

WHAT IS CLAIMED IS:

1. A sensing system, comprising:
 - a first sub-sensing system having a first azimuth plane, wherein the first sub-sensing system includes:
 - a Gradient-index lens, and
 - a first plurality of antenna elements arranged adjacent to the Gradient-index lens and configured to receive a first signal emanating from a first field of view; and
 - a second sub-sensing system having a second azimuth plane oriented at an angle with respect to the first azimuth plane and a second plurality of antenna elements configured to receive a second signal emanating from a second field of view.
2. The sensing system of claim 1, wherein a combination of the first field of view and the second field of view has a vertical field of view greater than about 90 degrees.
3. The sensing system of claim 1, further comprising a cover configured to enclose the first and the second sub-sensing systems.
4. The sensing system of claim 3, wherein the cover is configured to couple the first sub-sensing system and the second sub-sensing system to a vehicle.
5. The sensing system of claim 1, wherein the angle with respect to the first azimuth plane and a second plurality of antenna elements is about 90 degrees.
6. The sensing system of claim 1, further comprising a controller configured to:
 - receive a first plurality of antenna signals from the first plurality of antenna elements,
 - receive a second plurality of antenna signal from the second plurality of antenna elements, and
 - determine a direction of a target objected associated with the first signal or the second signal based on the first plurality of antenna signals and the second plurality of antenna signals.
7. The sensing system of claim 6, wherein the first signal and the second signal include a reflection, by the target object, of a portion of an outgoing signal generated by a transmitter of the sensing system.

8. A sensing system, comprising:
a receiver comprising:
a Gradient-index lens, and
a first plurality of antenna elements arranged adjacent to the Gradient-index lens and configured to receive a first incoming signal and generate a plurality of receiver signals in response to receiving the first incoming signal;
a transmitter including a second plurality of antenna elements configured to generate an outgoing signal, wherein each of the second plurality of antenna elements are separated by a predetermined distance; and
a controller configured to receive the plurality of receiver signals from the first plurality of antenna elements, and generate a plurality of transmitter signals based on which the transmitter generates the outgoing signal.
9. The sensing system of claim 8, further comprising plurality of transmission lines configured to transmit the plurality of receiver signals from the first plurality of antenna elements to the controller and/or transmit the plurality of transmitter signals from the controller to the transmitter.
10. The sensing system of claim 9, wherein the controller is included in a radar chip, wherein the controller includes at least one receiver circuit and at least one transmitter circuit.
11. The sensing system of claim 10, further comprising:
a first switch configured to electrically connect the at least one receiver circuit to a first antenna element of the first plurality of antenna elements during a first time period, and to a second antenna element of the first plurality of antenna elements during a second time period,
wherein the first time period is temporally separated from the second time period.
12. The sensing system of claim 10, further comprising:
a second switch configured to electrically connect the at least one transmitter circuit to a third antenna element of the second plurality of antenna elements during a third time period, and to a fourth antenna element of the second plurality of antenna elements during a fourth time period,
wherein the third time period is temporally separated from the fourth time period.

13. The sensing system of claim 10, wherein the radar chip, the first plurality of antenna elements, the second plurality of antenna elements, and the transmission lines are included in a flexible printed circuit board.
14. The sensing system of claim 13, wherein a first portion of the flexible printed circuit board comprising the first plurality of antenna elements surrounds a second portion of the gradient-index lens.
15. The sensing system of claim 8, further comprising a plurality of waveguides configured to transmit the plurality of receiver signals from the first plurality of antenna elements to the controller, wherein the first plurality of antenna elements include plurality of openings of the first plurality of waveguides.
16. The sensing system of claim 8, wherein the receiver is located within a vehicle and the second plurality of antenna elements are located at varied locations within the vehicle separate from the receiver.
17. The sensing system of claim 16, wherein a distance between the locations of the second plurality of antenna elements is proportional to an angular resolution associated with the sensing system.
18. The sensing system of claim 17, wherein a portion of the outgoing signal is transmitted to the receiver via one or more of a transmission line such as a waveguide, a coax cable, an optical fiber, etc.
19. The sensing system of claim 8, wherein the first incoming signal includes a portion of the outgoing signal reflected by a target object.
20. A method comprising:
transmitting, by a transmitter, a first outgoing signal during a first time period;
receiving, by a receiver, a first incoming signal comprising a portion of the first outgoing signal reflected by a first target object located at a first distance from the transmitter, wherein the first distance is greater than a threshold distance;
transmitting, by the transmitter, a second outgoing signal during a second time period, wherein the second outgoing signal is directed at the first target object;
receiving, by the receiver, a second incoming signal different from the first incoming

signal; and

determining, based on the second incoming signal, that a second target object is located at a second distance, wherein the second distance is smaller than the threshold distance.

