1. A method of providing a communication service to user terminals (517) distributed over multiple forward user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple forward receive/transmit signal paths (2001), the method comprising:

obtaining multiple forward beam signals (511) comprising forward user data streams (509) for transmission to a plurality of the user terminals grouped by the multiple forward user beam coverage areas;

identifying a forward beam weight matrix (918) for end-to-end beamforming of transmissions from a plurality of access nodes (515) at geographically distributed locations to the multiple forward user beam coverage areas via the end-to-end relay;

generating respective access node-specific forward signals (516) for the plurality of access nodes, each of the respective access node-specific forward signals comprising a composite of respective forward beam signals weighted by respective forward beamforming weights of the forward beam weight matrix; and

distributing the respective access node-specific forward signals to the plurality of access nodes with respective forward synchronization information for compensating for respective path delays and phase shifts between the plurality of access nodes and the end-to-end relay, wherein the respective access node-specific forward signals are transmitted to the end-to-end relay for relay to the multiple forward user beam coverage areas by the plurality of access nodes at respective time-domain offsets based at least in part on the forward synchronization information.

2. The method of claim 1, wherein the distributing comprises:

multiplexing the respective access node-specific forward signals with the respective forward synchronization information to obtain respective multiplexed access node-specific forward signals; and

sending, to each of the plurality of access nodes, one of the respective multiplexed access node-specific forward signals.

3. The method of claim 2, wherein:

the multiplexing comprises splitting each of the respective access node-specific forward signals into a plurality of sets of samples; and

the sending comprises sending the plurality of sets of samples of the respective access node-specific forward signals with the multiplexed respective forward synchronization information to the plurality of access nodes over packet-switched connections.

4. The method of any one of claims 1-3, wherein the distributing comprises: sending the respective access node-specific forward signals offset by the respective time-domain offsets to the plurality of access nodes.

5. The method of any one of claims 1-4, wherein the obtaining comprises:

grouping the forward user data streams according to the multiple forward user beam coverage areas to obtain multiple forward beam data streams (532), each of the multiple forward beam data streams comprising a respective subset of the forward user data streams; and

modulating the multiple forward beam data streams according to one or more modulation schemes to obtain the multiple forward beam signals.

6. The method of claim 5, wherein the obtaining comprises: multiplexing, for the each of the multiple forward beam data streams, the respective subset of the forward user data streams.

7. The method of claim 6, wherein the multiplexing comprises time-domain multiplexing, frequency-domain multiplexing, or a combination thereof.

8. The method of any one of claims 1-7, wherein the generating comprises:

de-multiplexing the forward beam signals into time-domain subsets of samples;

processing the time-domain subsets of samples with a plurality of forward time-slice beamformers (3006), wherein each of the plurality of forward time-slice beamformers obtains a time-domain subset of samples of each of the forward beam signals and outputs the respective access node-specific forward signals associated with the each of the plurality of access nodes for the time-domain subset of samples; and

multiplexing, into each of the respective access node-specific forward signals, the time-domain subsets of samples from the plurality of forward time-slice beamformers.

9. The method of claim 8, wherein each of the time-domain subsets of samples comprises a plurality of interleaved samples.

10. The method of any one of claims 1-9, wherein the end-to-end relay is a satellite.

11. The method of any one of claims 1-10, wherein the forward beam weight matrix has dimensions corresponding to a number of the access nodes and a number of the forward user beam coverage areas.

12. The method of any one of claims 1-11, wherein the forward beam weight matrix is determined based on a forward uplink radiation matrix having dimensions corresponding to a number of the access nodes and a number of the forward receive/transmit signal paths and a forward downlink radiation matrix having dimensions corresponding to the number of the forward receive/transmit signal paths and a number of the forward user beam coverage areas.

13. The method of claim 12, wherein the forward beam weight matrix is determined based on a forward payload matrix of the end-to-end relay having dimensions corresponding to a number of the forward receive/transmit signal paths.

14. The method of claim 13, wherein the forward beam weight matrix is determined as a product of the forward uplink radiation matrix, the forward payload matrix, and the forward downlink radiation matrix.

15. The method of claim 13, wherein the forward payload matrix is a diagonal matrix.

16. The method of any one of claims 1-12, wherein the number of the access nodes is greater than the number of the forward receive/transmit signal paths.

17. An apparatus for providing a communication service to user terminals (517) distributed over multiple forward user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple forward receive/transmit signal paths (2001), comprising:

a beam signal interface (524) that receives multiple forward beam signals (511) comprising forward user data streams (509) for transmission to a plurality of the user terminals grouped by the multiple forward user beam coverage areas;

a beam weight generator (910, 917) that generates a forward beam weight matrix (918) for end-to-end beamforming of transmissions from a plurality of access nodes (515) at geographically distributed locations to the multiple forward user beam coverage areas via the end-to-end relay;

a forward beamformer (529) coupled with the beam signal interface and the beam weight generator, the forward beamformer comprising a matrix multiplier that obtains a vector of access-node specific forward signals (516) based on a matrix product of the forward beam weight matrix and a vector of the forward beam signals; and

a distribution interface (536) that sends, via a distribution network (518), the respective access node-specific forward signals to the plurality of access nodes with respective forward synchronization information for compensating for respective path delays and phase shifts between the plurality of access nodes and the end-to-end relay, wherein the respective access node-specific forward signals are transmitted to the end-to-end relay for relay to the multiple forward user beam coverage areas by the plurality of access nodes at respective time-domain offsets based at least in part on the forward synchronization information.

18. The apparatus of claim 17, further comprising: a multiplexer that multiplexes the respective forward synchronization information with the respective access node-specific forward signals to obtain respective multiplexed access node-specific forward signals for distribution to the plurality of access nodes by the distribution interface.

19. The apparatus of claim 18, wherein:

the multiplexer splits each of the respective access node-specific forward signals into a plurality of sets of samples; and

the distribution interface sends the plurality of sets of samples of the respective access node-specific forward signals with the multiplexed respective forward synchronization information to the plurality of access nodes over packet-switched connections.

20. The apparatus of any one of claims 17-19, wherein the distribution interface sends the respective access node-specific forward signals offset by the respective time-domain offsets to the plurality of access nodes.

21. The apparatus of any one of claims 17-20, further comprising:

a forward beam data multiplexer (526) that groups the forward user data streams according to the multiple forward user beam coverage areas to obtain multiple forward beam data streams (532), each of the multiple forward beam data streams comprising a respective subset of the forward user data streams; and

a forward beam modulator (528) that modulates the multiple forward beam data streams according to one or more modulation schemes to obtain the multiple forward beam signals.

22. The apparatus of claim 21, wherein the beam data multiplexer multiplexes, for the each of the multiple forward beam data streams, the respective subset of the forward user data streams.

23. The apparatus of claim 22, wherein the multiplexing comprises time-domain multiplexing, frequency-domain multiplexing, or a combination thereof.

24. The apparatus of any one of claims 17-23, wherein the forward beamformer comprises: a plurality of forward time-slice beamformers (3006), wherein each of the plurality of forward time-slice beamformers obtains a respective time-domain subset of samples of each of the forward beam signals and outputs the respective access node-specific forward signals associated with the each of the plurality of access nodes for the respective time-domain subset of samples.

