CLAIMS

What is claimed is:

1. A method of operation by a ground segment of a satellite communication system comprising the ground segment and a space segment, the method comprising:

receiving incoming user data streams at one or more processing nodes of the ground segment, each incoming user data stream targeting a respective user terminal served by the satellite communication system; and

employing forward spatial diversity transmission for one or more of the incoming user data streams by, for each such incoming user data stream:

forming a corresponding set of two or more forward user data sub-streams by block encoding the incoming user data stream and dividing each encoded data block into different subsets of encoded data; and

mapping each forward user data sub-stream to a respective one among two or more forward beam signals respectively corresponding to two or more forward user beams of the satellite communication system that have respective forward user beam coverage areas encompassing a location of the user terminal targeted by the incoming user data stream; and

sending each forward beam signal to a different ground station among a plurality of geographically distributed ground stations that each transmit to the space segment using a respective optical forward uplink signal.

2. The method according to claim 1, further comprising, at each ground station among the plurality of geographically distributed ground stations, forming the respective forward uplink signal by multiplexing a plurality of forward optical channel signals conveying respective copies of the forward beam signal received by the ground station, weighted for beamforming transmission from respective antenna elements of a targeted antenna array in the space segment, for far-field formation of the corresponding forward user beam.

3. The method according to claim 1 or 2, further comprising, for each incoming user data stream for which forward spatial diversity is employed, embedding stream reassembly information in at least one of the forward user data sub-streams in the corresponding set of two or more forward user data sub-streams, the reassembly information providing for ordered reassembly of the incoming user data stream at the targeted user terminal.

4. The method according to any one of claims 1-3, wherein forward spatial diversity transmission is employed on a selective basis, and wherein the method further includes, for any incoming user data stream for which forward spatial diversity transmission is not employed, employing forward non-diversity transmission in which the incoming user data stream is block encoded and mapped to a single forward beam signal corresponding to a respective forward user beam.

5. The method according to any one of claims 1-4, wherein the satellite communication system provides a plurality of forward user beams via one or more satellites comprised in the space segment, wherein there are one or more forward spatial diversity beam subsets among the plurality of forward user beams, each forward spatial diversity beam subset comprising two or more forward user beams having distinctive combinations of signal frequency and polarization and having respective forward user beam coverage areas that overlap by more than a threshold amount, and wherein employing forward spatial diversity transmission for the one or more of the incoming user data streams comprises, for each such incoming user data stream, mapping the corresponding two or more forward user data sub-streams to respective forward beam signals corresponding to forward user beams that are members of a forward spatial diversity beam subset that provides coverage with respect to the location of the respective user terminal.

6. The method according to claim 5, wherein forward user traffic mapped to each forward user beam included in each forward spatial diversity beam subset is transmitted from the ground segment to the space segment via a different optical forward uplink signal originating from a different one among two or more among the geographically distributed ground stations.

7. The method according to any one of claims 1-6, further comprising deciding whether to use forward spatial diversity transmission for any one or more of the incoming user data streams based on corresponding user subscription agreements, such that forward spatial diversity transmission is used for a given incoming user data stream in dependence on the corresponding user subscription agreement.

8. The method according to any one of claims 1-6, further comprising deciding on an ongoing basis as to whether to use forward spatial diversity transmission for any one or more of the incoming user data streams, based on any one or any combination of: the number of ground stations available for transmitting forward beam signals to the space segment; detected impairments of any one or more of the optical forward uplink signals used to transmit the

forward beam signals from the ground segment to the space segment; and loading of the respective forward user beams.

9. The method according to any one of claims 1-8, wherein the satellite communication system provides a plurality of forward user beams via one or more satellites comprised in the space segment, each forward user beam based on a corresponding forward user beam signal and having a respective combination of downlink signal frequency and polarization, and wherein the method comprises:

receiving, at each of one or more ground stations among the plurality of the ground stations, two or more forward beam signals corresponding to two or more forward user beams having the same respective combination of downlink signal frequency and polarization, and at each such ground station:

forming a respective set of forward beam element signals for each of the two or more forward beam signals by generating a set of radio frequency signals, each radio frequency signal corresponding to an antenna element of a targeted satellite antenna array and modulated by the forward beam signal, and weighting each radio frequency signal with a corresponding forward beam weight from a corresponding set of forward beam weights calculated such that simultaneous transmission of the set of forward beam element signals from the targeted satellite antenna forms the corresponding forward user beam in the far field;

combining the respective sets of forward beam element signals to form a set of combined forward beam element signals;

modulating each optical carrier among a plurality of optical carriers at different wavelengths with a respective one among the set of combined forward beam element signals, to obtain a plurality of forward optical channel signals;

multiplexing the plurality of forward optical channel signals in the optical domain to form a corresponding optical forward uplink signal; and

transmitting the corresponding optical forward uplink signal toward a satellite having the targeted satellite antenna array.