21. The method of claim 20, wherein the determining includes:

calculating a differential metric indicative of a difference between amplitudes of the second incoming signal and the first incoming signal; and

determining, based on the differential metric, that the second target object is located at the second distance smaller than the threshold distance.

22. The method of claim 21, wherein the transmitter and the second target object move relative to each other between the first time period and the second time period.

23. The method of claim 20, wherein the receiver includes:

a Gradient-index lens; and

a first plurality of antenna elements arranged adjacent to the Gradient-index lens and configured to receive the first and the second incoming signals.

24. The method of claim 22, wherein the transmitter includes a second plurality of antenna elements configured to generate the first and the second outgoing signals.

25. A sensing system comprising:

a plurality of transmitter antenna elements, wherein a first transmitter antenna element of the plurality of transmitter antenna elements is configured to generate a first plurality of outgoing signals during a first time duration, and a second transmitter antenna element of the plurality of transmitter antenna elements is configured to generate a second plurality of outgoing signals during a second time duration;

a receiver configured to receive a first and a second plurality of incoming signals, wherein each incoming signal of the first and the second plurality of incoming signals includes a portion of a unique outgoing signal of the first and the second plurality of outgoing signals, respectively, wherein the first and the second plurality of incoming signals are reflected by a target object moving relative to the transmitter; and

a controller configured to:

receive data characterizing the first and the second plurality of incoming signals from the receiver,

sample data for one or more incoming signals of the first and the second plurality of incoming signals;

generate a first transformed data by applying a range Fourier transform to the sampled data of the one or more incoming signal, wherein the first transformed data is a function of a plurality of range values associated with the target object and duration of generation of the first and second plurality of outgoing signals;

generate a second transformed data by applying a velocity Fourier transform to portions of the first transformed data associated with each range values of the plurality of range values, wherein the second transformed data is a function of a plurality of velocity values and the plurality of range values associated with the target object;

interpolate, for a given range value, data associated with the plurality of velocity values in the second transformed data, and

determine, based on the interpolated data, a location of the target object.

26. The sensing system of claim 25, wherein the controller is configured to determine the location of the target object by applying a first Doppler phase to portions of the interpolated data associated with the first plurality of incoming signals and by applying a second Doppler phase to portions of the interpolated data associated with the second plurality of incoming signals, wherein the first Doppler phase is associated with relative velocity between the first transmitter and the target during the first time duration and the second Doppler phase is associated with relative velocity between the second transmitter and the target during the second time duration .

27. The sensing system of claim 26, wherein the first phase compensation and the second phase compensation is a function of the plurality of velocity values.

28. The sensing system of claim 25, wherein the receiver includes:

a Gradient-index lens; and

a first plurality of antenna elements arranged adjacent to the Gradient-index lens and configured to receive the first and the second incoming signals.

29. A sensing system comprising:

a plurality of transmitter antenna elements, wherein a first transmitter antenna element of the plurality of transmitter antenna elements is configured to generate a first plurality of outgoing signals during a first time duration, and a second transmitter antenna element of the

plurality of transmitter antenna elements is configured to generate a second plurality of outgoing signals during a second time duration;

a receiver configured to receive a first and a second plurality of incoming signals, wherein each incoming signal of the first and the second plurality of incoming signals includes a portion of a unique outgoing signal of the first and the second plurality of outgoing signals, respectively, wherein the first and the second plurality of incoming signals reflected by a target object moving relative to the transmitter; and

a controller configured to:

receive data characterizing the first and the second plurality of incoming signals from the receiver,

sample data for one or more incoming signals of the first and the second plurality of incoming signals;