25. The apparatus of claim 24, wherein:

the beam signal interface comprises a beam signal de-multiplexer (3002) that de-multiplexes the forward beam signals according to the respective time-domain subsets of samples and sends, to the each of the plurality of forward time-slice beamformers, the respective time-domain subset of samples of each of the forward beam signals; and

the distribution interface comprises a forward signal multiplexer (3010) that multiplexes the respective time-domain subsets of samples of the respective access node-specific forward signals output from the plurality of forward time-slice beamformers for sending to the each of the plurality of access nodes.

26. The apparatus of claim 25, further comprising: a forward beam signal interleaver that interleaves samples of the forward beam signals in the respective time-domain subsets of samples of the forward beam signals.

27. The apparatus of any one of claims 17-26, wherein the end-to-end relay is a satellite.

28. The apparatus of any one of claims 17-27, wherein the forward beam weight matrix has dimensions corresponding to a number of the access nodes and a number of the forward user beam coverage areas.

29. The apparatus of any one of claims 17-28, wherein the forward beam weight matrix is determined based on a forward uplink radiation matrix having dimensions corresponding to a number of the access nodes and a number

of the forward receive/transmit signal paths and a forward downlink radiation matrix having dimensions corresponding to the number of the forward receive/transmit signal paths and a number of the forward user beam coverage areas.

30. The apparatus of claim 29, wherein the forward beam weight matrix is determined based on a forward payload matrix of the end-to-end relay having dimensions corresponding to a number of the forward receive/transmit signal paths.

31. The apparatus of claim 30, wherein the forward beam weight matrix is determined as a product of the forward uplink radiation matrix, the forward payload matrix, and the forward downlink radiation matrix.

32. The apparatus of claim 30, wherein the forward payload matrix is a diagonal matrix.

33. The apparatus of any one of claims 29-32, wherein the number of the access nodes is greater than the number of the forward receive/transmit signal paths.

34. An apparatus for providing a communication service to user terminals (517) distributed over multiple forward user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple forward receive/transmit signal paths (2001), comprising:

at least one processor; and

a memory in electronic communication with the at least one processor, the memory comprising instructions executable by the at least one processor to cause the apparatus to:

obtain multiple forward beam signals (511) comprising forward user data streams (509) for transmission to a plurality of the user terminals grouped by the multiple forward user beam coverage areas;

identify a forward beam weight matrix (918) for end-to-end beamforming of transmissions from a plurality of access nodes (515) at geographically distributed locations to the multiple forward user beam coverage areas via the end-to-end relay;

generate respective access node-specific forward signals (516) for the plurality of access nodes, each of the respective access node-specific forward signals comprising a composite of respective forward beam signals weighted by respective forward beamforming weights of the forward beam weight matrix; and

send the respective access node-specific forward signals to the plurality of access nodes with respective forward synchronization information for compensating for respective path delays and phase shifts between the plurality of access nodes and the end-to-end relay, wherein the respective access node-specific forward signals are transmitted to the end-to-end relay for relay to the multiple forward user beam coverage areas by the plurality of access nodes at respective time-domain offsets based at least in part on the forward synchronization information.

35. The apparatus of claim 34, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to:

multiplex the respective access node-specific forward signals with the respective forward synchronization information to obtain respective multiplexed access node-specific forward signals; and

send, to each of the plurality of access nodes, one of the respective multiplexed access node-specific forward signals.

36. The apparatus of claim 35, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to:

split each of the respective access node-specific forward signals into a plurality of sets of samples; and

send the plurality of sets of samples of the respective access node-specific forward signals with the multiplexed respective forward synchronization information to the plurality of access nodes over packet-switched connections.

37. The apparatus of any one of claims 34-36, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to: send the respective access node-specific forward signals offset by the respective time-domain offsets to the plurality of access nodes.

38. The apparatus of any one of claims 34-37, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to:

group the forward user data streams according to the multiple forward user beam coverage areas to obtain multiple forward beam data streams (532), each of the multiple forward beam data streams comprising a respective subset of the forward user data streams; and

modulate the multiple forward beam data streams according to one or more modulation schemes to obtain the multiple forward beam signals.

39. The apparatus of claim 38, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to: multiplex, for the each of the multiple forward beam data streams, the respective subset of the forward user data streams.

40. The apparatus of claim 39, wherein the multiplexing comprises time-domain multiplexing, frequency-domain multiplexing, or a combination thereof.

41. The apparatus of any one of claims 34-40, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to:

de-multiplex the forward beam signals into time-domain subsets of samples;

process the time-domain subsets of samples with a plurality of forward time-slice beamformers (3006), wherein each of the plurality of forward time-slice beamformers receives a time-domain subset of samples of each of

the forward beam signals and outputs the respective access node-specific forward signals associated with the each of the plurality of access nodes for the time-domain subset of samples; and

multiplex, into each of the respective access node-specific forward signals, the time-domain subsets of samples output from the plurality of forward time-slice beamformers.

42. The apparatus of claim 41, wherein each of the time-domain subsets of samples comprises a plurality of interleaved samples.

43. The apparatus of any one of claims 34-42, wherein the end-to-end relay is a satellite.

44. The apparatus of any one of claims 34-43, wherein the forward beam weight matrix has dimensions corresponding to a number of the access nodes and a number of the forward user beam coverage areas.

45. The apparatus of any one of claims 34-44, wherein the forward beam weight matrix is determined based on a forward uplink radiation matrix having dimensions corresponding to a number of the access nodes and a number of the forward receive/transmit signal paths and a forward downlink radiation matrix having dimensions corresponding to the number of the forward receive/transmit signal paths and a number of the forward user beam coverage areas.

46. The apparatus of claim 45, wherein the forward beam weight matrix is determined based on a forward payload matrix of the end-to-end relay having dimensions corresponding to a number of the forward receive/transmit signal paths.

47. The apparatus of claim 46, wherein the forward beam weight matrix is determined as a product of the forward uplink radiation matrix, the forward payload matrix, and the forward downlink radiation matrix.

48. The apparatus of claim 46, wherein the forward payload matrix comprises a diagonal matrix.

49. The apparatus of any one of claims 45-48, wherein the number of the access nodes is greater than the number of the forward receive/transmit signal paths.

50. An apparatus for providing a communication service to user terminals (517) distributed over multiple forward user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple forward receive/transmit signal paths (2001), comprising:

means for obtaining (524) multiple forward beam signals (511) comprising forward user data streams (509) for transmission to a plurality of the user terminals grouped by the multiple forward user beam coverage areas;

means for generating (529) respective access node-specific forward signals (516) for transmission by a plurality of access nodes (515) at geographically distributed locations to the multiple forward user beam coverage

areas via the end-to-end relay, each of the respective access node-specific forward signals comprising a composite of respective forward beam signals weighted by respective forward beam weights of a forward beam weight matrix (918) for end-to-end beamforming of transmissions from the plurality of access nodes to the multiple forward user beam coverage areas via the end-to-end relay; and

means for sending (536) the respective access node-specific forward signals to the plurality of access nodes with respective forward synchronization information for compensating for respective path delays and phase shifts between the plurality of access nodes and the end-to-end relay, wherein the respective access node-specific forward signals are transmitted to the end-to-end relay for relay to the multiple forward user beam coverage areas by the plurality of access nodes at respective time-domain offsets based at least in part on the forward synchronization information.

