CLAIMS

1. An array antenna comprising,

a plurality of sub-arrays,

each of the plurality of sub-arrays comprising,

a plurality of antenna elements, each antenna element comprising a first feeding port and a second feeding port;

a physical integrated circuit (IC) comprising a plurality of first and second output channels;

a first feeding network comprising a plurality of first feed lines communicatively coupling each of the first output channels of the physical IC to a first feeding port of each of the plurality of antenna elements;

a second feeding network comprising a plurality of second feed lines communicatively coupling each of the second output channels of the physical IC to a second feeding port of each of the plurality of antenna elements; and

a virtual sub-array comprising antenna elements of neighboring sub-arrays;

wherein the physical IC is configured to excite the plurality of antenna elements via the first feeding network to generate a first circularly polarized (CP) beam and to excite the plurality of antenna elements via the second feeding network to generate a second CP beam,

wherein the respective first CP beams from each of the plurality of sub-arrays form a first combined CP beam; and the respective second CP beams from each of the plurality of sub-arrays form a second combined CP beam, and

wherein the physical ICs of the neighboring sub-arrays are configured to respectively excite the antenna elements of the virtual sub-array to generate a third and/or a fourth CP beam, said third CP beam contributing to form the first combined CP beam, and said fourth CP beam contributing to form the second combined CP beam.

2. The array antenna according to claim 1,

wherein the plurality of antenna elements in all the plurality of sub-arrays are collectively arranged in a square lattice configuration having a first direction and a second direction, wherein the second direction is substantially perpendicular to the first direction, and

wherein any two immediately adjacent antenna elements positioned along the first direction and any two immediately adjacent antenna elements positioned along the second direction are separated by a distance of about 0.5λ, where λ represents a free space wavelength of the first or second CP beam.

3. The array antenna according to claim 1 or 2, wherein the physical ICs of the neighboring sub-arrays are respectively configured to adjust an amplitude and a phase of excitation of respective antenna elements coupled thereto, in order to generate the third and/or fourth CP beams.

4. The array antenna according to claim 2 or 3, wherein the virtual sub-array is formed from antenna elements from two sub-arrays that are adjacent to each other along the first direction or the second direction, said antenna elements of the virtual sub-array immediately adjacent to each other within the square lattice.

5. The array antenna according to any one of claims 2 to 4, wherein the virtual sub-array is formed from antenna elements from four sub-arrays that are arranged in a 2 x 2 configuration, said antenna elements of the virtual sub-array immediately adjacent to each other within the square lattice.

6. The array antenna according to any one of claims 1 to 5, wherein each of the virtual sub-arrays comprises four antenna elements arranged in a 2 x 2 square lattice configuration.

7. The array antenna according to any one of claims 2 to 7, wherein each virtual sub-array is separated by a distance of about 0.5λ from an immediately adjacent sub-array or virtual sub-array positioned along the first direction or the second direction, where λ represents a free space wavelength of the first or second CP beam.

8. The array antenna according to any one of claims 1 to 7, wherein the physical ICs are configured to excite the plurality of antenna elements of each sub-array and virtual sub-array in a sequentially rotated manner with identical amplitude and 90° phase difference.

9. The array antenna according to any one of claims 1 to 8, wherein the first, second, third and fourth CP beams are simultaneously generated, and wherein the first and second CP beams are each independently a left-handed circularly polarized (LHCP) beam or a right-handed circularly polarized (RHCP) beam, and further wherein the third CP beam follows the direction of polarization of the first CP beam and the fourth CP beam follows the direction of polarization of the second CP beam.

10. The array antenna according to any one of claims 1 to 9, wherein the first and second feeding ports of each antenna element are orthogonally orientated with respect to each other.

11. The array antenna according to any one of claims 2 to 10, wherein for each sub-array, any two antenna elements that are immediately adjacent to each other along the first direction and second direction are orientated such that one antenna element is rotated at an angle of 90° with respect to the other antenna element.

12. The array antenna according to any one of claims 1 to 11, wherein the physical IC is configured to perform amplitude quantization of the CP beams, wherein the amplitude quantization is implemented by selecting a cut-off value of amplitude to achieve a distribution of amplitudes with less tapering and normalizing the distribution of amplitudes to a new reference value based on the cut-off value.

13. A method of generating CP beams using an array antenna comprising,

a plurality of sub-arrays,

each of the plurality of sub-arrays comprising,

a plurality of antenna elements, each antenna element comprising a first feeding port and a second feeding port;

a physical IC comprising a plurality of first and second output channels;

a first feeding network comprising a plurality of first feed lines communicatively coupling each of the first output channels of the physical IC to a first feeding port of each of the plurality of antenna elements;

a second feeding network comprising a plurality of second feed lines communicatively coupling each of the second output channels of the physical IC to a second feeding port of each of the plurality of antenna elements; and

a virtual sub-array comprising antenna elements of neighboring sub-arrays;

wherein the method comprises,

using the physical IC to excite the plurality of antenna elements via the first feeding network to generate a first circularly polarized (CP) beam and to excite the plurality of antenna elements via the second feeding network to generate a second CP beam,

forming a first combined CP beam from the respective first CP beams generated from each of the plurality of sub-arrays and forming a second combined CP beam from the respective second CP beams generated from each of the plurality of sub-arrays, and

configuring the physical ICs of the neighboring sub-arrays to respectively excite the antenna elements of the virtual sub-array to generate a third and/or a fourth CP beam, said third CP beam contributing to form the first combined CP beam, and said fourth CP beam contributing to form the second combined CP beam.

14. The method according to claim 13,

wherein the plurality of antenna elements in all the plurality of sub-arrays are collectively arranged in a square lattice configuration having a first direction and a second direction, wherein the second direction is substantially perpendicular to the first direction, and

wherein any two immediately adjacent antenna elements positioned along the first direction and any two immediately adjacent antenna elements positioned along the second direction are separated by a distance of about 0.5λ, where λ represents a free space wavelength of the first or second CP beam.

15. The method according to claim 13, wherein configuring the physical ICs of the neighboring sub-arrays to respectively excite the antenna elements of the virtual sub-array comprises adjusting an amplitude and a phase of excitation of respective antenna elements coupled thereto, in order to generate the third and/or fourth CP beams.

16. The method according to claim 14 or 15, wherein the virtual sub-array is formed from antenna elements from two sub-arrays that are adjacent to each other along the first direction or the second direction, said antenna elements of the virtual sub-array immediately adjacent to each other within the square lattice.

17. The method according to any one of claims 13 to 16, wherein the virtual sub-array is formed from antenna elements from four sub-arrays that are arranged in a 2 x 2 configuration, said antenna elements of the virtual sub-array immediately adjacent to each other within the square lattice.

18. The method according to any one of claims 13 to 17, further comprising exciting the plurality of antenna elements in each sub-array and virtual sub-array using the physical IC

in each sub-array in a sequentially rotated manner with identical amplitude and 90° phase difference.

19. The method according to any one of claims 13 to 18, further comprising simultaneously generating the first, second, third and fourth CP beams, wherein the first and second CP beams are each independently a left-handed circularly polarized (LHCP) beam or a right-handed circularly polarized (RHCP) beam, and further wherein the third CP beam follows the direction of polarization of the first CP beam and the fourth CP beam follows the direction of polarization of the second CP beam.

20. The method according to any one of claims 13 to 19, further comprising performing amplitude quantization of the CP beams using the physical IC in each sub-array, wherein the amplitude quantization is implemented by selecting a cut-off value of amplitude to achieve a distribution of amplitudes with less tapering and normalizing the distribution of amplitudes to a new reference value based on the cut-off value.