CLAIMS

1. An antenna, comprising:

a wave-propagating structure; and

a plurality of scattering elements distributed along the wave-propagating structure with inter-element spacings substantially less than a free-space wavelength corresponding to an operating frequency of the antenna, where the plurality of scattering elements have a plurality of adjustable individual electromagnetic responses to a guided wave mode of the wave-propagating structure, and the plurality of adjustable individual electromagnetic responses provide an adjustable radiation field of the antenna.

2. The antenna of claim 1, wherein the plurality of scattering elements is a plurality of substantially identical scattering elements.

3. The antenna of claim 1, wherein the plurality of adjustable individual electromagnetic responses provides an effective medium response for the guided wave mode of the wave-propagating structure.

4. The antenna of claim 1, wherein the plurality of adjustable individual electromagnetic responses is a plurality of magnetic dipole radiation fields.

5. The antenna of claim 1, wherein the operating frequency is a microwave frequency.

6. The antenna of claim 5, wherein the microwave frequency is a Ka band frequency.

7. The antenna of claim 5, wherein the microwave frequency is a Ku band frequency.

8. The antenna of claim 5, wherein the microwave frequency is a Q band frequency.

9. The system of claim 1, wherein the inter-element spacing is less than one-fourth of the free space wavelength.

10. The system of claim 1, wherein the inter-element spacing is less than one-fifth of the free space wavelength.

11. The antenna of claim 1, wherein the wave-propagating structure includes one or more conducting surfaces and the plurality of scattering elements corresponds to a plurality of apertures within the one or more conducting surfaces.

12. The antenna of claim 11, wherein the wave-propagating structure is a substantially two-dimensional wave-propagating structure.

13. The antenna of claim 12, wherein the substantially two-dimensional wave-propagating structure is a parallel plate waveguide, and the one or more conducting surfaces are an upper conductor of the parallel plate waveguide.

14. The antenna of claim 11, wherein the wave-propagating structure includes one or more substantially one-dimensional wave-propagating structures.

15. The antenna of claim 14, wherein the one or more substantially one-dimensional wave-propagating structures are a plurality of substantially one-dimensional wave-propagating structures composing a substantially two-dimensional antenna area.

16. The antenna of claim 14, wherein the one or more substantially one-dimensional wave-propagating structures include one or more microstrips.

17. The antenna of claim 16, wherein the one or more conducting surfaces are one or more respective upper conductors of the one or more microstrips.

18. The antenna of claim 16, wherein the one or more conducting surfaces are one or more conducting strips positioned parallel to one or more upper conductors of the one or more microstrips.

19. The antenna of claim 14, wherein the one or more substantially one-dimensional wave-propagating structures include one or more coplanar waveguides.

20. The antenna of claim 19, wherein the one or more conducting surfaces are positioned above the one or more coplanar waveguides.

21. The antenna of claim 14, wherein the one or more substantially one-dimensional wave-propagating structures include one or more closed waveguides.

22. The antenna of claim 21, wherein the one or more closed waveguides include one or more rectangular waveguides.

23. The antenna of claim 22, wherein the one or more rectangular waveguides includes one or more double-ridged rectangular waveguides.

24. The antenna of claim 21, wherein the one or more conducting surfaces are one or more respective upper surfaces of the one or more closed waveguides.

25. The antenna of claim 21, wherein the one or more conducting surfaces are positioned above one or more respective upper surfaces of the one or more closed waveguides, and the one or more respective upper surfaces include a plurality of irises adjacent to the plurality of apertures within the one or more conducting surfaces

26. The antenna of claim 11, wherein the plurality of apertures defines a respective plurality of conducting islands that are electrically disconnected from the one or more conducting surfaces, and the antenna further comprises:

a plurality of bias voltage lines configured to provide respective bias voltages between the one or more conducting surfaces and the respective plurality of conducting islands; and

an electrically adjustable material disposed at least partially within respective vicinities of the plurality of apertures.

