(54) Title: SYSTEM AND METHOD PROVIDING DELAYS FOR CDMA NULLING

(57) Abstract: A system and method are disclosed for avoiding nulls in a composite radiation pattern synthesized from a plurality of antenna beams. The disclosed invention teaches the use of delays in the signal paths associated with one of the antenna beams utilized to synthesize the desired radiation pattern in order to avoid destructive combining of the signals. In a preferred embodiment, delays are introduced in each antenna beam signal having a common attribute such as a common phase center. Accordingly, a minimum number of phase differential boundaries are introduced in order that certain communications, such as CDMA, are not adversely affected. Adaptive arrays may be utilized to form radiation patterns, for which the azimuthal width and/or length of a sector may be adjusted by way of adjustments of the relative amplitude and phase of signal components of signals at antennas of a phased array adaptively controlled according to communication parameters such as information indicating the quality of the communication channel on that sector or the number of calls serviced in particular sectors.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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SYSTEM AND METHOD PROVIDING DELAYS FOR CDMA NULLING

RELATED APPLICATIONS

The present application is a continuation-in-part of copending and commonly assigned U.S. Patent Application, Serial No. 09/060,921, entitled “SYSTEM AND METHOD PROVIDING DELAYS FOR CDMA NULLING”, filed April 15, 1998, the disclosure of which is hereby incorporated herein by reference. Reference is hereby made to the following co-pending and commonly assigned U.S. Patent Applications: “CONICAL OMNI-DIRECTIONAL COVERAGE MULTIBEAM ANTENNA WITH MULTIPLE FEED NETWORK,” Serial No. 08/808,304; “SYSTEM AND METHOD FOR PER BEAM ELEVATION SCANNING,” Serial No. 47586-P006CP3CP1-975460; “ANTENNA DEPLOYMENT SECTOR CELL SHAPING SYSTEM AND METHOD,” Serial No. 08/924,285; “MULTI-SECTOR PIVOTAL ANTENNA SYSTEM AND METHOD,” Serial No. 08/782,051; “MULTIPLE BEAM PLANAR ANTENNA ARRAY WITH PARASITIC ELEMENTS,” Serial No. 08/896,036; and “SYSTEM AND METHOD FOR FULLY SELF-CONTAINED CALIBRATION OF AN ANTENNA ARRAY,” Serial No. 09/092,429; the disclosures of which applications are incorporated herein by reference.
TECHNICAL FIELD

The present invention relates to the simulcasting of signals from a multibeam antenna system and, more particularly, to systems and methods for delaying signals simulcast from various of the multibeams to avoid destructive nulls.
BACKGROUND

It is often desirable to provide a signal simultaneously in multiple beams of a multibeam antenna system. For example, a cellular communication system may provide communications between a base transceiver station (BTS), having an antenna system associated therewith, and a plurality of mobile units operating within a predefined area, or "cell," defined by the antenna system's radiation pattern. Often such cells, although providing communications in a full 360° about the BTS, are broken down into three 120° sectors in order to provide more capacity and less interference over that of an omni cell 360° system. Additionally, such a sectorized cell achieves extended range as compared to an omni cell 360° system due to the greater signal gain at the sector antennas resulting from their more focused coverage.

Further advantage may be realized by providing multiple narrow beams at the BTS rather than the three 120° sectors. For example, twelve 30° narrow antenna beams may be utilized to provide the same 360° communication coverage within the cell as the 360° omni cell configuration and its 120° sectorized cell replacement. Such a multiple narrow beam arrangement is desirable because, as with the 120° sector system described above, the multiple beams provide a greater signal gain resulting from their greater focused coverage. A further advantage of the multiple narrow beams is the flexibility offered in synthesizing any desired sector size. Combining adjacent narrow beams provides a wider composite beam, with a beam width roughly equal to the sum of the individual beams widths. Accordingly, synthesized sectors may be formed of any size from a full 360°, by simulcasting a signal on each of the narrow beams, to as small as the narrow beams themselves, by providing the signal only within one narrow beam.

However, it should be appreciated that there is a potential for phase nulling associated with simulcasting of identical signals within multiple beams. For example, it may be necessary to synthesize a 120° sector pattern comprised of four 30° beams. Conceptually the 120° sector may be synthesized by simply simulcasting the desired signal (CDMA waveform or AMPS signaling channel) over the four contiguous 30° narrow beams making
up the desired 120° radiation pattern. However, phase differences between the signals radiated by the four constituent beams can cause signal cancellation. This cancellation leads to undesirable shaping, i.e. "holes," in the composite radiation pattern. For example, if the antennas creating the narrow beams are separated by several wavelengths, deep nulls occur in the resulting antenna pattern, giving it a "rippled" appearance azimuthally. This pattern is not desirable for a BTS as it implies that there are "holes" in the coverage corresponding to the nulls in the pattern.

This phase nulling problem created by simulcasting is an artifact of the multibeam approach and is potentially a problem regardless of the type of signal transmitted, i.e., phase nulling is not unique to digital systems such as with respect to dynamic beam mapping in Code Division Multiple Access (CDMA) systems, but also exists with respect to signaling in analogue systems such as the Advanced Mobile Phone System (AMPS) and Narrowband Advanced Mobile Phone System (NAMPS). Therefore, it is desirable to identify a solution that addresses both CDMA and AMPS/NAMPS. However, due to dynamic beam mapping desirable in CDMA, there may be some unique aspects associated with CDMA.

A need therefore exists in the art for systems and methods by which signals may be provided to a multibeam antenna system for simulcasting over multiple ones of the antenna beams without producing undesirable nulls.

A further need exists in the art for the systems and methods to avoid nulls in the simulcasting over multiple antenna beams of digital signals as well as analogue signals.

A still further need exists in the art for the systems and methods avoiding nulls to be adapted so as not to adversely affect forward link performance.
SUMMARY OF THE INVENTION

These and other objects, features and technical advantages are achieved by a system and method which introduces delays in ones of the simulcast signals in order to provide simulcast signals which do not destructively combine and produce an undesired composite radiation pattern. Time delay elements can smooth the composite antenna beams substantially when the antennas are separated by a significant distance. Accordingly, a preferred embodiment of the present invention uses a switch matrix adapted to selectively provide non-delayed or delayed versions of a signal to be simulcast to each antenna beam of the synthesized sector.

In order to provide the delays, the preferred embodiment includes delay elements associated with each signal of the sectors to be synthesized. Preferably, a switch selection is utilized to provide delay/non-delayed signals for each beam of the synthesized sector. Accordingly, a sector signal may be delayed by an associated delay element before being provided to a particular antenna beam of the antenna beams utilized to synthesize a sector. Therefore, a technical advantage of the present invention is that destructive combining of the wideband signals, whether digital or analogue, of multiple antenna beams used in synthesizing a desired sector radiation pattern is avoided.

