

ule 62 may be operable to execute one or more beam-selection algorithms to make beam selection determinations. In one embodiment, each processing module 62 is operable to execute a fast decision beam-selection algorithm or a smart decision beam-selection algorithm based on one or more parameters, such as whether the processor has knowledge of the number and/or location of mobile stations 15 using the frequency corresponding with that processing module 62.

[0067] One or more processing modules 62 may also be operable to synchronize smart antenna apparatus 16 with base station transceiver 24 in time and/or frequency. In particular, one or more processing modules 62 may be operable to execute one or more synchronization algorithms using control signals, including synchronization signals, received from control channel monitoring module 104 to synchronize smart antenna apparatus 16 with base station transceiver 24.

[0068] Processing system 102 may also include a central processing unit, such as host processor 118, operable to further process the output of each processing module 62. In one embodiment, host processor 118 is operable to determine errors or whether the outputs of one or more processing module 62 are valid or require modification.

[0069] Each processing module 62 may include one or more processors 63, such as microprocessors, digital signal processors, or any other type of processors capable of executing an algorithm. In one embodiment, each processing module 62 includes one or more programmable digital signal processors. Although processing system 102 as described above includes discrete processing modules 62 for processing signals at different frequencies or for performing different functions, it should be understood that the processing functions performed by smart antenna system 14 may be performed by any appropriate number and combination of processing modules 62.

[0070] Referring again to FIG. 2, storage system 103 is operable to store information or data for use by smart antenna apparatus 16. In particular, storage system 103 may store information received from signaling information monitoring system 106. Storage system 103 may also be operable to provide information to and receive information from processing system 102.

[0071] Control channel monitoring module 104 is generally operable to receive control channel signals, including synchronization signals, being communicated from base station transceiver 24 to antenna unit 18, and to prepare such signals to be processed by processing system 102. In some embodiments, control channel monitoring module 104 is operable to filter and convert the control channel signals from a base station transmitting frequency to a smart antenna receiving frequency, receive and sample the signals, and communicate the signals to processing system 102. The control channel signals, including the synchronization signals, may then be processed by processing system 102 in order to synchronize smart antenna apparatus 16 with base station transceiver 24, as discussed in greater detail below with reference to FIGS. 5 through 8.

[0072] Signaling information monitoring system 106 is generally operable to monitor, or receive, signaling information (in other words, base station control information)

being communicated between base station transceiver 24 and base station controller 26 via interface 36. Signaling information monitoring system 106 may also be operable to extract a subset of relevant information from the received signaling information to communicate to processing system 102 as an input in making beam-selection determinations. The relevant information may include information related to one or more mobile stations 15, such as frequency hopping, for example. The systems and methods for monitoring the signaling information are discussed in greater detail below with reference to FIGS. 9 and 10.

[0073] The various systems and modules of smart antenna apparatus 16, including receiving system 100, processing system 102, control channel monitoring module 104, and signaling information monitoring system 106, as well as the components of each system and module; may or may not be co-located, and may be divided and/or combined in any appropriate manner. For example, smart antenna apparatus 16 may include a ground unit located on or near the ground and a tower unit coupled to antenna tower 22. In one embodiment, smart antenna apparatus 16 includes a ground unit located on the ground and a tower unit located near the top of antenna tower 22 proximate antenna unit 18. In another embodiment, smart antenna apparatus 16 includes a ground unit and a tower unit both located on or near the ground. In another embodiment, smart antenna apparatus 16 includes only one unit such that the components of smart antenna apparatus 16 are generally co-located.

[0074] As shown in FIG. 2, antenna unit 18 may include antenna array 28 comprising antenna elements 30, as well as a beam forming network (BFN) 128. Beam forming network 128 is operable to form a plurality of uplink beams 130, each corresponding with, and communicating signals received via, one of the narrow beams 34 by controlling the amplitude and phase of signals received by antenna elements 30. In one embodiment, beam forming network 128 forms seven uplink beams 130.

[0075] In operation, uplink analog signals are communicated by one or more mobile stations 16 via one or more narrow beams 34 and received by antenna array 28. Beam forming network 128 forms a plurality of uplink beams 130 and communicates uplink beams 130 to smart antenna apparatus 16. Uplink beams 130 are received by receiving system 100. In one embodiment in which smart antenna apparatus 16 includes diplexer 122, uplink beams 130 are received by receiver system 100 after passing through diplexer 122. Each uplink beam 130 may be received by a separate frequency receiver unit 108. Each beam may then be converted from analog to digital by a sampler 116.

[0076] The digital uplink beams 130 are then communicated to processing system 102. Using the received uplink beams 130, signaling information received from signaling information monitoring system 106, and/or other parameters as input, processing system 102 executes one or more beam-selection algorithms to determine a receiving beam selection 126 corresponding to one of the uplink beams 130. The receiving beam selection 126 is communicated to a receiving beam switch 127 which filters the uplink beams 130 received from beam forming network 128 such that only the uplink beam 130 corresponding to the receiving beam selection 126 may pass through to base station transceiver 24. In one embodiment in which smart antenna apparatus 16