generate a first transformed data by applying a range Fourier transform to the sampled data of the one or more incoming signals, wherein the first transformed data is a function of a plurality of range values associated with the target object and duration of generation of the first and second plurality of outgoing signals;

generate a transmitter phase compensated data by applying a first phase compensation to portions of the first transformed data associated with the first plurality of incoming signals, and by applying a second phase compensation to portions of the first transformed data associated with the second plurality of incoming signals;

generate a second transformed data by applying a velocity Fourier transform to portions of the transmitter phase compensated data associated with each range values of the plurality of range values, wherein the second transformed data is a function of a plurality of velocity values and the plurality of range values associated with the target object; and

generate a Doppler phase compensated data by applying a first doppler phase to portions of the second transformed data associated with the first plurality of incoming signals and by applying a second doppler phase to portions of the second transformed data associated with the second plurality of incoming signals, and

determine, based on Doppler phase compensated data, a location of the target object.

30. The sensing system of claim 28, wherein the first Doppler phase is associated with relative velocity between the first transmitter and the target during the first time duration and

the second Doppler phase is associated with relative velocity between the second transmitter and the target during the second time duration.

31. The sensing system of claim 29, wherein the receiver includes:

- a Gradient-index lens; and

- a first plurality of antenna elements arranged adjacent to the Gradient-index lens and configured to receive the first and the second incoming signals.

32. A sensing system comprising:

- a plurality of transmitter antenna elements configured to generate a plurality of outgoing signals, wherein a first transmitter antenna element of the plurality of transmitter antenna elements is configured to generate a first plurality of outgoing signals during a first time duration, and a second transmitter antenna element of the plurality of transmitter antenna elements is configured to generate a second plurality of outgoing signals during a second time duration;

- a receiver configured to receive a plurality of incoming signals comprising a first and a second plurality of incoming signals, wherein each incoming signal of the first and the second plurality of incoming signals includes a portion of a unique outgoing signal of the first and the second plurality of outgoing signals, respectively, wherein the first and the second plurality of incoming signals are reflected by a target object moving relative to the transmitter; and

- a controller configured to:

- receive data characterizing the first and the second plurality of incoming signals from the receiver,

- sample data for one or more incoming signals of the first and the second plurality of incoming signals;

- generate a first transformed data by applying a range Fourier transform to the sampled data of the one or more incoming signal, wherein the first transformed data is a function of a plurality of range values associated with the target object and duration of generation of the first and second plurality of outgoing signals;

- generate a second transformed data by applying a velocity Fourier transform to portions of the first transformed data associated with each range values of the plurality of range values, wherein the second transformed data is a function of a plurality of velocity values and the plurality of range values associated with the target object;

determine, a first range value of the target object from portion of the second transformed data associated with the first transmitter antenna element and a second range value from portion of the second transformed data associated with the second transmitter antenna element;

determine an ambiguity integer based on the first range value, the second range value and the duration between the first time duration and the second time duration;
and

determine, based on the ambiguity integer, a real velocity value associated with each velocity value of the plurality of velocity values.

33. The sensing system of claim 32, wherein the controller is configured to interpolate, for a given velocity value, data associated with the plurality of range values in the second transformed data, prior to determination of ambiguity integer.

34. The sensing system of claim 32, wherein the receiver includes:

a Gradient-index lens; and

a plurality of antenna elements arranged adjacent to the Gradient-index lens and configured to receive the plurality of incoming signals generated by reflection of the plurality of outgoing signals by the target object, wherein the receiver includes the plurality of antenna elements.

35. A sensing system comprising:

a transmitter antenna element configured to generate a plurality of outgoing signals;

a receiver configured to receive a plurality of incoming signals, wherein each incoming signal of the plurality of incoming signals includes a portion of a unique outgoing signal of the plurality of outgoing signals, wherein the plurality of incoming signals are reflected by a target object;

a controller configured to:

receive data characterizing the plurality of incoming signals from the receiver,

and

calculate a standard deviation associated with amplitudes of the signals in the plurality of incoming signals.

36. The sensing system of claim 35, wherein the controller is configured to determine that the value of the standard deviation is above a predetermined threshold, and determine that the target object is a live object.

37. The sensing system of claim 35, wherein the controller is configured to determine that the value of the standard deviation is below a predetermined threshold, and determine that the target object is a non-living object.