In a preferred embodiment, the multiple antenna beams utilized according to the present invention are provided by using an adaptive array circuitry. The adaptive array circuitry may be utilized to dynamically form radiation patterns for which the azimuthal width and length of a sector may be adjusted to provide the desired coverage and quality of signals by providing a desired phase and/or amplitude differential at antenna elements of an antenna array with respect to a signal radiated by these elements. Thus, the adaptive array circuitry may include phase adjusting means and/or amplitude adjusting means for adjusting the relative phases and amplitudes of select signal components of the signals at multiple inputs to an antenna system.
The adaptive array circuitry may also be utilized to selectively provide non-delayed or delayed versions of a signal to ones of a plurality of antenna elements to form the sectors of a multi-sectored cell. In order to provide the signals with the desired delays, the adaptive array circuitry may include delay elements associated with each signal. Accordingly, a signal may be delayed by an associated delay element before being provided to a particular antenna beam of the antenna beams utilized to synthesize a sector.

The use of delays results in the addition of delay boundaries, as between the antenna beams having differing amounts of delay (or no delay) introduced into the simulcast signal. Such delay boundaries may create, for example, regions in which all demodulator fingers of a mobile unit's CDMA Rake receiver are utilized. Furthermore, the forward link performance may also be adversely affected, depending upon the relative strengths of the paths available relative to the amount of unrecovered energy acting as interference. Accordingly, it is desirable to introduce as few delay boundaries in the synthesized sector as possible while providing sufficient difference between the signals of the antenna beams in order to avoid destructive nulls. In the preferred embodiment, by intelligently selecting the antenna beams for which delayed versions of a signal are simulcast, the present invention operates so as not to adversely affect forward link performance.

Often ones of the multiple antenna beams of a multibeam antenna system are generated with a common phase center, i.e., a single antenna panel, such as a phased array, provides multiple antenna beams, often each associated with a different input of a beam forming matrix, from the same radiation elements. Because the same radiation elements are energized in various phase relationships to form the beams, each of these antenna beams has a common phase center. Assuming these antenna beams are otherwise calibrated to be in phase with each other, i.e., the respective signals experience substantially the same path lengths, signals simulcast over these beams having a common phase center should not destructively combine. Accordingly, the preferred embodiment of the present invention identifies antenna beams having a common phase center and does not introduce a delay as between these signals of a synthesized sector. Therefore, a technical advantage of the present
invention is that introduction of unnecessary delay boundaries in the synthesized sector is avoided.

However, often multiple antenna beam sources must be utilized in order to provide the desired geographical coverage. For example, multiple ones of the above described phased array panels may be utilized to provide coverage in a full 360°. Synthesized sectors including antenna beams from multiple ones of these panels will generally not enjoy common phase centers due to the physical separation of the multiple panels. Therefore, in order to avoid destructive combining of signals simulcast over beams of these two panels, delays as between the antenna beam signals of each panel are preferably introduced. Accordingly, the preferred embodiment of the present invention identifies antenna beams not having a common phase center and introduces a delay as between these signals of a synthesized sector. As such, a single delay boundary is introduced in a synthesized sector including antenna beams of two panels. Therefore, a technical advantage of the present invention is that a minimum number of delay boundaries are introduced in the synthesized sector.

A further technical advantage of the present invention is that the differential delays across the panel boundaries provides limited forward link spatial diversity for the mobiles. In other words, where the present invention introduces delays, the result is not just eliminating nulls but is also providing a degree of spatial diversity on the forward link.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.
BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGURE 1 shows multiple narrow antenna beams disposed to provide coverage within a predefined cell area;

FIGURE 2 shows a prior art omni cell radiation pattern;

FIGURE 3 shows a prior art three sectored cell radiation pattern;

FIGURE 4 shows a planar array adapted to provide multiple narrow antenna beams;

FIGURE 5 shows a plurality of planar arrays, such as that of FIGURE 4, deployed to provide multiple narrow antenna beams, such as those of FIGURE 1;

FIGURE 6 shows a preferred embodiment of circuitry adapted to provide the delay differentials of the present invention;

FIGURES 7-10 show sector synthesis according to the present invention;

FIGURE 11 shows an alternative embodiment of a portion of the circuitry of FIGURE 6 wherein multiple delays are provided for an input signal;

FIGURE 12 shows an alternative embodiment of a portion of the circuitry of FIGURE 6 wherein amplitude and phase adjustment is provided for the antenna beams; and

FIGURE 13 shows an alternative embodiment of circuitry adapted to provide delay differentials of the present invention.
DETAILED DESCRIPTION

The present invention provides a system and method for avoiding destructive combining of signals simulcast over multiple antenna beams. Preferably, the antenna beams are contiguous, substantially non-overlapping, narrow antenna beams such as those shown in FIGURE 1. However, the present invention is useful with any number of antenna beam configurations where destructive combining produces undesired nulls.

The preferred embodiment of FIGURE 1 includes twelve 30° antenna beams, antenna beams 121-132, radiating from BTS antenna structure 110 to illuminate the predefined area of cell 100. Of course, a greater or lesser number of antenna beams may be utilized according to the present invention, if desired. Furthermore, there is no limitation to the antenna beams being of substantially equivalent sizes, either in width or length.

It shall be appreciated that the preferred embodiment of FIGURE 1 may be utilized to provide radiation of, as well as reception of, signals within various desired radiation patterns within cell 100. For example, a prior art omni cell radiation pattern, illustrated as antenna beam 220 of FIGURE 2, may be synthesized by simulcasting a signal over antenna beams 120-132.

Likewise, a prior art 120° sectored cell radiation pattern, illustrated as antenna beams 321-323 of FIGURE 3 associated with an \( \alpha \), \( \beta \) and \( \gamma \) sector respectively, may be synthesized by simulcasting a signal associated with a particular sector over ones of the antenna beams. Specifically, the \( \alpha \) sector, antenna beam 321, may be synthesized utilizing antenna beams 121-124. Likewise, the \( \beta \) and \( \gamma \) sectors, antenna beams 322 and 323 respectively, may be synthesized utilizing antenna beams 125-128 and 129-132 respectively.

Preferably, ones of the antenna beams of the present invention are generated using an antenna panel such as that illustrated in FIGURE 4. Of course, any number of antenna systems providing multiple antenna beams may be utilized according to the present invention, if desired. For example, modified panel arrays such as disclosed in the above referenced applications entitled "System and Method for Per Beam Elevation Scanning," "Multi-Sector Pivotal Antenna System and Method," and "Multiple Beam Planar Antenna
Array with Parasitic Elements" may be utilized according to the present invention. Moreover, non-planar antennas, such as individual narrow beam antennas and conical multibeam antennas, such as disclosed in the above referenced application entitled "Conical Omni-Directional Coverage Multibeam Antenna with Multiple Feed Network," may be used, if desired.

