A method of verifying programmable antenna configurations is disclosed. The method comprises selecting a desired antenna configuration from a plurality of antenna configuration patterns, with the selected antenna configuration forming at least one reconfigurable antenna from reconfigurable antenna array elements. The method validates the formation of the selected antenna configuration to determine antenna performance of the at least one reconfigurable antenna.

20 Claims, 4 Drawing Sheets
Antenna Configuration Controller

Antenna Pattern Generation Module 108
Memory Module 110
Antenna Steering Module 106
Antenna Steering Verification Module 114

Configuration Inputs

Reconfigurable Antenna Array 104

Fig. 1
Select a programmable antenna configuration

Form a reconfigurable antenna from an array of programmable antenna elements

Monitor the selected configuration of the reconfigurable antenna

Compare energy threshold levels detected adjacent to the programmed antenna elements

Desired antenna performance achieved?

Yes

Validate selected antenna configuration

No

Fig. 4
The use of modeling in the design of antennas is known. Typically, antenna designers use classic Euclidean geometry (for example, simple squares, circles, and triangles) to design the shape of an antenna and its components (also known as antenna "elements") to obtain certain antenna characteristics. For example, the antenna designer will use a combination of shapes to control the antenna signal beam shape, also known as the antenna pattern or radiation pattern. This use of combinations of antenna elements and shapes to obtain desired antenna characteristics is typically referred to as antenna beam steering or beam shaping. Geometric antennas usually have well defined, fixed characteristics.

Reconfigurable antennas represent a class of antenna that normally does not have a specific characteristic. Instead, this class of antennas require configuration before they are usable. Reconfigurable antennas can operate over large frequency ranges and can be beam-steered without the use of multiple radiating elements and phase shifters as are found in a phased array type of antenna. In addition, this class of antenna does not generate grating lobes like a phased array antenna because the radiation source is a continuous element instead of a multiplicity of individual elements.

Reconfigurable antennas can accommodate a wide variety of specifications, such as beam width, operating frequency, and radiation angle. The difficulty with an antenna of this type is to determine a configuration that offers the desired performance based on a particular set of requirements and ensure that the configuration of the antenna is the desired configuration. At present, configurable antennas do not verify the configuration.

The following specification discloses reconfigurable antenna pattern verification for reconfigurable antenna arrays. This summary is made by way of example and not by way of limitation. It is merely provided to aid the reader in understanding some aspects of at least one embodiment described in the following specification.

Particularly, in one embodiment, a method of verifying programmable antenna configurations is provided. The method comprises selecting a desired antenna configuration from a plurality of antenna configuration patterns, with the selected antenna configuration forming at least one reconfigurable antenna from reconfigurable antenna array elements.

The method validates the formation of the selected antenna configuration to determine antenna performance of the at least one reconfigurable antenna.
The antenna array controller 102 comprises an antenna steering module 106 and an antenna pattern generation module 108. In the example embodiment of FIG. 1, the antenna pattern generation module 108 further comprises a memory module 110, and the antenna steering module 106 further comprises an antenna steering verification module 114. In one implementation, the memory module 110 is a portion of (that is, resides within) the antenna pattern generation module 108, and the at least one reconfigurable antenna array 104 is in direct communication with the antenna steering module 106. In the same and at least one alternate implementation, the antenna configuration controller 102 comprises a microprocessor, a microcontroller, a field-programmable gate array (FPGA), a field-programmable object array (FPOA), a programmable logic device (PLD), an application-specific integrated circuit (ASIC), or the like. It is understood that the system 100 is capable of accommodating any appropriate number of reconfigurable antenna arrays 104 (for example, a plurality of reconfigurable antenna arrays 104, to 104n) in a single system 100. The composition of the at least one reconfigurable antenna array 104 is discussed in further detail below with respect to FIGS. 2 and 3.

In operation, the antenna configuration controller 102 monitors and validates operation of the programmable elements of each of the reconfigurable antenna arrays 104 based on a desired radiation pattern to determine antenna performance. In the example embodiment of FIG. 1, the antenna configuration controller 102 receives one or more antenna configuration input commands as shown in FIG. 1. In one implementation, the desired radiation pattern is based on an antenna signal beam output requested by the one or more programmable antenna configuration inputs.

In one embodiment, the antenna configuration controller 102 instructs the system 100 to form at least one antenna configuration pattern using at least one of the reconfigurable antenna arrays 104. The antenna configuration controller 102 loads the at least one antenna configuration pattern configured to provide a prescribed signal beam strength for the antenna signal beam output at a desired frequency.

