CLAIMS

1. A method of controlling a reconfigurable intelligent surface (RIS) for multi-target spot beamforming at a plurality of target beam focus positions, the RIS comprising a two-dimensional (2D) array of unit cells, each unit cell being controllable to be at any selected one of a plurality of wave propagation path states for providing a corresponding degree of phase shift for incident electromagnetic waves irradiated thereon, the method comprising:

for each of the plurality of target beam focus positions:

determining, for each unit cell of the plurality of the 2D array of unit cells, an interference pattern at the unit cell between a reference wave from a multi-mode orbital angular momentum (OAM) signal transmitter to the unit cell and an object wave from the target beam focus position to the unit cell, the multi-mode OAM signal transmitter being configured to generate and transmit multi-mode OAM waves to irradiate the RIS at a surface thereof; and

for each unit cell of the plurality of the 2D array of unit cells:

determining a holograph pattern based on the interference patterns determined at the unit cell for the plurality of target beam focus positions;

determining a degree of phase shift for the unit cell to provide based on the holograph pattern determined for the unit cell; and

controlling the unit cell to be at a selected one of the plurality of wave propagation path states corresponding to the degree of phase shift determined for the unit cell to provide.

2. The method according to claim 1, wherein for each of the plurality of target beam focus positions, the reference wave is an OAM wave with an OAM mode corresponding to the target beam focus position.

3. The method according to claim 1 or 2, wherein the interference pattern at the unit cell between the reference wave and the object wave is determined based on an azimuth angle of the unit cell with respect to a center of the RIS serving as an OAM beam reference.

4. The method according to claim 3, wherein said determining, for each unit cell of the plurality of the 2D array of unit cells, the interference pattern at the unit cell between the reference wave and the object wave comprises:

determining a first distance between the multi-mode OAM signal transmitter and the unit cell;

determining a second distance between the target beam focus position and the unit cell;

determining the azimuth angle of the unit cell with respect to the center of the RIS; and

determining the interference pattern at the unit cell between the reference wave and the object wave based on the first distance, the second distance and the azimuth angle of the unit cell.

5. The method according to claim 4, wherein the interference pattern at the unit cell between the reference wave and the object wave is determined further based on an amplitude of the reference wave and an amplitude of the object wave.

6. The method according to claim 4 or 5, wherein

the first distance is determined based on a coordinate of the multi-mode OAM signal transmitter with respect to the center of the RIS and a coordinate of the unit cell with respect to the center of the RIS,

the second distance is determined based on a coordinate of the target beam focus position with respect to the center of the RIS and the coordinate of the unit cell, and

the azimuth angle of the unit cell is determined based on the coordinate of the unit cell.

7. The method according to any one of claims 1 to 6, wherein the holograph pattern is determined based on a summation of the interference patterns determined at the unit cell for the plurality of target beam focus positions.

8. The method according to any one of claims 1 to 7, wherein the plurality of target beam focus positions is located at a same side of the RIS as the OAM signal transmitter, or the plurality of target beam focus positions is located at an opposite side of the RIS with respect to the OAM signal transmitter.

9. The method according to any one of claims 1 to 8, wherein each unit cell is a 2-bit unit cell controllable to be at any selected one of four wave propagation path states for providing a corresponding degree of phase shift for the incident electromagnetic waves irradiated thereon.

10. The method according to claim 9, wherein the four wave propagation path states are configured to provide four corresponding degree of phase shifts of about 0 degrees, about 90 degrees, about 180 degrees and about 270 degrees, respectively, for the incident electromagnetic waves irradiated thereon.

11. The method according to any one of claims 1 to 10, wherein each unit cell is controllable to be at any selected one of the plurality of wave propagation path states based on controlling a state of a plurality of switching elements of the unit cell for configuring the unit cell to be at any selected one of the plurality of wave propagation path states for providing a corresponding degree of phase shift for the incident electromagnetic waves irradiated thereon.

12. The method according to claim 11, wherein said controlling the plurality of switching elements of the unit cell for configuring the unit cell to be at any selected one of the plurality of wave propagation path states configures one or more metal microstrip lines of the unit cell to provide a corresponding propagation path for the incident electromagnetic waves irradiated on the unit cell for providing the corresponding degree of phase shift for the incident electromagnetic waves.

13. A reconfigurable intelligent surface (RIS) controller for controlling a RIS for multi-target spot beamforming at a plurality of target beam focus positions, the RIS comprising a two-dimensional (2D) array of unit cells, each unit cell being controllable to be at any selected one of a plurality of wave propagation path states for providing a corresponding degree of phase shift for incident electromagnetic waves irradiated thereon, the RIS controller comprising:

at least one memory; and

at least one processor communicatively coupled to the at least one memory and configured to perform a method of controlling the RIS for multi-target spot beamforming at the plurality of target beam focus positions according to any one of claims 1 to 12.

14. A multi-target spot beamforming system comprising:

a reconfigurable intelligent surface (RIS) comprising a two-dimensional (2D) array of unit cells, each unit cell being controllable to be at any selected one of a plurality of wave propagation path states for providing a corresponding degree of phase shift for incident electromagnetic waves irradiated thereon;

a multi-mode orbital angular momentum (OAM) signal transmitter configured to generate and transmit a multi-mode OAM signal to irradiate the RIS at a surface thereof; and

a RIS controller according to claim 13 communicatively coupled to the RIS for controlling the RIS for multi-target spot beamforming at a plurality of target beam focus positions.

15. A computer program product, embodied in one or more non-transitory computer-readable storage mediums, comprising instructions executable by at least one processor to perform a method of controlling a reconfigurable intelligent surface (RIS) for multi-target spot beamforming at a plurality of target beam focus positions according to any one of claims 1 to 12.