Directing attention to the antenna array of FIGURE 4, antenna elements 401 are arranged on panel 400 to provide multiple narrow beams: Beam 1 through Beam 4. In the preferred embodiment, the narrow antenna beams are formed by providing a signal to be radiated in a particular antenna beam to a corresponding input of beam forming matrix 410, i.e., inputs 411-414 correspond to Beam 1 through Beam 4 respectively. Beam forming matrix 410 may, for example, be a Butler matrix or other circuitry which provides the signal applied to one of the inputs as components with a proper phase progression at the elements of panel 400 to result in the desired narrow antenna beam. Beam forming matrixes, such as the aforementioned Butler matrix, are well known in the art and, therefore, will not be discussed in detail herein.

The antenna panel of FIGURE 4, as well as other multibeam antenna systems, provides a convenient means by which a signal may be radiated within a predetermined area. For example, by providing a particular signal to input 411 of beam forming matrix 410, this signal will be radiated in the area associated with Beam 1. Likewise, by providing the signal to input 412 of beam forming matrix 410, the signal will be radiated in the area associated with Beam 2.

It shall be appreciated that, as each of beam of Beam 1 through Beam 4 are generated by excitation of the elements of panel 400, although utilizing a different phase progression there between, the phase centers of each of the antenna beams corresponding to the inputs of the beam forming matrix are the same, i.e., centered horizontally in the antenna panel face as illustrated in FIGURE 4. Accordingly, in the preferred embodiment if a radiation pattern larger than that of a single antenna beam is desired, a particular signal may be provided to multiple inputs of beam forming matrix 410 for radiation within the multiple corresponding antenna beams.
However, it shall be appreciated that both in generating the antenna beams through the use of a phased progression and in the radiation of a signal within multiple ones of the antenna beams there is a potential for destructive combining forming undesired nulls in the resulting radiation pattern caused by phase differences between the combined signals. There are two fundamentally different mechanisms that can create phase differences between the radiated signals of a multibeam antenna system: 1) path length differences, and 2) phase center differences.

Path length differences occur because the components in the transmit chain (cables, amplifiers, lightning arrestors, etc.) are not phase matched to one another, resulting in signals with differing phases being injected into the multibeam antenna inputs. Errors due to path length differences affect all applications, including both CDMA and AMPS/NAMPS applications.

A phase calibration approach, such as that shown in the above referenced application entitled "System and Method for Fully Self-Contained Calibration of an Antenna Array," may be implemented for phase nulls due to path length differences. However, the phase calibration approach cannot address the second source of nulls caused by phase center differences.

Phase center differences occur if the desired radiation pattern, such as a synthesized sector pattern, includes antenna beams generated from exciting different antenna elements, such as when antenna beams from different antenna panels are used in the synthesized pattern. Since the antenna panels generating the antenna beams are physically separate, the distance between the panels induces a phase difference as between antenna beams of different panels in the composite signal including these different antenna beams.

For example, directing attention to FIGURE 5, in order to provide the 360° coverage of cell 100 as shown in FIGURE 1, multiple antenna panels as shown in FIGURE 4 are deployed as panels 501-503 comprising BTS antenna structure 110. Beams of these different antenna panels may be utilized to radiate a signal within any area of cell 100 having a radiation pattern including any number of the antenna beams, i.e., beam mapping and sector synthesizing. Systems and methods for providing dynamic beam mapping are shown in the
above referenced application entitled "Antenna Deployment Sector Cell Shaping System and Method."

From analysis of computer models and experimental measurements of the quality of the synthesized antenna patterns for CDMA RF beam mapping, it has been discovered that the phase calibration approach, addressing the phase differences due to path length differences does not always result in a desired composite radiation pattern where antenna beams having different phase centers are utilized. Moreover, if phase calibration alone is performed, the synthesized patterns for CDMA steered sectors contain nulls that are deeper than those associated with an analogue signal provided in a synthesized radiation pattern including antenna beams having different phase centers, such as where a AMPS/NAMPS signaling channel is provided on all antenna beams. Although it is likely that, in real world deployments, many of these theoretical nulls will be completely or partially filled due to local scattering, near field effects, and multipath, the risk of a composite radiation pattern having undesired nulls remains.

The preferred embodiment of the present invention utilizes delay elements to avoid nulls in synthesized patterns including antenna beams from across panels, or otherwise are associated with different phase centers, in combination with phase calibration to avoid nulls caused by path length differences. Of course, the delays of the present invention may be utilized without the aforementioned phase calibration, although nulls created by the phase differences due to path length differences would not be addressed. However, where phase calibration cannot be performed or is otherwise unavailable, the present invention can operate to introduce alternating delay/non-delay signals in the antenna beams of a synthesized sector in order to mitigate the effects of nulling due to path length differences as well as phase center differences. For example, where antenna beams 121-124 of FIGURE 5 are utilized to synthesize a sector, signals of antenna beams 121 and 123 may be delayed whereas the signals of antenna beams 122 and 124 are not.

Directing attention to FIGURE 6, in a preferred embodiment of the present invention is shown. Inputs 601-603, associated with the signals to be radiated in a particular synthesized sector, are provided for coupling signals to the desired ones of the multiple
antenna beams. Here Beam 1 through Beam 12 correspond to antenna beams 121-132 of FIGURE 1. It shall be appreciated that, although three inputs are shown, associated with synthesized sectors α, β, and γ, any number of such inputs may be utilized according to the present invention through the expedient of scaling the circuitry shown in FIGURE 6 accordingly (as indicated by the ellipsis). Likewise, although beam 1 through beam 12 are shown, the present invention may be scaled to provide synthesized sector signals to any number of antenna beams through scaling of the circuitry shown in FIGURE 6.

Coupling of signals provided at inputs 601-603 to the antenna beams is provided by input splitters 611-613, each coupled to a synthesized sector input signal, delay devices 621-623, each coupled to one output of a corresponding input splitter, antenna beam splitters 631-633, each coupled to one output of a corresponding input splitter, delay antenna beam splitters 641-643, each coupled to one output of a corresponding delay device, and switch matrixes 651-662 (switch matrixes 653-661 being represented by the ellipsis), each coupled to one output of each antenna beam splitter and each delay antenna beam splitter and providing selective output to a corresponding one of Beam 1 through Beam 12. The outputs of switch matrixes 651-662 are each associated with an antenna beam input of a multibeam antenna, or antennas, such as illustrated in FIGURE 4. For example, the output of switch matrix 651 may be coupled to input 411, and thus Beam 1, of antenna panel 400 while the output of switch matrix 652 is coupled to input 412, and thus Beam 2, of antenna panel 400. Accordingly, through control of switch matrixes 651-662, various ones of the signals input at inputs 601-603 may be provided for radiation within beams 121-132. Moreover, as delay is provided in the signal paths of the input signals, a delay differential between the signal as provided to ones of the antenna beams may be introduced to avoid destructive nulling by selection at the switch matrixes the appropriate delayed or non-delayed signal.