In one embodiment, the antenna pattern generation module 108 further comprises a plurality of previously-identified programmable antenna configuration patterns based on the at least one antenna configuration pattern requested by the antenna configuration controller 102. In the same example, the antenna steering module 106 further comprises a memory module 110, and the antenna steering module 106 further comprises an antenna steering verification module 114. In one implementation, the memory module 110 is a portion of (that is, resides within) the antenna pattern generation module 108, and the at least one reconfigurable antenna array 104 is in direct communication with the antenna steering module 106. In the same and at least one alternate implementation, the antenna configuration controller 102 comprises a microprocessor, a microcontroller, a field-programmable gate array (FPGA), a field-programmable object array (FPOA), a programmable logic device (PLD), an application-specific integrated circuit (ASIC), or the like. It is understood that the system 100 is capable of accommodating any appropriate number of reconfigurable antenna arrays 104 (for example, a plurality of reconfigurable antenna arrays 104, to 104n) in a single system 100. The composition of the at least one reconfigurable antenna array 104 is discussed in further detail below with respect to FIGS. 2 and 3.

In operation, the antenna configuration controller 102 monitors and validates operation of the programmable elements of each of the reconfigurable antenna arrays 104 based on a desired radiation pattern to determine antenna performance. In the example embodiment of FIG. 1, the antenna configuration controller 102 receives one or more antenna configuration input commands as shown in FIG. 1. In one implementation, the desired radiation pattern is based on an antenna signal beam output requested by the one or more programmable antenna configuration inputs.

In one embodiment, the antenna configuration controller 102 instructs the system 100 to form at least one antenna configuration pattern using at least one of the reconfigurable antenna arrays 104. The antenna configuration controller 102 loads the at least one antenna configuration pattern configured to provide a prescribed signal beam strength for the antenna signal beam output at a desired frequency. For example, the antenna pattern generation module 108 provides a plurality of previously-identified programmable antenna configuration patterns based on the at least one antenna configuration pattern requested by the antenna configuration controller 102. In the same example, the antenna steering module 106 further comprises a memory module 110, and the antenna steering module 106 further comprises an antenna steering verification module 114. In one implementation, the memory module 110 is a portion of (that is, resides within) the antenna pattern generation module 108, and the at least one reconfigurable antenna array 104 is in direct communication with the antenna steering module 106. In the same and at least one alternate implementation, the antenna configuration controller 102 comprises a microprocessor, a microcontroller, a field-programmable gate array (FPGA), a field-programmable object array (FPOA), a programmable logic device (PLD), an application-specific integrated circuit (ASIC), or the like. It is understood that the system 100 is capable of accommodating any appropriate number of reconfigurable antenna arrays 104 (for example, a plurality of reconfigurable antenna arrays 104, to 104n) in a single system 100. The composition of the at least one reconfigurable antenna array 104 is discussed in further detail below with respect to FIGS. 2 and 3.

In operation, the antenna configuration controller 102 monitors and validates operation of the programmable elements of each of the reconfigurable antenna arrays 104 based on a desired radiation pattern to determine antenna performance. In the example embodiment of FIG. 1, the antenna configuration controller 102 receives one or more antenna configuration input commands as shown in FIG. 1. In one implementation, the desired radiation pattern is based on an antenna signal beam output requested by the one or more programmable antenna configuration inputs.

In one embodiment, the antenna configuration controller 102 instructs the system 100 to form at least one antenna configuration pattern using at least one of the reconfigurable antenna arrays 104. The antenna configuration controller 102 loads the at least one antenna configuration pattern configured to provide a prescribed signal beam strength for the antenna signal beam output at a desired frequency. For example, the antenna pattern generation module 108 provides a plurality of previously-identified programmable antenna configuration patterns based on the at least one antenna configuration pattern requested by the antenna configuration controller 102. In the same example, the antenna steering module 106 further comprises a memory module 110, and the antenna steering module 106 further comprises an antenna steering verification module 114. In one implementation, the memory module 110 is a portion of (that is, resides within) the antenna pattern generation module 108, and the at least one reconfigurable antenna array 104 is in direct communication with the antenna steering module 106. In the same and at least one alternate implementation, the antenna configuration controller 102 comprises a microprocessor, a microcontroller, a field-programmable gate array (FPGA), a field-programmable object array (FPOA), a programmable logic device (PLD), an application-specific integrated circuit (ASIC), or the like. It is understood that the system 100 is capable of accommodating any appropriate number of reconfigurable antenna arrays 104 (for example, a plurality of reconfigurable antenna arrays 104, to 104n) in a single system 100. The composition of the at least one reconfigurable antenna array 104 is discussed in further detail below with respect to FIGS. 2 and 3.