27. The antenna of claim 26, wherein the electrically adjustable material is a liquid crystal material.

28. The antenna of claim 27, wherein the liquid crystal material is a nematic liquid crystal.

29. The antenna of claim 27, wherein the liquid crystal material is a dual-frequency liquid crystal.

30. The antenna of claim 27, wherein the liquid crystal material is a polymer network liquid crystal.

31. The antenna of claim 27, wherein the liquid crystal material is a polymer dispersed liquid crystal.

32. The antenna of claim 11, wherein the plurality of apertures defines a respective plurality of conducting islands that are electrically disconnected from the one or more conducting surfaces, the plurality of apertures are arranged in rows and columns, and the antenna further comprises:

a plurality of biasing circuits configured to provide respective bias voltages between the one or more conducting surfaces and the respective plurality of conducting islands;

a set of row control lines each addressing a row of the plurality of biasing circuits;

a set of column control lines each addressing a column of the plurality of biasing circuits; and

an electrically adjustable material disposed at least partially within respective vicinities of the plurality of apertures.

33. The antenna of claim 32, wherein the plurality of biasing circuits are arranged in rows and columns respectively adjacent to the plurality of apertures.

34. The antenna of claim 11, wherein the plurality of apertures defines a plurality of complementary metamaterial elements having a plurality of magnetic dipole responses to a magnetic field of the guided wave.

35. The antenna of claim 34, wherein the plurality of complementary metamaterial elements is a plurality of complementary electric LC metamaterial elements.

36. The antenna of claim 34, wherein the plurality of magnetic dipole responses is a plurality of in-plane magnetic dipole responses oriented parallel to the one or more conducting surfaces.

37. The antenna of claim 36, wherein the plurality of in-plane magnetic dipole responses includes a first plurality of in-plane magnetic dipole responses oriented in a first direction parallel to the one or more conducting surfaces and a second plurality of in-plane magnetic dipole responses oriented in a second direction perpendicular to the first direction and parallel to the one or more conducting surfaces

38. A method, comprising:

providing a wave-propagating structure;

providing a plurality of scattering elements distributed along the wave-propagating structure with inter-element spacings substantially less than a free-space wavelength corresponding to an operating frequency of the antenna, where the plurality of scattering elements have a plurality of adjustable individual electromagnetic responses to a guided wave mode of the wave-propagating structure, and the plurality of adjustable individual electromagnetic responses provide an adjustable radiation field of the antenna.

propagating a first guided wave to deliver a first plurality of relative phases to a respective plurality of locations;

coupling to the first guided wave at a first set of locations selected from the respective plurality of locations to produce a first plurality of electromagnetic oscillations at the first set of locations, the first plurality of electromagnetic oscillations producing a first radiation field;

propagating a second guided wave to deliver a second plurality of relative phases to the respective plurality of locations, where the second plurality of

relative phases is substantially equal to the first plurality of relative phases; and

coupling to the second guided wave at a second set of locations selected from the respective plurality of locations to produce a second plurality of electromagnetic oscillations at the second set of locations, the second plurality of electromagnetic oscillations producing a second radiation field different from the first radiation field.

39. The method of claim 38, wherein:

the first guided wave and the first radiation field define a first interference pattern, and the first set of locations selected from the respective plurality of locations corresponds to a set of locations within constructive interference regions of the first interference pattern; and

the second guided wave and the second radiation field define a second interference pattern different from the first interference pattern, and the second set of locations selected from the respective plurality of locations corresponds to a set of locations within constructive interference regions of the second interference pattern.