Although control of switch matrixes 651-662 to couple a particular signal, having a delayed or non-delayed attribute, may be accomplished by many means, including manual operation of the switch matrixes, a preferred embodiment utilizes control circuitry to automatically control switch matrixes 651-662. Accordingly, controller 670, having control circuitry associated therewith, is coupled to switch matrixes 651-662. It shall be understood
that, although a single control interface is illustrated between all of the switch matrixes, each of these switch matrixes may be controlled independently by controller 670. Of course, controller 670 need not be a discrete component associated with a particular BTS antenna system, but may instead be an integral part of the cell's existing control circuitry or a part of the control circuitry for a plurality of such cells.

Controller 670 may comprise a processor-based system having a processing unit (CPU) and memory associated therewith (RAM). The RAM may have stored therein an algorithm operable to cause the CPU to operate the switch matrixes of the present invention to couple the various antenna beams to ones of the inputs as determined advantageous for communications provided by the system.

The preferred embodiment of the present invention illustrated in FIGURE 6 is flexible in that it may be operated in a number of ways to introduce delay differentials between a signal as provided to ones of the antenna beams. Specifically, the preferred embodiment may be operated to insert the absolute minimum number of delays (the advantages of which will be discussed hereinbelow) necessary to reduce the impacts of nulls between panels.

The present invention may be operated to provide delay differentials to avoid destructive combining by alternating the use of delay/non-delay signals for adjacent antenna beams. For example, in a synthesized sector (α) including beams 121-124, such as shown in FIGURE 7, the signal input at input 601 may be selected by switch matrixes 651 and 653 (represented by the ellipsis) for provision to antenna beams 121 and 123 without a delay (α signal from splitter 631) and by switch matrixes 652 and 654 (represented by the ellipsis) for provision to antenna beams 122 and 124 with a delay (αd signal from splitter 641). However, this is not the most advantageous allocation of the delay elements.

The alternating delay/non-delay method of introducing delay differentials, although simple to implement and useful in also compensating for path length differences, may produce unnecessary delay boundaries. For example, the above described synthesized sector includes three delay boundaries without considering any delay boundaries created by other synthesized sectors (a total of nine delay boundaries where three 120° sectors are synthesized). However, where only antenna beams of a particular panel are utilized in any
one synthesized sector, no delay elements are required as there is a common phase center for each of these antenna beams. The delay boundaries, being seen at the mobile as multiple signals delayed in time and thus possibly appearing in different fingers of a CDMA Rake receiver, may impact system performance by tying up all of a mobile’s demodulators.

Accordingly, when operated to provide synthesis of the three 120° sectors shown in FIGURE 3, without azimuth steering, i.e., only antenna beams of a particular panel are utilized in any one sector, the present invention operates to utilize no delay elements in the transmitted signals as there is a common phase center for each of these antenna beams. However, as synthesized sector patterns are steered across panel boundaries (as will be discussed in more detail hereinbelow), appropriate delay elements are inserted in the transmit paths. Therefore, the preferred embodiment of the present invention is operated to insert the absolute minimum number of delays necessary to avoid the undesired nulls. In the worst case, where all sector patterns are generated from beams on the three separate panels shown in FIGURES 8 and 9, only three delay/non-delay boundaries would be created in the cell according to the preferred embodiment.

Even utilizing the present invention to provide the absolute minimum number of delay differentials necessary to avoid destructive combining, operating conditions may still produce situations in which all mobile Rake fingers are utilized. For example, mobile Rake demodulator utilization may be a problem in multiple pilot regions and areas with extensive multipath returns. Additionally, the deployment of clusters of many closely-spaced cells utilizing sector mapping could have an impact on demodulator utilization.

However, if situations arise where the addition of delay/non-delay boundaries creates regions in which all mobile Rake fingers are utilized, the forward link performance may or may not be adversely affected, depending upon the relative strengths of the paths available (that is, the amount of unrecovered energy that acts as interference). Current CDMA mobiles incorporate a fixed number of Rake demodulators. Accordingly, the mobile receivers can re-assign Rake fingers on a rapid basis. Since the mobiles can rapidly re-assign demodulators, interference due to unrecovered energy should only become a problem if, of the strongest paths, four or more occur with similar amplitudes for extended periods.
Additionally, in such areas (clusters of cells utilizing beam mapping, pilot pollution, heavy multipath), it should be possible to adjust network parameters (per-beam transmit powers, handoff thresholds, search windows, etc.) in order to reduce the number of fingers in lock. Such an approach would require a change in network parameters associated with particular beam-to-sector mappings.

It should be appreciated that operation of the present invention to utilize beams having a different phase center, by introducing differential delays between the beams having the different phase centers, provides limited forward link spatial diversity for the mobiles, similar to softer handoff benefit. Accordingly, in all areas where the preferred embodiment of the present invention introduces delays, the result is not just to eliminate nulls, but to also provide a degree of spatial diversity in the forward link.

As described above, if sector azimuth beam widths or bore sights are adjusted so that synthesized sector radiation patterns including antenna beams having different phase centers, i.e., antenna beams from across panel boundaries, are required, delay elements are inserted such that all the signals of antenna beams having a particular phase center, such as all signals provided to a panel as illustrated in FIGURE 5, are either delayed or non-delayed. In order to better understand the use of delays for avoiding undesired nulls according to the preferred embodiment of the present invention, examples of various synthesized sectors are given hereinafter.

Directing attention to FIGURE 7, synthesis of the three 120° sectors shown in FIGURE 3, without azimuth steering, is shown as α sector 701, β sector 702, and γ sector 703. As all antenna beams utilized in synthesizing a particular sector in this example are generated by the same panel (have the same phase center) the present invention utilizes no delay elements in the transmitted signals. Accordingly, there are no delay/non-delay boundaries in this example.

With reference to FIGURE 6, in a preferred embodiment this radiation pattern may be generated by providing an α signal to input 601 and controlling switch matrixes 651-654 to couple the non-delayed α signal to antenna beams 121-124, providing a β signal to input 602 and controlling switch matrixes 655-658 to couple the non-delayed β signal to antenna
beams 125-128, and providing a γ signal to input 603 and controlling switch matrixes 659-662 to couple the non-delayed γ signal to antenna beams 129-132. This relationship is shown in the table below.