51. The apparatus of claim 50, further comprising:

means for multiplexing the respective access node-specific forward signals with the respective forward synchronization information to obtain respective multiplexed access node-specific forward signals,

wherein the means for sending sends, to each of the plurality of access nodes, one of the respective multiplexed access node-specific forward signals.

52. The apparatus of claim 51, wherein:

the means for multiplexing splits each of the respective access node-specific forward signals into a plurality of sets of samples; and

the means for sending sends the plurality of sets of samples of the respective access node-specific forward signals with the multiplexed respective forward synchronization information to the plurality of access nodes over packet-switched connections.

53. The apparatus of any one of claims 50-52, wherein the means for sending sends the respective access node-specific forward signals offset by the respective time-domain offsets to the plurality of access nodes.

54. The apparatus of any one of claims 50-53, wherein the means for obtaining comprises:

means for grouping (526) the forward user data streams according to the multiple forward user beam coverage areas to obtain multiple forward beam data streams (532), each of the multiple forward beam data streams comprising a respective subset of the forward user data streams; and

means for modulating (528) the multiple forward beam data streams according to one or more modulation schemes to obtain the multiple forward beam signals.

55. The apparatus of claim 54, wherein the means for obtaining comprises: means for multiplexing, for the each of the multiple forward beam data streams, the respective subset of the forward user data streams.

56. The apparatus of claim 55, wherein the multiplexing comprises time-domain multiplexing, frequency-domain multiplexing, or a combination thereof.

57. The apparatus of any one of claims 50-56, wherein the end-to-end relay is a satellite.

58. The apparatus of any one of claims 50-57, wherein the forward beam weight matrix has dimensions corresponding to a number of the access nodes and a number of the forward user beam coverage areas.

59. The apparatus of any one of claims 50-58, wherein the forward beam weight matrix is determined based on a forward uplink radiation matrix having dimensions corresponding to a number of the access nodes and a number of the forward receive/transmit signal paths and a forward downlink radiation matrix having dimensions corresponding to the number of the forward receive/transmit signal paths and a number of the forward user beam coverage areas.

60. The apparatus of claim 59, wherein the forward beam weight matrix is determined based on a forward payload matrix of the end-to-end relay having dimensions corresponding to a number of the forward receive/transmit signal paths.

61. The apparatus of claim 60, wherein the forward beam weight matrix is determined as a product of the forward uplink radiation matrix, the forward payload matrix, and the forward downlink radiation matrix.

62. The apparatus of claim 60, wherein the forward payload matrix is a diagonal matrix.

63. The apparatus of any one of claims 59-62, wherein the number of the access nodes is greater than the number of the forward receive/transmit signal paths.

64. A method of providing a communication service to user terminals (517) distributed over multiple return user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple return receive/transmit signal paths (1702), the method comprising:

obtaining respective composite return signals (907) from a plurality of access nodes (515) at geographically distributed locations, each of the respective composite return signals comprising a composite of return uplink signals (525) transmitted from a plurality of the user terminals and relayed by the end-to-end relay;

identifying a return beam weight matrix (937) for end-to-end beamforming of transmissions from the multiple return user beam coverage areas to the plurality of access nodes via the end-to-end relay; and

determining a vector of return beam signals (915) for the multiple return user beam coverage areas based on a matrix product of the return beam weight matrix and a vector of the respective composite return signals, wherein the respective composite return signals are corrected for timing and phase for respective path delays and phase shifts between the end-to-end relay and the plurality of access nodes.

65. The method of claim 64, wherein the obtaining comprises receiving, from the plurality of access nodes, respective multiplexed composite return signals comprising the respective composite return signals and respective return synchronization information.

66. The method of claim 65, wherein the correcting for the respective path delays and phase shifts comprises aligning, based on the respective return synchronization information, portions of the respective composite return signals corresponding to a same transmission timing from the end-to-end relay prior to the determining.

67. The method of any one of claims 65-66, wherein the correcting for the respective path delays and phase shifts comprises determining respective adjustments for the respective composite return signals to compensate for downlink channel impairment based at least in part on the respective return synchronization information.

68. The method of any one of claims 64-67, wherein each of the composite return signals comprises a plurality of time-domain subsets of samples.

69. The method of claim 68, wherein the determining comprises:

processing the time-domain subsets of samples of the composite return signals with a plurality of return time-slice beamformers (3016), wherein each of the plurality of return time-slice beamformers receives a time-domain subset of samples of each of the composite return signals and outputs the vector of the return beam signals associated with the each of the multiple return user beam coverage areas for the time-domain subset of samples; and

multiplexing, into each of the return beam signals, the time-domain subsets of samples from the plurality of return time-slice beamformers.

70. The method of any one of claims 68-69, wherein each of the plurality of time-domain subsets of samples comprises a plurality of interleaved samples.

71. The method of any one of claims 64-70, further comprising: offsetting the respective composite return signals offset by respective timing offsets to correct for the respective path delays and phase shifts and for respective distribution path delays and phase shifts between the plurality of access nodes and a return beamformer.

72. The method of any one of claims 64-71, further comprising: demodulating each of the return beam signals to obtain a return beam data stream (534) associated with the each of the multiple return user beam coverage areas.

73. The method of claim 72, further comprising: de-multiplexing each of the return beam data streams into respective return user data streams (535) associated with the return uplink signals transmitted from the plurality of the user terminals.

74. The method of claim 73, wherein the de-multiplexing comprises time-domain de-multiplexing, frequency-domain de-multiplexing, or a combination thereof.

75. The method of any one of claims 64-74, wherein the plurality of access nodes has a first number of the access nodes and the end-to-end relay has a second number of the return receive/transmit signal paths, wherein the first number is different than the second number.

76. The method of claim 75, wherein the first number is greater than the second number.

77. The method of any one of claims 64-76, wherein the return beam weight matrix has dimensions corresponding to a number of the return user beam coverage areas and a number of the access nodes.

78. The method of any one of claims 64-77, wherein the return beam weight matrix is determined based on a return uplink radiation matrix having dimensions corresponding to a number of the return user beam coverage areas and a number of the return receive/transmit signal paths and a return downlink radiation matrix having dimensions corresponding to the number of the return receive/transmit signal paths and a number of the access nodes.

79. The method of claim 78, wherein the return beam weight matrix is determined based on a return payload matrix of the end-to-end relay having dimensions corresponding to a number of the return receive/transmit signal paths.

80. The method of claim 79, wherein the return beam weight matrix is determined as a product of the return uplink radiation matrix, the return payload matrix, and the return downlink radiation matrix.