40. A method, comprising:

providing a wave-propagating structure;

providing a plurality of scattering elements distributed along the wave-propagating structure with inter-element spacings substantially less than a free-space wavelength corresponding to an operating frequency of the antenna, where the plurality of scattering elements have a plurality of adjustable individual electromagnetic responses to a guided wave mode of the wave-propagating structure, and the plurality of adjustable individual electromagnetic responses provide an adjustable radiation field of the antenna.

receiving a first free-space wave at a plurality of locations of the plurality of scattering elements;

coupling to the first free-space wave at a first set of locations selected from the plurality of locations to produce a first plurality of electromagnetic oscillations at the first set of locations, the first plurality of electromagnetic oscillations producing a first guided wave having a first plurality of relative phases at the plurality of locations;

receiving a second free-space wave different from the first free-space wave at the plurality of locations;

coupling to the second free-space wave at a second set of locations selected from the plurality of locations to produce a second plurality of electromagnetic oscillations at the second set of locations, the second plurality of electromagnetic oscillations producing a second guided wave having a second plurality of relative phases at the plurality of locations, where the second plurality of relative phases is substantially equal to the first plurality of relative phases.

41. The method of claim 40, wherein:

the first guided wave and the first free-space wave define a first interference pattern, and the first set of locations selected from the respective plurality of locations corresponds to a set of locations within constructive interference regions of the first interference pattern; and

the second guided wave and the second free-space wave define a second interference pattern different from the first interference pattern, and the second set of locations selected from the respective plurality of locations corresponds to a set of locations within constructive interference regions of the second interference pattern.

42. A method, comprising:

providing a surface scattering antenna that is adjustable responsive to one or more control inputs, the surface scattering antenna including:

a wave-propagating structure; and

a plurality of scattering elements distributed along the wave-propagating structure with inter-element spacings substantially less than a free-space

wavelength corresponding to an operating frequency of the antenna, where the plurality of scattering elements have a plurality of adjustable individual electromagnetic responses to a guided wave mode of the wave-propagating structure, and the plurality of adjustable individual electromagnetic responses provide an adjustable radiation pattern of the antenna.

selecting a first antenna radiation pattern; and

~~for a surface scattering antenna that is adjustable responsive to one or more control inputs,~~ determining first values of the one or more control inputs corresponding to the first selected antenna radiation pattern.

43. The method of claim 42, wherein the ~~surface scattering antenna has a~~ plurality of scattering elements ~~with~~ have respective adjustable physical parameters that are functions of the one or more control inputs.

44. The method of claim 43, wherein the determining of the first values of the one or more control inputs includes:

determining respective first values of the respective adjustable physical parameters to provide the first selected antenna radiation pattern; and

determining the first values of the one or more control inputs corresponding to the determined respective first values of the respective adjustable physical parameters.

45. The method of claim 43, wherein the respective adjustable physical parameters are respective adjustable resonance frequencies of the plurality of scattering elements.

46. The method of claim 43, wherein the one or more control inputs include a plurality of respective bias voltages for the plurality of scattering elements.

47. The method of claim 43, wherein the plurality of scattering elements are addressable by row and column, and the one or more control inputs includes a set of row inputs and a set of column inputs.

48. The method of claim 43, wherein the plurality of scattering elements are fed by a set of feed lines having adjustable gains, and the one or more control inputs include the adjustable gains.

49. The method of claim 43, further comprising:
providing the first values of the one or more control inputs for the surface scattering antenna.

50. The method of claim 42, wherein the selecting of the first antenna radiation pattern includes a selecting of an antenna beam direction.

51. The method of claim 50, wherein the antenna beam direction corresponds to a direction of a telecommunications satellite.

52. The method of claim 50, wherein the antenna beam direction corresponds to a direction of a telecommunications base station.

53. The method of claim 50, wherein the antenna beam direction corresponds to a direction of a telecommunications mobile platform.

54. The method of claim 42, wherein the selecting of the first antenna radiation pattern includes a selecting of one or more null directions

55. The method of claim 42, wherein the selecting of the first antenna radiation pattern includes a selecting of an antenna beam width.

56. The method of claim 42, wherein the selecting of the first antenna radiation pattern includes a selecting of an arrangement of multiple beams.

57. The method of claim 42, wherein the selecting of the first antenna radiation pattern includes a selecting of an overall phase.

58. The method of claim 42, wherein the selecting of the first antenna radiation pattern includes a selecting of a polarization state.