<table>
<thead>
<tr>
<th>Antenna Beam</th>
<th>Sector Synthesis Mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Panel 501 - Beam 121 (2L)</td>
<td>Alpha Non-Delayed (α)</td>
</tr>
<tr>
<td>Antenna Panel 501 - Beam 122 (1L)</td>
<td>Alpha Non-Delayed (α)</td>
</tr>
<tr>
<td>Antenna Panel 501 - Beam 123 (1R)</td>
<td>Alpha Non-Delayed (α)</td>
</tr>
<tr>
<td>Antenna Panel 501 - Beam 124 (2R)</td>
<td>Alpha Non-Delayed (α)</td>
</tr>
<tr>
<td>Antenna Panel 502 - Beam 125 (2L)</td>
<td>Beta Non-Delayed (β)</td>
</tr>
<tr>
<td>Antenna Panel 502 - Beam 126 (1L)</td>
<td>Beta Non-Delayed (β)</td>
</tr>
<tr>
<td>Antenna Panel 502 - Beam 127 (1R)</td>
<td>Beta Non-Delayed (β)</td>
</tr>
<tr>
<td>Antenna Panel 502 - Beam 128 (2R)</td>
<td>Beta Non-Delayed (β)</td>
</tr>
<tr>
<td>Antenna Panel 503 - Beam 129 (2L)</td>
<td>Gamma Non-Delayed (γ)</td>
</tr>
<tr>
<td>Antenna Panel 503 - Beam 130 (1L)</td>
<td>Gamma Non-Delayed (γ)</td>
</tr>
<tr>
<td>Antenna Panel 503 - Beam 131 (1R)</td>
<td>Gamma Non-Delayed (γ)</td>
</tr>
<tr>
<td>Antenna Panel 503 - Beam 132 (2R)</td>
<td>Gamma Non-Delayed (γ)</td>
</tr>
</tbody>
</table>

Directing attention to FIGURE 8, synthesis of three 120° sectors as shown in FIGURE 3, with azimuth steering resulting in a 30° clockwise shift in the sector orientation, is shown as α sector 801, β sector 802, and γ sector 803. As some of the antenna beams utilized in synthesizing a particular sector in this example are generated by different panels (have different phase centers) the present invention utilizes delay elements in the transmitted signals. Accordingly, there are three delay/non-delay boundaries in this example.

With reference to FIGURE 6, in a preferred embodiment, this radiation pattern may be generated by providing an α signal to input 601 and controlling switch matrixes 652-654 to couple the non-delayed α signal to antenna beams 122-124 and controlling switch matrix 655 to couple the delayed α signal to antenna beam 125, providing a β signal to input 602 and controlling switch matrixes 656-658 to couple the non-delayed β signal to antenna beams 126-128 and controlling switch matrix 659 to couple the delayed β signal to antenna beam 129, and providing a γ signal to input 603 and controlling switch matrixes 660-662 to couple the non-delayed γ signal to antenna beams 130-132 and controlling switch matrix 651 to
couple the delayed $\gamma$ signal to antenna beam 121. This relationship is shown in the below table.

<table>
<thead>
<tr>
<th>Antenna Beam Description</th>
<th>Sector Synthesis Mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel 501 - Beam 121 (2L)</td>
<td>Gamma Delayed ($\gamma_d$)</td>
</tr>
<tr>
<td>Panel 501 - Beam 122 (1L)</td>
<td>Alpha Non-Delayed ($\alpha$)</td>
</tr>
<tr>
<td>Panel 501 - Beam 123 (1R)</td>
<td>Alpha Non-Delayed ($\alpha$)</td>
</tr>
<tr>
<td>Panel 501 - Beam 124 (2R)</td>
<td>Alpha Non-Delayed ($\alpha$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 125 (2L)</td>
<td>Alpha Delayed ($\alpha_d$)</td>
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<td>Beta Non-Delayed ($\beta$)</td>
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<td>Panel 502 - Beam 127 (1R)</td>
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<tr>
<td>Panel 502 - Beam 128 (2R)</td>
<td>Beta Non-Delayed ($\beta$)</td>
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<tr>
<td>Panel 503 - Beam 129 (2L)</td>
<td>Beta Delayed ($\beta_d$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 130 (1L)</td>
<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 131 (1R)</td>
<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 132 (2R)</td>
<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
</tbody>
</table>

Directing attention to FIGURE 9, synthesis of three $120^\circ$ sectors as shown in FIGURE 3, with azimuth steering resulting in a $60^\circ$ clockwise shift in the sector orientation, is shown as $\alpha$ sector 901, $\beta$ sector 902, and $\gamma$ sector 903. As in the example above, some of the antenna beams utilized in synthesizing a particular sector in this example are generated by different panels (have different phase centers) and, therefore, the present invention utilizes delay elements in the transmitted signals. Accordingly, there are also three delay/non-delay boundaries in this example.

With reference to FIGURE 6, this radiation pattern may be generated by providing an $\alpha$ signal to input 601 and controlling switch matrixes 653 and 654 to couple the non-delayed $\alpha$ signal to antenna beams 123 and 124 and controlling switch matrixes 655 and 656 to couple the delayed $\alpha$ signal to antenna beams 125 and 126, providing a $\beta$ signal to input 602 and controlling switch matrixes 657 and 658 to couple the non-delayed $\beta$ signal to antenna beams 127 and 128 and controlling switch matrixes 659 and 660 to couple the delayed $\beta$ signal to antenna beams 129 and 130, and providing a $\gamma$ signal to input 603 and controlling switch matrixes 661 and 662 to couple the non-delayed $\gamma$ signal to antenna beams.
131 and 132 and controlling switch matrixes 651 and 652 to couple the delayed $\gamma$ signal to antenna beams 121 and 122. This relationship is shown in the below table.

<table>
<thead>
<tr>
<th>Antenna Beam Description</th>
<th>Sector Synthesis Mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel 501 - Beam 121 (2L)</td>
<td>Gamma Delayed ($\gamma_d$)</td>
</tr>
<tr>
<td>Panel 501 - Beam 122 (1L)</td>
<td>Gamma Delayed ($\gamma_d$)</td>
</tr>
<tr>
<td>Panel 501 - Beam 123 (1R)</td>
<td>Alpha Non-Delayed ($\alpha$)</td>
</tr>
<tr>
<td>Panel 501 - Beam 124 (2R)</td>
<td>Alpha Non-Delayed ($\alpha$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 125 (2L)</td>
<td>Alpha Delayed ($\alpha_o$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 126 (1L)</td>
<td>Alpha Delayed ($\alpha_o$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 126 (1R)</td>
<td>Beta Non-Delayed ($\beta$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 127 (2R)</td>
<td>Beta Non-Delayed ($\beta$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 129 (2L)</td>
<td>Beta Delayed ($\beta_o$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 130 (1L)</td>
<td>Beta Delayed ($\beta_o$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 131 (1R)</td>
<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 132 (2R)</td>
<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
</tbody>
</table>

It shall be appreciated that the present invention is not limited to the 120° synthesized sectors used in the above examples. In the preferred embodiment, any size sector limited only by the size and number of the individual antenna beams forming the composite radiation pattern, may be synthesized according to the present invention. Directing attention to FIGURE 10, synthesis of sectors other than the aforementioned 120° sectors is shown.

FIGURE 10 shows synthesis of three sectors wherein an $\alpha$ sector 1001 has a 60° azimuthal width, a $\beta$ sector 1002 has a 120° azimuthal width, and a $\gamma$ sector 1003 has a 180° azimuthal width. Accordingly, some of the antenna beams utilized in synthesizing the $\gamma$ sector in this example are generated by different panels (have different phase centers) and, therefore, the present invention utilizes delay elements in the transmitted signals. Accordingly, there is one delay/non-delay boundaries in this example.