81. The method of claim 79, wherein the return payload matrix comprises a diagonal matrix.

82. An apparatus for providing a communication service to user terminals (517) distributed over multiple return user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple return receive/transmit signal paths (1702), comprising:

a distribution interface (536, 931) that receives respective composite return signals (907) from a plurality of access nodes (515) at geographically distributed locations, each of the respective composite return signals comprising a composite of return uplink signals (525) transmitted from a plurality of the user terminals and relayed by the end-to-end relay;

a beam weight generator (910, 935) that generates a return beam weight matrix (937) for end-to-end beamforming of transmissions from the multiple return user beam coverage areas to the plurality of access nodes via the end-to-end relay; and

a return beamformer (531) coupled with the distribution interface and the beam weight generator, the beamformer comprising a matrix multiplier that obtains a vector of return beam signals (915) for the multiple return user beam coverage areas based on a matrix product of the return beam weight matrix and a vector of the respective composite return signals, wherein the respective composite return signals are corrected for timing and phase for respective path delays and phase shifts between the end-to-end relay and the plurality of access nodes.

83. The apparatus of claim 82, wherein the distribution interface receives, from the plurality of access nodes, respective multiplexed composite return signals comprising the respective composite return signals and respective return synchronization information.

84. The apparatus of claim 83, further comprising a timing module (947) that aligns, based on the respective synchronization timing information, portions of the respective composite return signals corresponding to a same transmission timing from the end-to-end relay for input to the beamformer.

85. The apparatus of any one of claims 83-84, further comprising a plurality of demodulators (2511) that determine respective adjustments for the respective composite return signals to compensate for downlink channel impairment based at least in part on the respective return synchronization information.

86. The apparatus of any one of claims 82-85, wherein each of the composite return signals comprises a plurality of time-domain subsets of samples.

87. The apparatus of claim 86, further comprising:

a plurality of return time-slice beamformers (3016), wherein each of the plurality of return time-slice beamformers receives a time-domain subset of samples of each of the composite return signals and outputs the vector of the return beam signals associated with the each of the multiple return user beam coverage areas for the time-domain subset of samples; and

a return beam signal multiplexer (3020) that multiplexes, into each of the return beam signals, the time-domain subsets of samples from the plurality of return time-slice beamformers.

88. The apparatus of any one of claims 86-87, wherein each of the plurality of time-domain subsets of samples comprises a plurality of interleaved samples.

89. The apparatus of any one of claims 82-88, further comprising a timing module (947) that offsets the respective composite return signals by respective timing offsets to correct for the respective path delays and phase shifts and for respective distribution path delays and phase shifts between the plurality of access nodes and the return beamformer.

90. The apparatus of any one of claims 82-89, further comprising: a return beam signal demodulator (552) that demodulates each of the return beam signals to obtain a return beam data stream (534) associated with the each of the multiple return user beam coverage areas.

91. The apparatus of claim 90, further comprising:

a return beam de-multiplexer (554) that de-multiplexes each of the return beam data streams into respective return user data streams (535) associated with the return uplink signals transmitted from the plurality of the user terminals.

92. The apparatus of claim 91, wherein the de-multiplexing comprises time-domain de-multiplexing, frequency-domain de-multiplexing, or a combination thereof.

93. The apparatus of any one of claims 82-92, wherein the plurality of access nodes has a first number of the access nodes and the end-to-end relay has a second number of the return receive/transmit signal paths, wherein the first number is different than the second number.

94. The apparatus of claim 93, wherein the first number is greater than the second number.

95. The apparatus of any one of claims 82-94, wherein the return beam weight matrix has dimensions corresponding to a number of the return user beam coverage areas and a number of the access nodes.

96. The apparatus of any one of claims 82-95, wherein the return beam weight matrix is determined based on a return uplink radiation matrix having dimensions corresponding to a number of the return user beam coverage areas and a number of the return receive/transmit signal paths and a return downlink radiation matrix having dimensions corresponding to the number of the return receive/transmit signal paths and a number of the access nodes.

97. The apparatus of claim 96, wherein the return beam weight matrix is determined based on a return payload matrix of the end-to-end relay having dimensions corresponding to a number of the return receive/transmit signal paths.

98. The apparatus of claim 97, wherein the return beam weight matrix is determined as a product of the return uplink radiation matrix, the return payload matrix, and the return downlink radiation matrix.

99. The apparatus of claim 97, wherein the return payload matrix comprises a diagonal matrix.

100. An apparatus for providing a communication service to user terminals (517) distributed over multiple return user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple receive/transmit signal paths (1702), comprising:

at least one processor; and

a memory in electronic communication with the at least one processor, the memory comprising instructions executable by the at least one processor to cause the apparatus to:

obtain respective composite return signals (907) from a plurality of access nodes (515) at geographically distributed locations, each of the respective composite return signals comprising a composite of return uplink signals (525) transmitted from a plurality of the user terminals and relayed by the end-to-end relay;

identify a return beam weight matrix (937) for end-to-end beamforming of transmissions from the multiple return user beam coverage areas to the plurality of access nodes via the end-to-end relay; and

determine a vector of return beam signals (915) for the multiple return user beam coverage areas based on a matrix product of the return beam weight matrix and a vector of the respective composite return signals, wherein the respective composite return signals are corrected for timing and phase for respective path delays and phase shifts between the end-to-end relay and the plurality of access nodes.

101. The apparatus of claim 100, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to:

receive, from the plurality of access nodes, respective multiplexed composite return signals comprising the respective composite return signals and respective return synchronization information.

102. The apparatus of claim 101, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to: align, based on the respective return synchronization information, portions of the respective composite return signals corresponding to a same transmission timing from the end-to-end relay prior to the determining.

103. The apparatus of any one of claims 101-102, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to: determine respective adjustments for the respective composite return signals to compensate for downlink channel impairment based at least in part on the respective return synchronization information.

104. The apparatus of any one of claims 100-103, wherein each of the composite return signals comprises a plurality of time-domain subsets of samples.

105. The apparatus of claim 104, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to:

process corresponding time-domain subsets of samples for each of the composite return signals to obtain the vector of the return beam signals associated with the each of the multiple return user beam coverage areas for the corresponding time-domain subsets of samples; and

multiplex, for each of the return beam signals, the time-domain subsets of samples.

106. The apparatus of any one of claims 104-105, wherein each of the plurality of time-domain subsets of samples comprises a plurality of interleaved samples.

107. The apparatus of any one of claims 100-106, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to: offset the respective composite return signals by respective timing offsets to correct for the respective path delays and phase shifts and for respective distribution path delays and phase shifts between the plurality of access nodes and the apparatus.

108. The apparatus of any one of claims 100-107, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to: demodulate each of the return beam signals to obtain a return beam data stream (534) associated with the each of the multiple return user beam coverage areas.

109. The apparatus of claim 108, wherein the memory further comprises instructions executable by the at least one processor to cause the apparatus to: de-multiplex each of the return beam data streams into respective return user data streams (535) associated with the return uplink signals transmitted from the plurality of the user terminals.

110. The apparatus of claim 109, wherein the de-multiplexing comprises time-domain de-multiplexing, frequency-domain de-multiplexing, or a combination thereof.

111. The apparatus of any one of claims 100-110, wherein the plurality of access nodes has a first number of the access nodes and the end-to-end relay has a second number of the return receive/transmit signal paths, wherein the first number is different than the second number.