In operation, the antenna configuration controller 102 monitors and validates operation of the programmable elements of each of the reconfigurable antenna arrays 104 based on a desired radiation pattern to determine antenna performance. In the example embodiment of FIG. 1, the antenna configuration controller 102 receives one or more antenna configuration input commands as shown in FIG. 1. In one implementation, the desired radiation pattern is based on an antenna signal beam output requested by the one or more programmable antenna configuration inputs.

In one embodiment, the antenna configuration controller 102 instructs the system 100 to form at least one antenna configuration pattern using at least one of the reconfigurable antenna arrays 104. The antenna configuration controller 102 loads the at least one antenna configuration pattern configured to provide a prescribed signal beam strength for the antenna signal beam output at a desired frequency. For example, the antenna pattern generation module 108 provides a plurality of previously-identified programmable antenna configuration patterns based on the at least one antenna configuration pattern requested by the antenna configuration controller 102. In the same example, the antenna steering module 106 further comprises a memory module 110, and the antenna steering module 106 further comprises an antenna steering verification module 114. In one implementation, the memory module 110 is a portion of (that is, resides within) the antenna pattern generation module 108, and the at least one reconfigurable antenna array 104 is in direct communication with the antenna steering module 106. In the same and at least one alternate implementation, the antenna configuration controller 102 comprises a microprocessor, a microcontroller, a field-programmable gate array (FPGA), a field-programmable object array (FPOA), a programmable logic device (PLD), an application-specific integrated circuit (ASIC), or the like. It is understood that the system 100 is capable of accommodating any appropriate number of reconfigurable antenna arrays 104 (for example, a plurality of reconfigurable antenna arrays 104, to 104n) in a single system 100. The composition of the at least one reconfigurable antenna array 104 is discussed in further detail below with respect to FIGS. 2 and 3.
array pattern as configured is substantially functional as the selected antenna array pattern.

FIG. 4 is a flow diagram of a method 400 of verifying programmable antenna configurations, similar to the programmable antenna configurations available from the system 100 of FIG. 1. The method 400 addresses validating the formation of programmable antenna configurations by monitoring selected antenna configurations to determine antenna performance of at least one reconfigurable antenna. In one implementation, the method of FIG. 4 selects the programmable antenna configurations based on previously identified antenna configuration patterns (block 402). The selected programmable antenna configuration forms the at least one reconfigurable antenna from an array of programmable antenna elements (block 404). In one embodiment, the method 400 loads the selected programmable antenna configuration as at least one reconfigurable antenna steering pattern related to at least one of the previously identified antenna configuration patterns. Moreover, each of the programmable antenna configurations can be formed based on at least one signal beam pattern having known signal beam characteristics.

The method 400 monitors each of the selected antenna configurations by detecting a configuration state of the antenna array elements (block 406). In one implementation, the configuration state is indicative of an energy threshold level for configured array elements. The method 400 further compares the detected energy threshold levels at a plurality of switches adjacent to the configured array elements to determine that the programmable antenna configuration is substantially functional as that at least one reconfigurable antenna (block 408). To further validate the configured array elements, the method 400 evaluates each of the monitored antenna configurations based on the configuration of the switches selected to steer the reconfigurable antenna array elements in a desired signal beam direction (block 410). In one embodiment, the configuration is valid once the desired antenna performance is achieved (block 412).

The methods and techniques described here may be implemented in digital electronic circuitry, or with firmware or software in a programmable processor (for example, a special-purpose processor or a general-purpose processor such as a computer), or in combinations of them. An apparatus embodying these techniques may include appropriate input and output devices, a programmable processor, and a storage medium tangibly embodying program instructions for execution by the programmable processor. A process embodying these techniques may be performed by a programmable processor executing a program of instructions to perform desired functions by operating on input data and generating an appropriate output. The techniques may be implemented in one or more programs that are executable on a programmable system including at least one programmable processor coupled to receive data and instructions from, and to transmit data and instructions to, a data storage system, at least one input device, and at least one output device. Generally, a processor will receive instructions and data from a read-only memory (RAM) or a random access memory (ROM).

Storage devices suitable for tangibly embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, such as (electrically) erasable programmable read-only memory (EPROM or EEPROM), and flash memory devices; magnetic disks such as internal hard disks and removable disks; and magneto-optical disks, including but not limited to digital video disks (DVDs). Any of the foregoing may be supplemented by, or incorporated in, specially-designed application-specific integrated circuits (ASICs), and the like.

This description has been presented for purposes of illustration, and is not intended to be exhaustive or limited to the embodiments disclosed. Variations and modifications may occur, which fall within the scope of the following claims.

What is claimed is:

1. A method of verifying programmable antenna configurations, the method comprising:
   selecting a desired antenna configuration pattern from a plurality of antenna configuration patterns;
   issuing commands to an array of antenna element switches coupled to a plurality of reconfigurable antenna elements, wherein the commands cause the array of antenna element switches to switch to programmed positions causing the reconfigurable antenna array elements to form the desired antenna configuration pattern;
   monitoring actual positions of the array of antenna element switches; and
   verifying that the actual positions of the array of antenna element switches match the programmed positions of the array of antenna element switches.

