at step 1404, the signal level of all elements of SCB is measured (step 1406). Then, the running average of the signal level is updated (step 1408). If a new strongest element of SCB is found in step 1410, and timer T1 is zero, the active beam is set to this strongest element of SCB, and the decrementing timer T1 is reset to T1_MAX (step 1412). The process returns to step 1404 to determine whether there is another dormant timeslot available. If there is no dormant time slot available, the process 1400 proceeds to step 1426 to determine whether there is another available frame. If so, go to the next frame (step 1428) and the process proceeds to step 1402.

[094] If the frame belongs to FN, and it is determined that there is a dormant time slot at step 1414, the signal level of all elements of ONC is measured (step 1416). Then, the running average of the signal level is updated (step 1418). The process returns to step 1404 to determine whether there is another dormant timeslot available. If there is no dormant time slot available, the process 1400 proceeds to step 1426 to determine whether there is another available frame. If so, go to the next frame (step 1428) and the process 1400 proceeds to step 1402.

[095] If the frame belongs to FB, elements of NCB having the six highest averaged signal level are determined (step 1420). If it is determined at step 1422 that there are new elements of NC in the list of elements having the six highest averaged signal levels, the BSIC of the new elements is decoded at step 1424 starting from the strongest element. In decoding the new elements of NC, if decoding succeeded on the last trial, or the number of attempts to decode on the current trial has exceeded three times, the next element in ONC is tried (not shown in Figure 14).

[096] In GSM voice, during the SACCH frame the WTRU reports to the network the BSICs of the carriers in the neighbor list with the highest six signal levels. In GPRS, the WTRU must report this information to the network anytime the network requests this information.

[097] As a summary, features of the foregoing four embodiments are provided in Table 1.

	Measure all beams for neighbor cells	Decode BSIC for active beam
Procedure 1	Yes	Yes
Procedure 2	Yes	NO
Procedure 3	NO	YES
Procedure 4	NO	NO

Table 1: Features of SBSA Procedures

[098] During each FS frame, the WTRU attempts to decode the BSIC on the BCCH carrier of the serving cell. Since the BSIC is only transmitted in small subset of the time slots on the BCCH carrier of the serving cell, and since the WTRU knows when these timeslots carrying the BSIC occur on the BCCH carrier of the serving cell, it is advantageous to schedule FS frames so that each FS frame coincides with those frames carrying a BSIC on the BCCH of the serving cell.

[099] A similar approach can be applied to scheduling of FN frames, if the WTRU knows when frames carrying BSIC on the BCCH carrier of the neighboring cell occur. In a GSM/GPRS network, each WTRU always synchronizes itself to the timing of its serving cell. Hence, the WTRU always knows when the frames carrying BSIC will occur on the BCCH carrier of its serving cell. However, a GSM/GPRS WTRU is typically not synchronized to the neighboring cells (and different cells in GSM/GPRS are not synchronized together). Hence, acquiring timing of neighboring cells is an extra step for the WTRU.

[0100] In accordance with the present invention, data reception on the traffic channel is not affected by implementation of SBSA. The measurements for SBSA beam selection are performed during the idle frames and dormant timeslots. The most important choice to make is whether to measure the signal

strength on all three beams for the carriers in the neighbor list or to just measure the signal strength on the omni-directional beam for the carriers in the neighbor list.

[0101] The ratio (denoted by R) of the number of elements in the set FN divided by the number of elements in set FS can be used to tradeoff measurements on the serving cell against measurements on the neighbor cells.

[0102] While this invention has been particularly shown and described with reference to preferred embodiments, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention described hereinabove.

CLAIMS

What is claimed is:

1. A method for steering a subscriber based smart antenna (SBSA), the method comprising:
measuring a signal level on each element of a serving carrier/beams (SCB) list in a dormant time slot of an FS frame, the SCB list including all serving cell broadcast control channel (BCCH) carrier and SBSA beam combinations; and
if a current frame is a synchronization frame on a BCCH of the serving cell, and there is a new strongest element in the SCB list, decoding a BSIC on the new strongest element in the SCB list and setting an active beam to the new strongest element in the SCB list.
2. The method of claim 1 further comprising:
measuring a signal level on each element of a neighbor carrier/beams (NCB) list in a dormant time slot of an FN frame, the NCB list including all neighbor cell BCCH carriers and SBSA beam combinations.
3. The method of claim 2 further comprising:
if the current frame is an FB frame and there is a new element among a predetermined number of strongest elements of the NCB list, decoding a base station identity code (BSIC) of the new element.
4. The method of claim 1 further comprising:
measuring a signal level on each element of a neighbor carrier (NC) list in a dormant time slot of an FN frame, the NC list including all neighbor cell BCCH carriers.
5. The method of claim 4 further comprising:
if the current frame belongs to the FB frame and there is a new element among a predetermined number of strongest elements of the NC list, decoding a base station identity code (BSIC) of the new element.
6. The method of claim 1 wherein the signal level is measured using a midamble in a time slot.
7. The method of claim 6 wherein a first half of the midamble is used for measuring a signal level in one SBSA beam and a second half of the midamble is used for measuring a signal level in the other SBSA beam.