112. The apparatus of claim 111, wherein the first number is greater than the second number.

113. The apparatus of any one of claims 100-112, wherein the return beam weight matrix is determined based on a return uplink radiation matrix having dimensions corresponding to a number of the return user beam coverage areas and a number of the return receive/transmit signal paths and a return downlink radiation matrix having dimensions corresponding to the number of the return receive/transmit signal paths and a number of the access nodes.

114. The apparatus of claim 113, wherein the return beam weight matrix is determined based on a return payload matrix of the end-to-end relay having dimensions corresponding to a number of the return receive/transmit signal paths.

115. The apparatus of claim 114, wherein the return beam weight matrix is determined as a product of the return uplink radiation matrix, the return payload matrix, and the return downlink radiation matrix.

116. The apparatus of claim 114, wherein the return payload matrix comprises a diagonal matrix.

117. The apparatus of any one of claims 100-116, wherein the return beam weight matrix has dimensions corresponding to a number of the return user beam coverage areas and a number of the access nodes.

118. An apparatus for providing a communication service to user terminals (517) distributed over multiple return user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple receive/transmit signal paths (1702), comprising:

means for receiving (536, 931) respective composite return signals (907) from a plurality of access nodes (515) at geographically distributed locations, each of the respective composite return signals comprising a composite of return uplink signals (525) transmitted from a plurality of the user terminals and relayed by the end-to-end relay;

means for synchronizing (947, 3006) the respective composite return signals to compensate for timing and phase for respective path delays and phase shifts between the end-to-end relay and the plurality of access nodes;

means for determining (531, 3006) a vector of return beam signals (915) for the multiple return user beam coverage areas based on a matrix product of a return beam weight matrix for end-to-end beamforming of transmissions from the multiple return user beam coverage areas to the plurality of access nodes via the end-to-end relay and a vector of the synchronized respective composite return signals.

119. The apparatus of claim 118, wherein the means for receiving receives, from the plurality of access nodes, respective multiplexed composite return signals comprising the respective composite return signals and respective return synchronization information.

120. The apparatus of claim 119, wherein the means for synchronizing aligns, based on the respective return synchronization information, portions of the respective composite return signals corresponding to a same transmission timing from the end-to-end relay prior to the determining.

121. The apparatus of any one of claims 119-120, further comprising:

means for determining respective adjustments for the respective composite return signals to compensate for downlink channel impairment based at least in part on the respective return synchronization information.

122. The apparatus of any one of claims 118-121, wherein each of the composite return signals comprises a plurality of time-domain subsets of samples.

123. The apparatus of claim 122, wherein the means for determining comprises:

means for processing (3006) corresponding time-domain subsets of samples for each of the composite return signals to obtain the vector of the return beam signals associated with the each of the multiple return user beam coverage areas for the corresponding time-domain subsets of samples; and

means for multiplexing (3020), for each of the return beam signals, the time-domain subsets of samples.

124. The apparatus of any one of claims 122-123, wherein each of the plurality of time-domain subsets of samples comprises a plurality of interleaved samples.

125. The apparatus of any one of claims 118-123, further comprising: means for demodulating each of the return beam signals to obtain a return beam data stream associated with the each of the multiple return user beam coverage areas.

126. The apparatus of claim 125, further comprising: means for de-multiplexing each of the return beam data streams into respective return user data streams associated with the return uplink signals transmitted from the plurality of the user terminals.

127. The apparatus of claim 126, wherein the de-multiplexing comprises time-domain de-multiplexing, frequency-domain de-multiplexing, or a combination thereof.

128. The apparatus of any one of claims 118-127, wherein the plurality of access nodes has a first number of the access nodes and the end-to-end relay has a second number of the return receive/transmit signal paths, wherein the first number is different than the second number.

129. The apparatus of claim 128, wherein the first number is greater than the second number.

130. The apparatus of any one of claims 118-129, wherein the return beam weight matrix has dimensions corresponding to a number of the return user beam coverage areas and a number of the access nodes.

131. The apparatus of any one of claims 118-130, wherein the return beam weight matrix is determined based on a return uplink radiation matrix having dimensions corresponding to a number of the return user beam coverage areas and a number of the return receive/transmit signal paths and a return downlink radiation matrix having dimensions corresponding to the number of the return receive/transmit signal paths and a number of the access nodes.

132. The apparatus of claim 131, wherein the return beam weight matrix is determined based on a return payload matrix of the end-to-end relay having dimensions corresponding to a number of the return receive/transmit signal paths.

133. The apparatus of claim 132, wherein the return beam weight matrix is determined as a product of the return uplink radiation matrix, the return payload matrix, and the return downlink radiation matrix.

134. The apparatus of claim 132, wherein the return payload matrix comprises a diagonal matrix.

135. A method of communication at an access node (515) of a communication system comprising a plurality of access nodes at geographically distributed locations providing a communication service to user terminals (517) distributed over multiple forward user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple forward receive/transmit signal paths (2001), the method comprising:

obtaining an access node-specific forward signal (516) for transmission via the end-to-end relay to a plurality of the user terminals grouped by the multiple forward user beam coverage areas, the access node-specific forward signal comprising a composite of forward beam signals (511) corresponding to a plurality of the multiple forward user beam coverage areas, the forward beam signals weighted by respective beam weights of a beam weight vector associated with the access node;

identifying forward signal transmit timing information (4016) indicating transmission timing for the access node-specific forward signal;

transmitting a forward uplink signal (521) comprising the access node-specific forward signal and an access node beacon signal (2530) to the end-to-end relay, the access node-specific forward signal having the forward signal transmit timing information synchronized to corresponding transmit timing information in the access node beacon signal;

receiving signaling (527) from the end-to-end relay comprising a relay beacon signal and the access node beacon signal relayed from the end-to-end relay; and

adjusting the forward uplink signal to time and phase align the relayed access node beacon signal with the received relay beacon signal.

136. The method of claim 135, further comprising: demodulating the relay beacon signal to obtain receive timing information (4026, 2525) and receive phase information (4026, 2542).

137. The method of claim 136, further comprising: demodulating the relayed access node beacon signal to obtain relayed transmit timing information (4028, 2521) and relayed transmit phase information (4028, 2521).

138. The method of claim 137, wherein the adjusting comprises: adjusting timing of the forward uplink signal based on comparing the receive timing information to the relayed transmit timing information.

139. The method of any one of claims 137-138, wherein the adjusting comprises: adjusting a phase of the forward uplink signal based on comparing the receive phase information to the relayed transmit phase information.

140. The method of any one of claims 135-139, wherein the identifying comprises: demultiplexing the forward signal transmit timing information from a multiplexed access node-specific forward signal received at the access node.

141. The method of any one of claims 135-140, wherein the access node-specific forward signal comprises a plurality of time-domain subsets of samples.

142. The method of claim 141, wherein each of the plurality of time-domain subsets of samples comprises a plurality of interleaved samples for the access node-specific forward signal, the method further comprising: de-interleaving the interleaved samples of the access node-specific forward signal.

