

What is claimed is:

1. A communication system comprising:
 - a Gradient-index lens;
 - a first plurality of antenna elements arranged on a first surface parallel to a surface of the Gradient-index lens, wherein the first plurality of antenna elements are configured to generate a first plurality of antenna signals in response to receiving a signal from an end user device; and
 - a control system configured to receive the first plurality of antenna signals from the first plurality of antenna elements and determine an end user direction associated with the end user signal based on a predetermined set of antenna signal values associated with the first plurality of antenna elements.
2. The communication system of claim 1, wherein the predetermined set of antenna signal values include a plurality of subsets of voltage signal values, and the plurality of subsets of voltage signal values are indicative of a plurality of predetermined end user signal directions.
3. The communication system of claim 2, wherein to determine the end user direction, the control system is configured to:
 - execute a correlation and/or a compressive sensing algorithm that calculates a plurality of correlation values between the first plurality of antenna signals and the plurality of subsets of voltage signal values; and
 - select the end user direction from the plurality of predetermined end user signal directions based on the calculated plurality of correlation values.
4. The communication system of claim 3, wherein the control system generates a control signal and the first plurality of antenna elements are configured to generate and scan a reference signal in a solid angle based on the control signal, wherein the end user device is configured to generate the end user signal in response to receiving the reference signal.
5. The communication system of claim 4, wherein the reference signal includes a pulsed and/or a frequency modulated signal and the control system is configured to determine an end user distance between the communication system and the end user device based on a time

difference between a first time of transmission of the reference signal and a second time of reception of the signal from the end user signal.

6. The communication system of claim 5, wherein the control system is configured to generate a second plurality of control signals to control the operation of the first plurality of antenna elements based on the end user direction and the end user distance.

7. The communication system of any one of claims 1 through 6, wherein the plurality of antenna elements are arranged in an azimuth plane of the Gradient-index lens and/or in a sector of elevation of the Gradient-index lens.

8. The communication system of any one of claims 1 through 7, wherein a first Gradient-index lens includes a birefringent material configured to focus a first beam having a first polarization at a first distance from the surface of the Gradient-index lens and focus a second beam having a second polarization at a second distance from the surface of the Gradient-index lens.

9. The communication system of claim 8, wherein the first surface is located at the first distance from the surface of the Gradient-index lens, and the first plurality of antenna elements are configured to generate radiation having the first polarization.

10. The communication system of claim 9, further comprising a second plurality of antenna elements arranged on a second surface parallel to the surface of the Gradient-index lens, wherein the second surface is located at the second distance from the surface of the Gradient-index lens.

11. The communication system of claim 10, wherein the second plurality of antenna elements are configured to generate radiation having the second polarization.

12. The communication system of claim 11, wherein a first antenna element of the first plurality of antenna elements has a first orientation and a second antenna element of the second plurality of antenna elements has a second orientation.
13. The communication system of claim 4, wherein the control system includes:
 - a controller; and
 - a third plurality of control circuitry configured to generate one or more control sub-signals, wherein the control signal includes the one or more control sub-signals and wherein the controller determines the amplitude and/or phase of the one or more control sub-signals.
14. The communication system of claim 13, wherein the first plurality of antenna elements have a characteristic bandwidth and the controller is configured to determine an operational bandwidth of the one or more control sub-signals, wherein the operational bandwidth lies within the characteristic bandwidth.
15. The communication system of claim 13, wherein the first plurality of antenna elements have a characteristic bandwidth and the controller is configured to vary the characteristic bandwidth by reorganizing radiating sections of the first plurality of antenna elements.
16. The communication system of claim 15, wherein the first plurality of antenna elements are reconfigurable antennas.
17. The communication system of claim 16, wherein the reconfigurable antennas are pixelated printed monopoles.
18. The communication system of claim 13, further comprising a switch matrix configured to electrically connect the first plurality of antenna elements and the third plurality of control circuitry, wherein the switch matrix is configured to connect a first antenna element of the first plurality of antenna elements to a first control circuitry of the third

plurality of control circuitry during a first time period and to a second control circuitry of the third plurality of control circuitry during a second time period.

19. The communication system of claim 4, wherein the control system generates a second control signal and the first plurality of antenna elements are configured to generate a communication signal directed to the end user device based on the second control signal.

20. The communication system of claim 19, wherein the control system is further configured to:

- determine an interference direction associated with an interference signal; and
- generate a reconfiguration signal, wherein the first plurality of antenna elements are configured to generate a null beam directed along the interference direction based on the reconfiguration signal.