With reference to FIGURE 6, this radiation pattern may be generated by providing an $\alpha$ signal to input 601 and controlling switch matrixes 653 and 654 to couple the non-delayed $\alpha$ signal to antenna beams 123 and 124, providing a $\beta$ signal to input 602 and controlling switch matrixes 655-658 to couple the non-delayed $\beta$ signal to antenna beams 125-128, and providing a $\gamma$ signal to input 603 and controlling switch matrixes 659-662 to
couple the non-delayed $\gamma$ signal to antenna beams 129-132 and controlling switch matrixes 651 and 652 to couple the delayed $\gamma$ signal to antenna beams 121 and 122. This relationship is shown in the below table.

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<td>Panel 501 - Beam 123 (1R)</td>
<td>Alpha Non-Delayed ($\alpha$)</td>
</tr>
<tr>
<td>Panel 501 - Beam 124 (2R)</td>
<td>Alpha Non-Delayed ($\alpha$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 125 (2L)</td>
<td>Beta Non-Delayed ($\beta$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 126 (1L)</td>
<td>Beta Non-Delayed ($\beta$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 127 (1R)</td>
<td>Beta Non-Delayed ($\beta$)</td>
</tr>
<tr>
<td>Panel 502 - Beam 128 (2R)</td>
<td>Beta Non-Delayed ($\beta$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 129 (2L)</td>
<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
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<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
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<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
<tr>
<td>Panel 503 - Beam 132 (2R)</td>
<td>Gamma Non-Delayed ($\gamma$)</td>
</tr>
</tbody>
</table>

Application of delays according to the preferred embodiment of the present invention, such that pattern nulls are reduced and the CDMA mobiles encounter the minimum number of delay/non-delay boundaries, may be summarized as follows: Delays are not necessary for any sector synthesized from beams having a common phase center, i.e., contained totally within a single antenna panel. For any sector synthesized across antenna panels, delay changes are used only as between beams having a different phase center, i.e., antenna beams at the panel boundaries. Where a delay is used for an antenna beam having a particular phase center, all antenna beams with that phase center should also have a delay associated with the particular signal, i.e., all antenna beams on a particular antenna panel used in synthesizing a sector should have the same delay or non-delay.

With an approach as outlined above, the number of delay/non-delay boundaries created by an antenna system such as illustrated in FIGURE 5 will range from zero (where all antenna beams of synthesized sectors have a common phase center) to three (where the antenna beams of all synthesized sectors include different phase centers). For comparison, alternating beam delay/non-delay, as described above, in a system such as illustrated in
FIGURE 5 always produces nine delay/non-delay boundaries (excluding sector handoff boundaries).

Although the preferred embodiment of the present invention for providing delays in signals to avoid nulls in the radiation pattern has been described with regard to fixed beam switching, it should be appreciated by those of skill in the art that the present invention is not so limited. For example, in the embodiment shown in FIGURE 13 of the present invention, adaptive array circuitry is used to provide coherent radiation patterns without the aforementioned undesirable nulls, wherein the beams are dynamically adjustable. The adaptive array circuitry utilizes delay elements as part of the adaptive array circuitry to avoid nulls in synthesized patterns including antenna beams from across different panels.

FIGURE 13 shows circuitry used in an alternative embodiment of the present invention to provide the desired radiation pattern. The adaptive array circuitry of FIGURE 13 is capable of selectively providing signal components of non-delayed or delayed versions of a signal to ones of a plurality of antenna elements to form the plurality of beams of the radiation pattern. The shape of a particular beam or sector may be adjusted by adjusting the relative amplitudes and phases of signal components of signals at multiple inputs of an antenna array. The relative phase of the signal components of the signals as provided to antenna elements of a cell site antenna array, may also be adjusted to change the azimuthal orientation of a beam of the plurality of beams according to the present invention. Similarly, the relative amplitude of the signal components of the signals as provided to antenna elements of a cell site antenna array may be adjusted to increase or decrease the effective outboard reach or length of a sector or beam referenced in the direction of propagation of the radiation. These amplitudes and phases of the signal components may be adaptively controlled according to communication parameters such as information indicating the quality of the communication channel on particular sectors or the number of calls serviced in particular sectors.

Thus, the block diagram of a preferred embodiment communication system using adaptive array circuitry for providing the desired radiation pattern comprises a service controller 1308 and adaptive array circuitry 1301 as shown in FIGURE 13.
As shown in FIGURE 13, signals 1 through N are provided to adaptive array circuitry 1301. The adaptive array circuitry 1301 includes delay elements 1307a through 1307n, a Tx/Rx switch circuitry 1302, and a Tx/Rx weight circuitry 1303. In the embodiment shown in FIGURE 13, a separate delay element is associated with each of the signals 1 through N. Thus, both delayed and non-delayed versions of the same signal may be provided to the Tx/Rx switch circuitry 1302. The Tx/Rx weight circuitry 1303 may include phase adjusting circuitry (not shown) such as phase adjusters, adjustable phase shifters, I/Q modulators, Surface Acoustic Wave (SAW) devices, switched transmission line lengths, PIN diode circuits and/or the like. The weight circuitry may additionally or alternatively include amplitude adjusting circuitry (not shown), such as adjustable attenuators, adjustable amplifiers, stepped attenuators, PIN diode switched attenuators, variable gain stages, and/or the like. Moreover, adaptive array 1301 may include any other circuitry for suitably manipulating signal components of signals as provided to antenna columns 1309a through 1309m to provide the adjustable beam forming while avoiding nulls in a composite radiation pattern of the present invention.

In order to synthesize the desired radiation patterns, Tx/Rx switch circuitry 1302 preferably comprises a plurality of splitters which split the delayed and non-delayed signals 1 through N into signal components. Each delayed and non-delayed signal may have a corresponding splitter associated with it. The Tx/Rx switch circuitry 1302 may also include switch matrixes (not shown). The signal components, preferably of each delayed and non-delayed signal, from the splitters are provided to the switch matrixes (not shown). The switch matrixes switch the desired signal components to the appropriate portions of the Tx/Rx weighting circuitry 1303 for adjusting.

The phase adjusting circuitry of the weighting circuitry preferably operates to adjust the relative phases of the different signal components of the delayed and non-delayed signals. A phase progression of the different signal components provided to the antenna elements to form the desired beams may be calculated and the phase adjusting circuitry utilized to adjust the different signal components to provide the calculated phase progression to the different signal components to form the desired beams. Thereafter, the phase of the signal components may be adjusted to change the angle or direction of a beam formed using the signals provided...
to the antenna elements. Accordingly, the beam azimuth or orientation is a function of the relative phase progression of the signals as provided to antenna columns. Accordingly, the orientation or direction of the various beams and/or sectors may be changed by adjusting the phase of the signal components in the adaptive array circuitry.

Similarly, the amplitude of the signal components may be adjusted in the adaptive array circuitry. Preferably, the amplitude adjusting circuitry of the weighting circuitry is used to adjust the relative amplitudes of the different signals components of the delayed and non-delayed signals. The effective outboard length of a beam is a function of the relative amplitudes of the signals as provided to antenna columns. Moreover, the shape of the beams is also a function of the relative amplitudes of the signals as provided to the antenna columns. Each antenna element radiates the received signal. The signals from particular antenna elements combine in free space to form the beams or sectors of the communication system.