143. The method of any one of claims 135-142, wherein the relay beacon signal comprises a pseudo-noise (PN) code (2307).

144. The method of any one of claims 135-143, wherein the relay beacon signal comprises relay frame timing information.

145. The method of any one of claims 135-144, wherein the access node beacon signal comprises a pseudo-noise (PN) code (2301) associated with the access node.

146. The method of claim 145, wherein the access node beacon signal comprises transmit frame timing information.

147. The method of claim 146, wherein the adjusting the forward uplink signal comprises: adjusting timing of the transmit frame timing information.

148. The method of claim 146, wherein the adjusting the forward uplink signal comprises: shifting a subsequent portion of the transmit frame timing information relative to the PN code.

149. The method of any one of claims 145-148, wherein the adjusting the forward uplink signal comprises: adjusting a chip timing of the PN code.

150. The method of any one of claims 135-149, wherein the relay beacon signal comprises a plurality of signals in a plurality of sub-bands.

151. The method of any one of claims 135-150, wherein the forward uplink signal is transmitted in a circularly polarized signal and the relay beacon signal is received in a linearly polarized signal.

152. The method of any one of claims 135-151, wherein:

the access node-specific forward signal comprises a plurality of sub-signals associated with different subsets of the multiple forward user beam coverage areas; and

the transmitting the forward uplink signal comprises upconverting the plurality of sub-signals to different carrier frequencies.

153. The method of any one of claims 135-152, wherein the access node beacon signal is transmitted to the end-to-end relay during a calibration interval not overlapping in time with the access node-specific forward signal.

154. The method of any one of claims 135-153, wherein the access node beacon signal is transmitted to the end-to-end relay at a higher power spectral density than the access node-specific forward signal.

155. The method of any one of claims 135-154, wherein the plurality of access nodes has a first number of the access nodes and the end-to-end relay has a second number of the forward receive/transmit signal paths, wherein the first number is different than the second number.

156. The method of claim 155, wherein the first number is greater than the second number.

157. The method of any one of claims 135-156, wherein the end-to-end relay is a satellite.

158. The method of any one of claims 135-157, wherein the forward uplink signal comprises a plurality of signals transmitted over different frequency sub-bands.

159. The method of claim 158, wherein the multiple forward user beam coverage areas comprise a plurality of subsets of forward user beam coverage areas associated with the different frequency sub-bands.

160. The method of claim 159, wherein each of the plurality of subsets of forward user beam coverage areas comprises a plurality of non-overlapping forward user beam coverage areas.

161. The method of any one of claims 158-159, wherein a bandwidth for each of the different frequency sub-bands is greater than or equal to 500 MegaHertz.

162. An access node (515) for communication in a communication system comprising a plurality of access nodes at geographically distributed locations providing a communication service to user terminals (517) distributed over multiple forward user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple forward receive/transmit signal paths (2001), comprising:

a network interface (2415, 4006) that obtains an access node-specific forward signal (516) for transmission to a plurality of the user terminals grouped by the multiple forward user beam coverage areas via the end-to-end relay, the access node-specific forward signal comprising a composite of forward beam signals (511) corresponding to a plurality of the multiple forward user beam coverage areas, the forward beam signals weighted by respective beam weights of a beam weight vector associated with the access node;

a de-multiplexer (4060) that obtains forward signal transmit timing and phase information (4016) for the access node-specific forward signal;

a transmitter (4012) that transmits a forward uplink signal (521) comprising an access node beacon signal (2530) and the access node-specific forward signal to the end-to-end relay;

a receiver (4002) that receives a downlink signal (527) from the end-to-end relay, the downlink signal comprising a relay beacon signal and the relayed access node beacon signal relayed from the end-to-end relay;

a controller (2523) that determines a timing and phase adjustment (2524) to align relayed transmit timing and phase information in the relayed access node beacon signal with received relay timing and phase information in the received relay beacon signal; and

a transmit timing and phase compensator (4020) that outputs the forward uplink signal to the transmitter based on the timing and phase adjustment, the transmit timing and phase compensator multiplexing the access node-specific forward signal with the access node beacon signal such that the forward signal transmit timing and phase information is synchronized to corresponding transmit timing and phase information in the access node beacon signal.

163. The access node of claim 162, further comprising: a relay beacon signal demodulator (2511) that demodulates the relay beacon signal to obtain receive timing and phase information (4028).

164. The access node of claim 163, further comprising: an access beacon signal demodulator (2519) that demodulates the relayed access node beacon signal to obtain relayed transmit timing and phase information (4026).

165. The access node of claim 164, wherein the controller determines the timing and phase adjustment based on a comparison of the receive timing and phase information with the relayed transmit timing and phase information.

166. The access node of any one of claims 162-165, wherein the de-multiplexer de-multiplexes the forward signal transmit timing information from a multiplexed access node-specific forward.

167. The access node of any one of claims 162-166, wherein the access node-specific forward signal comprises a plurality of time-domain subsets of samples.

168. The access node of claim 167, wherein each of the plurality of time-domain subsets of samples comprises a plurality of interleaved samples for the access node-specific forward signal, the access node further comprising: a de-interleaver (4050) that de-interleaves the interleaved samples of the access node-specific forward signal.

169. The access node of any one of claims 162-168, wherein the relay beacon signal comprises a pseudo-noise (PN) code (2307).

170. The access node of any one of claims 162-169, wherein the relay beacon signal comprises relay frame timing information.

171. The access node of any one of claims 162-170, wherein the access node beacon signal comprises a pseudo-noise (PN) code (2301) associated with the access node.

172. The access node of claim 171, wherein the access node beacon signal comprises transmit frame timing information.

173. The access node of claim 172, wherein, based on the beacon timing adjustment, the access beacon timing generator adjusts timing of the transmit frame timing information.

174. The access node of claim 172, wherein, based on the beacon timing adjustment, the access beacon timing generator shifts a subsequent portion of the transmit frame timing information relative to the PN code.

175. The access node of any one of claims 171-174, wherein, based on the beacon timing adjustment, the access beacon timing generator adjusts a chip timing of the PN code.

176. The access node of any one of claims 162-175, wherein the relay beacon signal comprises a plurality of signals in a plurality of sub-bands.

177. The access node of any one of claims 162-176, wherein the forward uplink signal is transmitted in a circularly polarized signal and the relay beacon signal is received in a linearly polarized signal.

178. The access node of any one of claims 162-177, wherein:

the access node-specific forward signal comprises a plurality of sub-signals associated with different subsets of the multiple forward user beam coverage areas; and

the transmitting the forward uplink signal comprises upconverting the plurality of sub-signals to different carrier frequencies.

179. The access node of any one of claims 162-178, wherein the access node beacon signal is transmitted to the end-to-end relay during a calibration interval not overlapping in time with the access node-specific forward signal.

180. The access node of any one of claims 162-179, wherein the access node beacon signal is transmitted to the end-to-end relay at a higher power spectral density than the access node-specific forward signal.

181. The access node of any one of claims 162-180, wherein the plurality of access nodes has a first number of the access nodes and the end-to-end relay has a second number of the forward receive/transmit signal paths, wherein the first number is different than the second number.

182. The access node of claim 181, wherein the first number is greater than the second number.

183. The access node of any one of claims 162-182, wherein the end-to-end relay is a satellite.

184. The access node of any one of claims 162-183, wherein the forward uplink signal comprises a plurality of signals transmitted over different frequency sub-bands.