8. A method for steering a subscriber based smart antenna (SBSA), the method comprising:
measuring a signal level on each element of a serving carrier/beams (SCB) list in a dormant time slot of an FS frame, the SCB list including all serving cell broadcast control channel (BCCH) carrier and SBSA beam combinations; and

if there is a new strongest element in the SCB list, changing an active beam to the new strongest element in the SCB list.

9. The method of claim 8 further comprising:
measuring a signal level on each element of a neighbor carrier/beams (NCB) list in a dormant time slot of an FN frame, the NCB list including all neighbor cell BCCH carriers and SBSA beam combinations.

10. The method of claim 9 further comprising:
if a current frame belongs to an FB frame and there is a new element among a predetermined number of strongest elements in the NCB list, decoding a base station identity code (BSIC) of the new element.

11. The method of claim 8 further comprising:
measuring a signal level on each element of a neighbor carrier (NC) list in a dormant time slot of an FN frame, the NC list including all neighbor cell BCCH carriers.

12. The method of claim 11 further comprising:
if a current frame belongs to an FB frame and there is a new element among a predetermined number of strongest elements of the NC list, decoding a base station identity code (BSIC) of the new element.

13. The method of claim 8 wherein the signal level is measured using a midamble in a time slot.

14. The method of claim 13 wherein a first half of the midamble is used for measuring a signal level in one SBSA beam and a second half of the midamble is used for measuring a signal level in the other SBSA beam.

15. A wireless transmit/receive unit (WTRU) for steering a subscriber based smart antenna (SBSA), the WTRU comprising:

an SBSA for generating a plurality of beams;

a transceiver for transmitting and receiving a signal via the SBSA;

a beam steering unit for steering a beam to one of the plurality of beams; and

a controller configured to measure a signal level on each element of a serving carrier/beams (SCB) list in a dormant time slot of an FS frame, the SCB list including all serving cell broadcast control channel (BCCH) carrier and SBSA beam combinations, and if a current frame is a synchronization frame on a BCCH of the serving cell, and there is a new strongest element in the SCB list, decode a BSIC on the new strongest element in the SCB list and setting an active beam to the new strongest element in the SCB list.

16. The WTRU of claim 15 wherein the controller is configured to measure a signal level on each element of a neighbor carrier/beams (NCB) list in a dormant time slot of an FN frame, the NCB list including all neighbor cell BCCH carriers and SBSA beam combinations.

17. The WTRU of claim 16 wherein the controller is configured to, if the current frame is an FB frame and there is a new element among a predetermined number of strongest elements of the NCB list, decode a base station identity code (BSIC) of the new element.

18. The WTRU of claim 15 wherein the controller is configured to measure a signal level on each element of a neighbor carrier (NC) list in a dormant time slot of an FN frame, the NC list including all neighbor cell BCCH carriers.

19. The WTRU of claim 18 wherein the controller is configured to, if the current frame belongs to the FB frame and there is a new element among a predetermined number of strongest elements of the NC list, decode a base station identity code (BSIC) of the new element.

20. The WTRU of claim 15 wherein the signal level is measured using a midamble in a time slot.

21. The WTRU of claim 20 wherein a first half of the midamble is used for measuring a signal level in one SBSA beam and a second half of the midamble is used for measuring a signal level in the other SBSA beam.

22. A wireless transmit/receive unit (WTRU) for steering a subscriber based smart antenna (SBSA), the WTRU comprising:

an SBSA for generating a plurality of beams;

a transceiver for transmitting and receiving a signal via the SBSA;

a beam steering unit for steering a beam to one of the plurality of beams; and

a controller configured to measure a signal level on each element of a serving carrier/beams (SCB) list in a dormant time slot of an FS frame, the SCB list including all serving cell broadcast control channel (BCCH) carrier and SBSA beam combinations and, if there is a new strongest element in the SCB list, change an active beam to the new strongest element in the SCB list.

23. The WTRU of claim 22 wherein the controller is configured to measure a signal level on each element of a neighbor carrier/beams (NCB) list in a dormant time slot of an FN frame, the NCB list including all neighbor cell BCCH carriers and SBSA beam combinations.

24. The WTRU of claim 23 wherein the controller is configured to, if a current frame belongs to an FB frame and there is a new element among a predetermined number of strongest elements in the NCB list, decode a base station identity code (BSIC) of the new element.

25. The WTRU of claim 22 wherein the controller is configured to measure a signal level on each element of a neighbor carrier (NC) list in a dormant time slot of an FN frame, the NC list including all neighbor cell BCCH carriers.

26. The WTRU of claim 25 wherein the controller is configured to, if a current frame belongs to an FB frame and there is a new element among a predetermined number of strongest elements of the NC list, decode a base station identity code (BSIC) of the new element.

27. The WTRU of claim 22 wherein the signal level is measured using a midamble in a time slot.

28. The WTRU of claim 27 wherein a first half of the midamble is used for measuring a signal level in one SBSA beam and a second half of the midamble is used for measuring a signal level in the other SBSA beam.