Manual adjustment of the signal components may be acceptable where, for example, azimuth and/or outboard length are rarely, if ever, changed. However, it is envisioned that the azimuth and/or outboard length of the beams in the present invention will advantageously be adjusted depending on different utilization patterns through any given day or week. Therefore, control signals 1304, 1305 and 1306 may be provided by a controller to the Tx/Rx switch circuitry 1302, the Tx/Rx weight circuitry 1303, and delay elements 1307a, . . . , 1307n to adjust the relative phase and/or amplitude of signal components of signals as provided to antenna elements of an antenna array.

In order to provide automated manipulation of signal components of the signals of the present invention, a service controller is preferably coupled thereto as shown. For example, service controller 1308 adapted to manipulate signals passing through the delay elements, the Tx/Rx switch circuitry and Tx/Rx weight circuitry is provided to form the desired radiation patterns.

Controller 1308 receives communication parameters such as information indicating the quality of the communication channel in any particular sector or the number of calls received in particular sectors. Controller 1308 may also receive similar information from other sectors and also other cell sites. Based on this information, controller 1308 may
calculate the desired switching and/or phase/amplitude adjustments of the signal components desirable to expand or reduce the azimuthal width and/or the outboard length of a sector and may produce control signals 1304, 1305 that are fed to Tx/Rx switch circuit 1302 and Tx/Rx weight circuit 1303, respectively. Furthermore, if a particular sector extends across antenna panels as shown in FIGURES 8, 9 and 10, then control signal 1306 may be fed to one or more of delay elements 1307a through 1307n to introduce desired delays in the signals as fed to switch circuit 1302. Moreover, control signal 1304 fed to Tx/Rx switch 1302 may also include delay information which may be used by the switch circuit 1302 to switch particular signal components of particular delayed signals to the weight circuit 1303. The undelayed signal may be used to form a first portion of the sector and the delayed signal may be used to form another portion of the sector.

Although the above described embodiment of FIGURE 13 shows the delay elements as being part of the adaptive array circuitry, the invention is not so limited and in alternative embodiments of the present invention, the delay elements may be separate from the adaptive array circuitry.

In order to be effective in a typical CDMA cellular system, the delay elements shown in FIGURES 6 and 13 should provide greater than 1 chip duration (Tc) of delay (D) at the CDMA carrier frequency. Because Rake receivers typically implement a duplicate detection algorithm to identify path components spaced too close in time to distinguish, the delay (D) should actually be somewhat greater than the chip duration (Tc) to avoid false alarms. In order to comply with the IS-95A standard, the cell site should transmit signals within \( \pm 3 \mu \text{sec} \) of GPS time, and must transmit signals within \( \pm 10 \mu \text{sec} \) of GPS time. To provide effective performance and simultaneously comply with the recommended \( \pm 3 \mu \text{sec} \) of GPS time in the standard, the constraint on the delay is \( 0.81 \mu \text{sec} < D < 3 \mu \text{sec} \). Accordingly, a value of \( D = 2 \) or \( 2.5 \mu \text{sec} \), selected from the middle of the acceptable range, is a preferred amount of delay to introduce according to the present invention.

The delay elements, if the delay value D is greater than the chip duration Tc, cause the phase cancellation observed at a mobile unit to become frequency selective (multiple narrow fades within the signal bandwidth). If the delay elements were not present, the phase
nulling observed at the mobile unit would be flat faded (the entire signal bandwidth would be attenuated). In a CDMA system, advantage may be taken of the fact that the mobile units have multiple demodulator elements (Rake fingers). By introduction of the delay element, as long as \( D \) is greater than \( T_c \), the mobile unit can assign separate demodulators to the non-delayed and the delay paths.

By introducing the delay element, the nulling (also called fading) across the signal bandwidth can be made frequency selective versus flat faded. As such, the introduction of the delay element can result in more average energy across the signal bandwidth, because with the delay element the width of the nulls as function of frequency is significantly less than the signal bandwidth (\( BW \approx \frac{1}{T_c} \)). Without the delay element, the width of the nulls as a function of frequency can be much greater than the signal bandwidth, resulting the possibility that the entire signal is highly attenuated. In a spread spectrum communication system, such a CDMA, it is possible for the receiver to perform well in a frequency selective fading (nulling) environment due to the fact that the Rake receiver provides multiple demodulator elements that can receive signals at different time delays.

The delay element of the present invention may be any form device adapted to introduce an amount of delay in the signals to be communicated. For example, a predetermined length of cable, a surface acoustic wave (SAW) device, or a digital signal processor (DSP) may be utilized according to the present invention.

Although a preferred embodiment utilizing one delay element for each sector to be synthesized has been shown, different numbers of delay elements may be utilized according to the present invention. For example, where it is anticipated that a synthesized sector will provide 360° coverage, i.e., utilize all antenna beams shown in FIGURE 5, multiple delay elements may be associated with this sector's signal. Directing attention to FIGURE 11, a portion of the circuitry of the preferred embodiment of FIGURE 6 is shown wherein an additional delay element is associated with a input 601. In this alternative embodiment, splitter 1111 provides the signal of input 601 not only to splitter 631 and through delay 621 to splitter 641, but also through delay 1121 to splitter 1141. The switch matrixes associated with the various antenna beams can select as between a non-delayed signal and a signal
having one of two possible delays. This is shown by switch matrix 1151 adapted to accept
the additional signals associated with additional delay elements. Accordingly, a sector
including each of the antenna beams could be synthesized where a delay differential is
introduced as between the antenna beams of each panel of FIGURE 5, i.e, non-delayed α
signal provided to antenna beams 121-124, delayed α₁ signal provided to antenna beams
125-128, and delayed α₂ signal provided to antenna beams 129-132.

Moreover, although a same amount of delay for the delay elements associated with
each input has been discussed herein, it shall be appreciated that there is no such limitation
of the present invention. For example, different delays associated with synthesized sectors
utilizing antenna beams not having a common phase center (i.e. a synthesized sector utilizing
two antenna panels) may be utilized in order to provide both the delay differential to avoid
nulling within a synthesized sector as well as reduced interference in an adjacent synthesized
sector, also including the use of delays for antenna beams having different phase centers, by
causing the signals of the adjacent sectors to be demodulated in different fingers of the Rake
receiver.

Additionally, it should be appreciated that where less than all the narrow beams
emanating from a panel antenna, such as that illustrated in FIGURE 4, are combined, the size
of the composite beam is slightly less that the sum of the individual antenna beams. This is
due to the beam forming matrix being designed for the delivery of multiple antenna beams
and the phase and amplitude losses associated therewith. Accordingly, an alternative
embodiment of the present invention utilizes phase and amplitude adjustments to adjust the
beam width and shape of the composite beams when the individual narrow beams come from
the same panel antenna. This is illustrated in FIGURE 12 as attenuator/amplifier 1201 and
phase shifter 1211 disposed in the signal path of antenna beam 121.