21. The communication system of claim 1, wherein the Gradient-index lens includes a Luneburg lens.

22. A method comprising:

- providing a communication system comprising a Gradient-index lens, a first plurality of antenna elements arranged on a first surface parallel to a surface of the Gradient-index lens and a control system;

- generating, by the plurality of antenna elements, a first plurality of antenna signals in response to receiving a signal from an end user device;

- receiving, by the control system, the first plurality of antenna signals from the first plurality of antenna elements; and

- determining, by the control system, an end user direction associated with the end user signal based on a predetermined set of antenna signal values associated with the first plurality of antenna elements.

23. The method of claim 22, wherein the predetermined set of antenna signal values include a plurality of subsets of voltage signal values, and the plurality of subsets of voltage signal values are indicative of a plurality of predetermined end user signal directions.
24. The method of claim 22, further comprising:
executing, by the control system, a correlation and/or a compressive sensing algorithm that calculates a plurality of correlation values between the first plurality of antenna signals and the plurality of subsets of voltage signal values; and
selecting, by the control system, the end user direction from the plurality of predetermined end user signal directions based on the calculated plurality of correlation values.
25. The method of claim 24, further comprising:
generating, by the control system, a control signal; and
generating and scanning, by the first plurality of antenna elements, a reference signal in a solid angle based on the control signal, wherein the end user device is configured to generate the end user signal in response to receiving the reference signal.
26. The method of claim 25, further comprising determining, by the control system, an end user distance between the communication system and the end user device based on a time difference between a first time of transmission of the reference signal and a second time of reception of the signal from the end user signal, wherein the reference signal includes a pulsed and/or a frequency modulated signal.
27. The method of claim of claim 26, further comprising generating, by the control system, a second plurality of control signals to control the operation of the first plurality of antenna elements based on the end user direction and the end user distance.
28. The method of any one of claims 22 through 27, wherein the plurality of antenna elements are arranged in an azimuth plane of the Gradient-index lens and/or in a sector of elevation of the Gradient-index lens.

29. The method of any one of claims 22 through 28, further comprising focusing, by the Gradient-index lens, a first beam having a first polarization at a first distance from the surface of the Gradient-index lens, and a second beam having a second polarization at a second distance from the surface of the Gradient-index lens, wherein, the Gradient-index lens includes a birefringent material.

30. The method of claim 29, further comprising generating, by the first plurality of antenna elements, radiation having the first polarization, wherein the first surface is located at the first distance from the surface of the Gradient-index lens.

31. The method of claim 30, wherein the communication system further comprises a second plurality of antenna elements arranged on a second surface parallel to the surface of the Gradient-index lens, wherein the second surface is located at the second distance from the surface of the Gradient-index lens.

32. The method of claim 31, further comprising, generating, by the second plurality of antenna elements, radiation having the second polarization.

33. The method of claim 32, wherein a first antenna element of the first plurality of antenna elements has a first orientation and a second antenna element of the second plurality of antenna element has a second orientation.

34. The method of claim 25, further comprising:
generating, by a third plurality of control circuitry, one or more control sub-signals, wherein the control system includes the third plurality of control circuitry and a controller, and the controller determines the amplitude and/or phase of the one or more control sub-signals.

35. The method of claim 34, further comprising determining, by the controller, an operational bandwidth of the one or more control sub-signals, wherein the operational

bandwidth lies within a characteristic bandwidth associated with the first plurality of antenna elements.

36. The method of claim 34, further comprising varying, by the controller, a characteristic bandwidth of the first plurality of antenna elements by reorganizing radiating sections of the first plurality of antenna elements.

37. The method of claim 36, wherein the first plurality of antenna elements are reconfigurable antennas

38. The method of claim 37, wherein the reconfigurable antennas are pixelated printed monopoles.

39. The method of claim 34, further comprising:
connecting, by a switch matrix, a first antenna element of the first plurality of antenna elements to a first control circuitry of the third plurality of control circuitry during a first time period; and
connecting, by the switch matrix, the first antenna element of the first plurality of antenna elements to a second control circuitry of the third plurality of control circuitry during a second time period.

40. The method of claim 25, further comprising:
generating, by the control system, a second control signal; and
generating, by the first plurality of antenna elements, a communication signal directed to the end user device based on the second control signal.

41. The method of claim 40, further comprising:
determining, by the control system, an interference direction associated with an interference signal;
generating, by the control system, a reconfiguration signal; and

generating, by the first plurality of antenna elements, a null beam directed along the interference direction based on the reconfiguration signal.

42. The method of claim 22, wherein the Gradient-index lens includes a Luneburg lens.