59. The method of claim 58, wherein the selected polarization state is a circular polarization state.

60. The method of claim 58, wherein the selected polarization state is a linear polarization state.

61. The method of claim 42, further comprising:
selecting a second antenna radiation pattern different from the first antenna radiation pattern; and
determining second values of the one or more control inputs corresponding to the second selected antenna radiation pattern.

62. The method of claim 61, further comprising:
providing the second values of the one or more control inputs for the surface scattering antenna.

63. The method of claim 61, wherein the selecting of the first antenna radiation pattern includes a selecting of a first antenna beam direction, and the selecting of the second antenna radiation pattern includes a selecting of a second antenna beam direction different from the first antenna beam direction.

64. The method of claim 63, wherein the first selected antenna radiation pattern provides a first polarization state corresponding to the first antenna beam direction, the second selected antenna radiation pattern provides a second polarization state corresponding to the second antenna beam direction, and the first polarization state is substantially equal to the second polarization state.

65. The method of claim 64, wherein the first and second polarization states are circular polarization states.

66. The method of claim 64, wherein the first and second polarization states are linear polarization states.

67. The method of claim 63, wherein the first and second antenna beam directions correspond to directions of first and second telecommunications satellites.

68. The method of claim 63, wherein the first and second antenna beam directions correspond to directions of first and second objects selected from a plurality of objects including telecommunications satellites, telecommunications base stations, or telecommunications mobile platforms.

69. A method, comprising:

providing a first surface scattering antenna having a first adjustable radiation pattern responsive to one or more first control inputs, the first surface scattering antenna including:

a wave-propagating structure; and

a plurality of scattering elements distributed along the wave-propagating structure with inter-element spacings substantially less than a free-space wavelength corresponding to an operating frequency of the antenna, where the plurality of scattering elements have a plurality of adjustable individual electromagnetic responses to a guided wave mode of the wave-propagating structure, and the plurality of adjustable individual electromagnetic responses provide the first adjustable radiation pattern of the antenna.

identifying a first target for a first surface scattering antenna~~, the first surface scattering antenna having a first adjustable radiation pattern responsive to one or more first control inputs~~; and

repeatedly adjusting the one or more first control inputs to provide a substantially continuous variation of the first adjustable radiation pattern responsive to a first relative motion between the first target and the first surface scattering antenna.

70. The method of claim 69, wherein the first relative motion is a translation of the first target.

71. The method of claim 69, wherein the first relative motion is a translation or rotation of the first surface scattering antenna.

72. The method of claim 69, wherein the first relative motion is a combination of a translation of the first target and a translation or rotation of the first surface antenna.

73. The method of claim 69, wherein the substantially continuous variation of the first adjustable radiation pattern is selected to keep the first target substantially within a primary beam of the first adjustable radiation pattern.

74. The method of claim 69, wherein the substantially continuous variation of the first adjustable radiation pattern is selected to keep the first target substantially at a null of the first adjustable radiation pattern.

75. The method of claim 69, wherein the substantially continuous variation of the first adjustable radiation pattern is selected to provide a substantially constant polarization state at a location of the first target.

76. The method of claim 75, wherein the substantially constant polarization state is a circular polarization state.

77. The method of claim 75, wherein the substantially constant polarization state is a linear polarization state.

78. The method of claim 69, wherein the first target is a telecommunications satellite.

79. The method of claim 69, wherein the first target is a telecommunications base station.

80. The method of claim 69, wherein the first target is a telecommunications mobile platform.

81. The method of claim 69, further comprising:

providing a second surface scattering antenna having a second adjustable radiation pattern responsive to one or more second control inputs;

identifying a second target for ~~a~~ the second surface scattering antenna~~, the second surface scattering antenna having a second adjustable radiation pattern responsive to one or more second control inputs~~; and

repeatedly adjusting the one or more second control inputs to provide a substantially continuous variation of the second adjustable radiation pattern responsive to a relative motion between the second target and the second surface scattering antenna.

82. The method of claim 81, wherein the first and second targets are members of a constellation of telecommunications satellites.