It shall be appreciated that, although the present invention has been described herein
with reference to a cellular wireless communication system, there is no such limitation with
respect to the present invention. The advantages of the present invention are useful in any
number of communication systems wherein multiple antenna beams are utilized to simulcast
a signal.
Furthermore, although the present invention has been discussed in the forward link, it shall be appreciated that the systems and methods described herein are also suitable for use in the reverse link to avoid destructive combining of a signal as received in multiple antenna beams.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.
WHAT IS CLAIMED IS:

1. A system avoid nulls in a composite radiation pattern formed from a plurality of adjustable antenna beams, said system comprising:

   an adaptive array circuitry for providing signals to a plurality of antenna interfaces for forming said plurality of adjustable antenna beams, said adaptive array circuitry comprising:

   delay circuitry for providing a delayed version of a signal to avoid nulls in said radiation pattern;

   splitting circuitry for splitting said signal and said delayed signal into signal components; and

   circuitry for adjusting an attribute of said delayed signal components and said non-delayed signal components, wherein said adjusted delayed signal components are provided to select ones of said plurality of antenna interfaces and said adjusted non-delayed signal components are provided to other ones of said plurality of antenna interfaces to thereby avoid destructive combining of signals radiated from said plurality of antenna interfaces.

2. The system of claim 1, wherein said select ones of said plurality of antenna interfaces are part of a first antenna panel and said other ones of said plurality of antenna interfaces are part of a second antenna panel.

3. The system of claim 1, wherein said delay circuitry introduces a desired delay in said signal to thereby avoid nulls in said radiation pattern.

4. The system of claim 1, wherein said adaptive array circuitry further comprises:

   switching circuitry for selectively providing said delayed signal components and said non-delayed signal components to selected portions of said circuitry for adjusting.
5. The system of claim 1, further comprising:

a controller coupled to said adaptive array circuitry to control said delay circuitry, wherein said controller controls an amount of delay introduced in said signal to provide said delayed signal based on information received from a communication apparatus associated with said system.

6. The system of claim 1, wherein the delay circuitry comprises a delay element disposed in the signal path to introduce a predetermined amount of delay.

7. The system of claim 6, wherein said predetermined amount of delay is provided by a controller based on information received by said controller from said radiation pattern.

8. The system of claim 7, wherein said delay element is selected from the group consisting of:

a predetermined length of cable, a surface acoustic wave device, and a digital signal processor.

9. The system of claim 1, wherein said attribute to be adjusted is selected from the group consisting of a phase and an amplitude.

10. The system of claim 1, wherein circuitry for adjusting provides a desired phase progression to said signal components thereby providing a desired orientation to said radiation pattern.
11. An antenna system for generating a radiation pattern from a plurality of antenna beams, said system comprising:

a plurality of sector signals;

a plurality of delay elements, each delay element being associated with a sector signal for providing a delayed version of its associated sector signal;

a switching circuitry for receiving said plurality of sector signals along with the delayed versions of select ones of said sector signals, wherein said switching circuitry splits said received plurality of sector signals and said delayed versions of select ones of said sector signals into signal components and provides selected signal components of said plurality of sector signals and said plurality of delayed sector signals to be radiated by a plurality of antenna interfaces; and

an adjusting circuitry for adjusting an attribute of said signal components received from said switching circuitry to be provided to said plurality of antenna interfaces, wherein said adjustment of said attribute of signal components to be provided to said antenna interfaces provides a desired radiation pattern, and wherein the introduction of delay by said delay elements functions in part to avoid nulling effects due to destructive combining of the signals radiated from said plurality of antenna interfaces.

12. The antenna system of claim 11, wherein said adjusting circuitry is part of an adaptive array circuitry.

13. The antenna system of claim 11, wherein said attribute is selected from the group consisting of a phase and an amplitude.

14. The antenna system of claim 11, wherein an azimuthal orientation of different beams of said radiation pattern is in part defined as a function of a particular phase progression provided by said adjusting circuitry to selected signal components.
15. The antenna system of claim 11, further comprising:

means for controlling wherein said means for controlling provides a desired
adjustment of said attribute of signal components provided to said antenna interfaces,
wherein said means for controlling utilizes information with respect to communications
associated with said antenna interfaces.

16. The antenna system of claim 15, wherein said means for controlling provides
delay information to said switching circuitry to switch selected signal components of said
plurality of sector signals to selected portions of said adjusting circuitry and selected signal
components of said plurality of delayed sector signals to selected portions of said adjusting
circuitry.

17. A method for providing a radiation pattern by avoiding destructive combining
of signals, the method comprising:

delaying an input signal thereby providing a delayed input signal;

providing said input signal and said delayed input signal to a splitting device wherein
said splitting device splits said input signal and said delayed input signal into signal
components, wherein said splitting device has a plurality of inputs and a plurality of outputs,
and wherein said splitting device provides switchable signal path connections between ones
of said plurality of inputs and ones of said plurality of outputs;

providing said signal components of said input signal to predetermined ones of a
plurality of inputs of an adjusting device and said delayed signal components to
predetermined other ones of said plurality of inputs of said adjusting device; and

adjusting an attribute of the signal components, by said adjusting device, wherein
select ones of said adjusted delayed signal components are provided to select ones of a
plurality of antenna interfaces and select ones of said adjusted non-delayed signal
components are provided to select other ones of said plurality of antenna interfaces, wherein
radiation of signals by said plurality of antenna interfaces provides said radiation pattern
avoiding destructive combining of signals.
18. The method of claim 17, wherein said splitting device is part of an adaptive array circuitry.

19. The method of claim 17, wherein said adjusting device is part of an adaptive array circuitry.

20. The method of claim 17, further comprising:

selecting ones of said adjusted delayed signal components to be provided to select ones of said plurality of antenna interfaces and selecting ones of said adjusted non-delayed signal components to be provided to select other ones of said plurality of antenna interfaces.

21. The method of claim 17, wherein said selected ones of said plurality of antenna interfaces are part of a first antenna panel and said selected other ones of said plurality of antenna interfaces are part of a second antenna panel.

22. The method of claim 17, wherein ones of a plurality of antenna beams associated with said select ones of said plurality of antenna interfaces have a same preselected attribute and ones of said plurality of antenna beams associated with said other ones of said plurality of antenna interfaces have a same preselected attribute.

23. The method of claim 22, wherein said preselected attribute is a phase center.

24. The method of claim 17, further comprising:

identifying antenna beams of said radiation pattern having a common phase center for providing a minimum number of delay boundaries between antenna beams in said radiation pattern.
25. The method of claim 17, wherein the predetermined ones of the plurality of inputs and the predetermined other ones of said plurality of inputs of said adjusting device are each associated with an antenna interface of said plurality of antenna interfaces.