185. The access node of claim 184, wherein the multiple forward user beam coverage areas comprise a plurality of subsets of forward user beam coverage areas associated with the different frequency sub-bands.

186. The access node of claim 185, wherein each of the plurality of subsets of forward user beam coverage areas comprises a plurality of non-overlapping forward user beam coverage areas.

187. The access node of any one of claims 184-186, wherein a bandwidth for each of the different frequency sub-bands is greater than or equal to 500 MegaHertz.

188. An access node (515) for communication in a communication system comprising plurality of access nodes at geographically distributed locations providing a communication service to user terminals (517) distributed over multiple forward user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple forward receive/transmit signal paths (2001), comprising:

means for obtaining (2415, 4006) an access node-specific forward signal (516) for transmission via the end-to-end relay to a plurality of the user terminals grouped by the multiple forward user beam coverage areas, the access node-specific forward signal comprising a composite of forward beam signals (511) corresponding to a plurality of the multiple forward user beam coverage areas, the forward beam signals weighted by respective beam weights of a beam weight vector associated with the access node;

means for identifying (4060) forward signal transmit timing information (4016) indicating transmission timing for the access node-specific forward signal;

means for transmitting (4012) a forward uplink signal (521) comprising the access node-specific forward signal to the end-to-end relay, the access node-specific forward signal having the forward signal transmit timing information synchronized to corresponding transmit timing information; and

means for adjusting timing and phase (4020) of the forward uplink signal to compensate the access node-specific forward signal for a path delay and a phase shift between the access node and the end-to-end relay.

189. The access node of claim 188, further comprising: means for receiving (4002) signaling from the end-to-end relay comprising a relay beacon signal and an access node beacon signal (2530) transmitted by the access node and relayed by the end-to-end relay.

190. The access node of claim 189, further comprising: means for determining (2511) receive timing information (4028, 2521) and receive phase information (4028, 2521) based on the relay beacon signal.

191. The access node of claim 190, further comprising: means for determining relayed transmit timing information (4026, 2540) and relayed transmit phase information (4026, 2542) based on the relayed access node beacon signal.

192. The access node of claim 191, wherein the means for adjusting adjusts timing of the forward uplink signal based on a comparison of the receive timing information with the relayed transmit timing information.

193. The access node of any one of claims 191-192, wherein the means for adjusting timing and phase adjusts phase of the forward uplink signal based on a comparison of the receive phase information with the relayed transmit phase information.

194. The access node of any one of claims 189-193, wherein the relay beacon signal comprises a pseudo-noise (PN) code (2307).

195. The access node of any one of claims 189-194, wherein the relay beacon signal comprises relay frame timing information.

196. The access node of any one of claims 189-195, wherein the access node beacon signal comprises a pseudo-noise (PN) code (2301) associated with the access node.

197. The access node of claim 196, wherein the access node beacon signal comprises transmit frame timing information.

198. The access node of claim 197, wherein the means for adjusting adjusts timing of the transmit frame timing information.

199. The access node of claim 197, wherein the means for adjusting shifts a subsequent portion of the transmit frame timing information relative to the PN code.

200. The access node of any one of claims 196-199, wherein the means for adjusting adjusts a chip timing of the PN code.

201. The access node of any one of claims 189-200, wherein the access node beacon signal is transmitted to the end-to-end relay during a calibration interval not overlapping in time with the access node-specific forward signal.

202. The access node of any one of claims 189-201, wherein the access node beacon signal is transmitted to the end-to-end relay at a higher power spectral density than the access node-specific forward signal.

203. The access node of any one of claims 189-202, wherein the relay beacon signal comprises a plurality of signals in a plurality of sub-bands.

204. The access node of any one of claims 189-203, wherein the forward uplink signal is transmitted in a circularly polarized signal and the relay beacon signal is received in a linearly polarized signal.

205. The access node of any one of claims 188-204, further comprising: means for de-multiplexing the forward signal transmit timing information from a multiplexed access node-specific forward signal received at the access node.

206. The access node of any one of claims 188-205, wherein the access node-specific forward signal comprises a plurality of time-domain subsets of samples.

207. The access node of claim 206, wherein each of the plurality of time-domain subsets of samples comprises a plurality of interleaved samples for the access node-specific forward signal, the access node further comprising: means for de-interleaving the interleaved samples of the access node-specific forward signal.

208. The access node of any one of claims 188-207, wherein:

the access node-specific forward signal comprises a plurality of sub-signals associated with different subsets of the multiple forward user beam coverage areas; and

the means for transmitting upconverts the plurality of sub-signals to different carrier frequencies.

209. The access node of any one of claims 188-208, wherein the plurality of access nodes has a first number of the access nodes and the end-to-end relay has a second number of the forward receive/transmit signal paths, wherein the first number is different than the second number.

210. The access node of claim 209, wherein the first number is greater than the second number.

211. The access node of any one of claims 188-210, wherein the end-to-end relay is a satellite.

212. The access node of any one of claims 188-211, wherein the forward uplink signal comprises a plurality of signals transmitted over different frequency sub-bands.

213. The access node of claim 212, wherein the multiple forward user beam coverage areas comprise a plurality of subsets of forward user beam coverage areas associated with the different frequency sub-bands.

214. The access node of claim 213, wherein each of the plurality of subsets of forward user beam coverage areas comprises a plurality of non-overlapping forward user beam coverage areas.

215. The access node of any one of claims 212-214, wherein a bandwidth for each of the different frequency sub-bands is greater than or equal to 500 MegaHertz.

216. A method of communication at an access node (515) of a communication system comprising a plurality of access nodes at geographically distributed locations providing a communication service to user terminals (517) distributed over multiple return user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple return receive/transmit signal paths (1702), the method comprising:

receiving a return downlink signal (527) comprising a composite return signal (907) and a relay beacon signal from the end-to-end relay, the composite return signal comprising return uplink signals (525) from a plurality of the user terminals relayed by the end-to-end relay;

demodulating the relay beacon signal to obtain receive timing information (2520);

multiplexing the composite return signal with the receive timing information to obtain a multiplexed composite return signal; and

sending the multiplexed composite return signal to a return beamformer (531).

217. The method of claim 216, wherein the demodulating comprises: determining a receive timing adjustment (2512, 2513) and a receive phase adjustment (2512, 2514) to compensate for downlink channel impairment based at least in part on a comparison of the relay beacon signal to a local reference signal.

218. The method of claim 217, further comprising: adjusting timing of the composite return signal based on the receive timing adjustment.

219. The method of any one of claims 217-218, further comprising: adjusting a phase of the composite return signal based on the receive phase adjustment.

220. The method of any one of claims 216-219, wherein the multiplexed composite return signal comprises a plurality of time-domain subsets of samples.

221. The method of claim 220, further comprising: interleaving samples of the multiplexed composite return signal in the plurality of time-domain subsets of samples.

222. The method of any one of claims 216-221, wherein the relay beacon signal comprises a pseudo-noise (PN) code (2307).

223. The method of any one of claims 216-222, wherein the relay beacon signal comprises frame timing information.

224. The method of any one of claims 216-223, wherein the relay beacon signal comprises a plurality of signals at a plurality of sub-bands.