83. The method of claim 81, wherein the first relative motion is a translation of the first target, and the second relative motion is a translation of the second target.

84. The method of claim 81, wherein:

the first relative motion is a combination of a translation of the first target and a translation or rotation of the first surface antenna;

the second relative motion is a combination of a translation of the second target and a translation or rotation of the second surface antenna; and

the translation or rotation of the first surface antenna is equal to the translation or rotation of the second surface antenna.

85. The method of claim 81, wherein the substantially continuous variation of the first adjustable radiation pattern is selected to keep the first target substantially within a primary beam of the first adjustable radiation pattern, and the substantially continuous variation of the second adjustable radiation pattern is selected to keep the second target substantially within a primary beam of the second adjustable radiation pattern.

86. The method of claim 85, further comprising:

adjusting the one or more first control inputs to place the second target substantially within the primary beam of the first adjustable radiation pattern.

87. The method of claim 86, further comprising:

identifying a new target for a second surface scattering antenna different from the first and second targets; and

adjusting the one or more second control inputs to place the new target substantially within the primary beam of the second adjustable radiation pattern.

88. A system, comprising:

a surface scattering antenna that is adjustable responsive to one or more control inputs;

antenna control circuitry configured to provide the one or more control inputs; and

communications circuitry coupled to a feed structure of the surface scattering antenna~~.~~

wherein the surface scattering antenna comprises:

a wave-propagating structure; and

a plurality of scattering elements distributed along the wave-propagating structure with inter-element spacings substantially less than a free-space wavelength corresponding to an operating frequency of the antenna, where the plurality of scattering elements have a plurality of adjustable individual electromagnetic responses to a guided wave mode of the wave-propagating structure, and the plurality of adjustable individual electromagnetic responses provide an adjustable radiation field of the antenna.

89. The system of claim 88, wherein the ~~surface scattering antenna has a~~ plurality of scattering elements ~~with~~ have respective adjustable physical parameters that are functions of the one or more control inputs.

90. The system of claim 89, wherein the one or more control inputs include a plurality of respective bias voltages for the plurality of scattering elements.

91. The system of claim 89, wherein the plurality of scattering elements are addressable by row and column, and the one or more control inputs includes a set of row inputs and a set of column inputs.

92. The system of claim 89, wherein the feed structure includes a plurality of feeds having a respective plurality of amplifiers, and the one or more control inputs include adjustable gains of the respective plurality of amplifiers.

93. The system of claim 88, wherein the antenna control circuitry includes:

a storage medium that includes a lookup table mapping a set of antenna radiation pattern parameters to a corresponding set of values for the one or more control inputs.

94. The system of claim 93, wherein the set of antenna radiation pattern parameters includes a set of antenna beam directions.

95. The system of claim 93, wherein the set of antenna radiation pattern parameters includes a set of antenna null directions.

96. The system of claim 93, wherein the set of antenna radiation pattern parameters includes a set of antenna beam widths.

97. The system of claim 93, wherein the set of antenna radiation pattern parameters includes a set of polarization states.

98. The system of claim 88, wherein the antenna control circuitry includes:

processor circuitry configured to calculate a set of values for the one or more control inputs corresponding to a desired antenna radiation pattern parameter.

99. The system of claim 98, wherein the processor circuitry is configured to calculate the set of values for the for the one or more control inputs by computing a

holographic pattern corresponding to the desired antenna radiation pattern parameter.

100. The system of claim 88, further comprising:
a sensor unit configured to detect an environmental condition of the surface scattering antenna.

101. The system of claim 100, wherein the sensor unit includes one or more sensors selected from GPS sensors, thermometers, gyroscopes, accelerometers, and strain gauges.

102. The system of claim 100, wherein the environmental condition includes a position, an orientation, a temperature, or a mechanical deformation of the surface scattering antenna.

103. The system of claim 100, wherein the sensor unit is configured to provide environmental condition data to the antenna control circuitry, and the antenna control circuitry includes:
circuitry configured to adjust the one or more control inputs to compensate for changes in the environmental condition of the surface scattering antenna.