10. A satellite communication system comprising a ground segment, the ground segment comprising:

interface circuitry configured to receive incoming user data streams, each incoming user data stream targeting a respective user terminal served by the satellite communication system; and

processing circuitry that is configured to employ forward spatial diversity transmission for one or more of the incoming user data streams based on being configured to, for each such incoming user data stream:

form a corresponding set of two or more forward user data sub-streams by block encoding the incoming user data stream and dividing each encoded data block into different subsets of encoded data; and

map each forward user data sub-stream to a respective one among two or more forward beam signals respectively corresponding to two or more forward user beams of the satellite communication system that have respective forward user beam coverage areas encompassing a location of the user terminal targeted by the incoming user data stream; and

send each forward beam signal to a different ground station among a plurality of geographically distributed ground stations, with each ground station configured to transmit to a space segment of the satellite communications system using a respective optical forward uplink signal.

11. The satellite communications system according to claim 10, further comprising the plurality of geographically distributed ground stations, wherein each ground station among the plurality of geographically distributed ground stations is configured to form the respective forward uplink signal by multiplexing a plurality of forward optical channel signals conveying respective copies of the forward beam signal received by the ground station, weighted for beamforming transmission from respective antenna elements of a targeted antenna array in the space segment, for far-field formation of the corresponding forward user beam.

12. The satellite communications system according to claim 10 or 11, wherein, for each incoming user data stream for which forward spatial diversity is employed, processing circuitry in the ground segment is configured to embed stream reassembly information in at least one of the forward user data sub-streams in the corresponding set of two or more forward user data sub-streams, the reassembly information providing for ordered reassembly of the incoming user data stream at the targeted user terminal.

13. The satellite communications system according to any one of claims 10-12, wherein forward spatial diversity transmission is employed on a selective basis, and wherein processing circuitry included in the ground segment is configured to, for any incoming user data stream for which forward spatial diversity transmission is not employed, employ forward non-diversity transmission in which the incoming user data stream is block encoded and mapped to a single forward beam signal corresponding to a respective forward user beam.

14. The satellite communications system according to any one of claims 10-13, wherein the satellite communication system provides a plurality of forward user beams via one or more satellites comprised in the space segment, wherein there are one or more forward spatial diversity beam subsets among the plurality of forward user beams, each forward spatial diversity beam subset comprising two or more forward user beams having distinctive combinations of signal frequency and polarization and having respective forward user beam coverage areas that overlap by more than a threshold amount, and wherein, to employ forward spatial diversity transmission for the one or more of the incoming user data streams, processing circuitry in the ground segment is configured to, for each such incoming user data stream, map the corresponding two or more forward user data sub-streams to respective forward beam signals corresponding to forward user beams that are members of a forward spatial diversity beam subset that provides coverage with respect to the location of the respective user terminal.

15. The satellite communications system according to claim 14, wherein the ground segment is configured such that forward user traffic mapped to each forward user beam included in each forward spatial diversity beam subset is transmitted from the ground segment to the space segment via a different optical forward uplink signal originating from a different one among two or more geographically distributed ground stations.

16. The satellite communications system according to any one of claims 10-15, wherein processing circuitry included in the ground segment is configured to decide whether to use forward spatial diversity transmission for any one or more of the incoming user data streams based on corresponding user subscription agreements, such that forward spatial diversity transmission is used for a given incoming user data stream in dependence on the corresponding user subscription agreement.

17. The satellite communications system according to any one of claims 10-16, wherein processing circuitry included in the ground segment is configured to decide on an ongoing basis

as to whether to use forward spatial diversity transmission for any one or more of the incoming user data streams, based on any one or any combination of: the number of ground stations available for transmitting forward beam signals to the space segment; detected impairments of any one or more of the optical forward uplink signals used to transmit the forward beam signals from the ground segment to the space segment; and loading of the respective forward user beams.

18. The satellite communications system according to any one of claims 10-17, wherein the satellite communication system provides a plurality of forward user beams via one or more satellites comprised in the space segment, each forward user beam based on a corresponding forward user beam signal and having a respective combination of downlink signal frequency and polarization, and wherein each ground station comprises:

interface circuitry configured to receive two or more forward beam signals corresponding to two or more forward user beams having the same respective combination of downlink signal frequency and polarization; and

processing and transmission circuitry configured to:

form a respective set of forward beam element signals for each of the two or more forward beam signals by generating a set of radio frequency signals, each radio frequency signal corresponding to an antenna element of a targeted satellite antenna array and modulated by the forward beam signal, and weighting each radio frequency signal with a corresponding forward beam weight from a corresponding set of forward beam weights calculated such that simultaneous transmission of the set of forward beam element signals from the targeted satellite antenna array forms the corresponding forward user beam in the far field;

combine the respective sets of forward beam element signals to form a set of combined forward beam element signals;

modulate each optical carrier among a plurality of optical carriers at different wavelengths with a respective one among the set of combined forward beam element signals, to obtain a plurality of forward optical channel signals;

multiplex the plurality of forward optical channel signals in the optical domain to form a corresponding optical forward uplink signal; and

transmit the corresponding optical forward uplink signal toward a satellite having the targeted satellite antenna array.