225. The method of any one of claims 216-224, wherein the composite return signal comprises a circularly polarized signal and the relay beacon signal comprises a linearly polarized signal.

226. The method of any one of claims 216-225, wherein the communication system has a first number of the access nodes and the end-to-end relay has a second number of the return receive/transmit signal paths, wherein the first number is different than the second number.

227. The method of claim 226, wherein the first number is greater than the second number.

228. The method of any one of claims 216-227, wherein the end-to-end relay is a satellite.

229. The method of any one of claims 216-228, wherein the composite return signal comprises a plurality of signals in different frequency sub-bands.

230. The method of claim 229, wherein the multiple return user beam coverage areas comprise a plurality of subsets of return user beam coverage areas associated with the different frequency sub-bands.

231. The method of claim 230, wherein each of the plurality of subsets of return user beam coverage areas comprises a plurality of non-overlapping return user beam coverage areas.

232. The method of any one of claims 229-231, wherein a bandwidth for each of the different frequency sub-bands is greater than or equal to 500 MegaHertz.

233. An access node (515) for communication in a communication system comprising a plurality of access nodes at geographically distributed locations providing a communication service to user terminals (517) distributed

over multiple return user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple return receive/transmit signal paths (1702), comprising:

a receiver (4002) that receives a return dowlink signal (527) from the end-to-end relay, the return signal downlink signal comprising a relay beacon signal and return uplink signals (525) from a plurality of the user terminals relayed by the end-to-end relay, to form a composite return signal (907);

a relay beacon signal demodulator (2511) that demodulates the relay beacon signal to obtain relay timing information (2520);

a multiplexer (2518, 4004) that multiplexes the composite return signal with the relay timing information to obtain a multiplexed composite return signal; and

a signal interface (2415, 4006) that sends the multiplexed composite return signal to a return beamformer (531).

234. The access node of claim 233, wherein the relay beacon signal demodulator compares the relay beacon signal with a local reference signal to obtain a receive timing adjustment (2512, 2513) and a receive phase adjustment (2512, 2514) to compensate for downlink channel impairment.

235. The access node of claim 234, further comprising: a timing adjuster (4024, 2515) that adjusts timing of the composite return signal based on the receive timing adjustment.

236. The access node of any one of claims 234-235, further comprising: a phase adjuster (4024, 2517) that adjusts a phase of composite return signal based on the receive phase adjustment.

237. The access node of any one of claims 233-236, wherein the multiplexed composite return signal comprises a plurality of time-domain subsets of samples.

238. The access node of claim 237, further comprising: an interleaver (4044) that interleaves samples of the multiplexed composite return signal in the plurality of time-domain subsets of samples.

239. The access node of any one of claims 233-238, wherein the relay beacon signal comprises a pseudo-noise (PN) code (2307).

240. The access node of any one of claims 233-239, wherein the relay beacon signal comprises frame timing information.

241. The access node of any one of claims 233-240, wherein the relay beacon signal comprises a plurality of signals at a plurality of sub-bands.

242. The access node of any one of claims 233-241, wherein the composite return signal comprises a circularly polarized signal and the relay beacon signal comprises a linearly polarized signal.

243. The access node of any one of claims 233-242, wherein the communication system has a first number of the access nodes and the end-to-end relay has a second number of the return receive/transmit signal paths, wherein the first number is different than the second number.

244. The access node of claim 243, wherein the first number is greater than the second number.

245. The access node of any one of claims 233-244, wherein the end-to-end relay is a satellite.

246. The access node of any one of claims 233-245, wherein the composite return signal comprises a plurality of signals in different frequency sub-bands.

247. The access node of claim 246, wherein the multiple return user beam coverage areas comprise a plurality of subsets of return user beam coverage areas associated with the different frequency sub-bands.

248. The access node of claim 247, wherein each of the plurality of subsets of return user beam coverage areas comprises a plurality of non-overlapping return user beam coverage areas.

249. The access node of any one of claims 246-248, wherein a bandwidth for each of the different frequency sub-bands is greater than or equal to 500 MegaHertz.

250. An access node (515) for communication in a communication system comprising a plurality of access nodes at geographically distributed locations providing a communication service to user terminals (517) distributed over multiple return user beam coverage areas (519) via an end-to-end relay (503, 1202, 1502, 3403) comprising multiple return receive/transmit signal paths (1702), comprising:

means for receiving (4002) a return downlink signal (527) from the end-to-end relay, the return downlink signal comprising a relay beacon signal and return uplink signals (525) from a plurality of the user terminals relayed by the end-to-end relay, to form a composite return signal (907);

means for obtaining (2511) receive timing information (2520) based on the relay beacon signal;

means for multiplexing (2518, 4004) the composite return signal with the receive timing information to obtain a multiplexed composite return signal; and

means for sending (2415, 4006) the multiplexed composite return signal to a return beamformer (531).

251. The access node of claim 250, wherein the means for obtaining determines a receive timing adjustment (2512, 2513) and a receive phase adjustment (2512, 2514) to compensate for downlink channel impairment based at least in part on a comparison of the relay beacon signal to a local reference signal.

252. The access node of claim 251, further comprising: means for adjusting timing (4024, 2515) of the composite return signal based on the receive timing adjustment.

253. The access node of any one of claims 251-252, further comprising: means for adjusting a phase (4024, 2517) of the composite return signal based on the receive phase adjustment.

254. The access node of any one of claims 250-253, wherein the multiplexed composite return signal comprises a plurality of time-domain subsets of samples.

255. The access node of claim 254, further comprising means for interleaving (4044) samples of the multiplexed composite return signal in the plurality of time-domain subsets of samples.

256. The access node of any one of claims 250-255, wherein the relay beacon signal comprises a pseudo-noise (PN) code (2307).

257. The access node of any one of claims 250-256, wherein the relay beacon signal comprises frame timing information.

258. The access node of any one of claims 250-257, wherein the relay beacon signal comprises a plurality of signals at a plurality of sub-bands.

259. The access node of any one of claims 250-258, wherein the composite return signal comprises a circularly polarized signal and the relay beacon signal comprises a linearly polarized signal.

260. The access node of any one of claims 250-259, wherein the communication system has a first number of the access nodes and the end-to-end relay has a second number of the return receive/transmit signal paths, wherein the first number is different than the second number.

261. The access node of claim 260, wherein the first number is greater than the second number.

262. The access node of any one of claims 250-261, wherein the end-to-end relay is a satellite.

263. The access node of any one of claims 250-262, wherein the composite return signal comprises a plurality of signals in different frequency sub-bands.

264. The access node of claim 263, wherein the multiple return user beam coverage areas comprise a plurality of subsets of return user beam coverage areas associated with the different frequency sub-bands.

265. The access node of claim 264, wherein each of the plurality of subsets of return user beam coverage areas comprises a plurality of non-overlapping return user beam coverage areas.

266. The access node of any one of claims 263-264, wherein a bandwidth for each of the different frequency sub-bands is greater than or equal to 500 MegaHertz.