2. The method of claim 1 and further comprising selecting the desired antenna configuration pattern based on at least one antenna radiation pattern having known signal beam characteristics.

3. The method of claim 1, wherein selecting the desired antenna configuration pattern further comprises loading at least one reconfigurable antenna steering pattern related to at least one of the plurality of antenna configuration patterns.

4. The method of claim 1, further comprising monitoring a configuration state of the reconfigurable antenna array elements that form the desired antenna configuration pattern, the configuration state indicative of an energy threshold level for the reconfigurable antenna array elements.

5. The method of claim 4, wherein monitoring the configuration state of the reconfigurable antenna array elements comprises evaluating the desired antenna configuration pattern based on the actual positions of the array of antenna element switches.

6. The method of claim 5, wherein evaluating the desired antenna configuration pattern further comprises comparing energy levels at a plurality of antenna element switches adjacent to the reconfigurable antenna array elements to determine that the desired antenna configuration pattern is substantially functional as a reconfigurable antenna.

7. An antenna configuration controller for antenna configuration pattern verification, comprising:
   an antenna pattern generation module operable to provide a plurality of antenna configuration patterns; and
   an antenna steering module in communication with the antenna pattern generation module, the antenna steering module operable to load at least one of the antenna configuration patterns on a reconfigurable antenna array having an array of antenna element switches coupled to a plurality of reconfigurable antenna elements by causing the array of antenna element switches to switch to programmed positions causing the reconfigurable antenna array elements to form the desired antenna configuration pattern;
   wherein the antenna steering module is further operable to verify that actual positions of the array of antenna element switches match the programmed positions of the array of antenna element switches of the reconfigurable antenna array.
8. The controller of claim 7, wherein the antenna configuration controller is operable to monitor the at least one antenna configuration pattern formed on the reconfigurable antenna array.

9. The controller of claim 7, wherein the antenna configuration controller is operable to receive one or more antenna configuration input commands.

10. The controller of claim 7, wherein the antenna configuration controller comprises at least one of a microprocessor, a microcontroller, a field-programmable gate array, a field-programmable object array, a programmable logic device, or an application-specific integrated circuit.

11. The controller of claim 7, wherein the antenna pattern generation module further comprises a memory module.

12. The controller of claim 11, wherein the memory module is operable to store each of the antenna configuration patterns with a corresponding switching pattern for the reconfigurable antenna array.

13. The controller of claim 7, wherein the antenna steering module further includes an antenna steering verification module.

14. The controller of claim 13, wherein the antenna steering verification module is operable to verify that the actual positions of the array of antenna element switches match the programmed positions of the array of antenna element switches of the reconfigurable antenna array.

15. The controller of claim 13, wherein the antenna steering verification module is operable to detect configuration states of the reconfigurable antenna elements, the configuration states indicative of energy threshold levels for configured reconfigurable antenna elements.

16. The controller of claim 13, wherein the antenna steering verification module is further operable to compare energy levels at a plurality of antenna element switches adjacent to the configured reconfigurable antenna elements to determine that the desired antenna configuration pattern is substantially functional as the at least one reconfigurable antenna.

17. A computer program product comprising program instructions, embodied on a non-transitory machine-readable storage medium, the program instructions cause at least one programmable processor of an antenna configuration pattern verification system to:

receive configuration commands to form at least one desired antenna configuration pattern using a reconfigurable antenna array;

issue commands to an array of antenna element switches coupled to a plurality of reconfigurable antenna elements in the reconfigurable antenna array, wherein the commands cause the array of antenna element switches to switch to programmed positions causing the reconfigurable antenna array elements to form the desired antenna configuration pattern;

monitor actual positions of the array of antenna element switches; and

verify that the actual positions of the array of antenna element switches match the programmed positions of the array of antenna element switches.

18. The computer program product of claim 17, wherein the desired antenna configuration pattern is configured to provide a prescribed signal beam characteristics for an antenna signal beam output at a desired frequency.

19. The computer program product of claim 17, further comprising program instructions that cause the at least one programmable processor to detect a configuration state of the reconfigurable antenna array elements, the configuration state indicative of an energy threshold level.

20. The computer program product of claim 19, wherein the program instructions that detect the configuration state of the reconfigurable antenna array elements cause the at least one programmable processor to compare energy levels at a plurality of antenna element switches adjacent to the reconfigurable antenna array elements to verify that an antenna signal beam output is substantially functional for the at least one desired antenna configuration pattern.