CLAIMS:

1. A radar sensor comprising:

a first and a second continuous wave (CW) radar transceiver, whereby each CW radar transceiver comprises:

a voltage-controlled oscillator (VCO) configured to generate an output signal having a specific frequency;

a divider circuit configured to divide the output signal from the VCO into a reference signal and a transmission signal;

a double periodic composite right/left hand (CRLH) substrate integrated waveguide (SIW) leaky wave antenna configured to:

receive the transmission signal from the divider circuit;

transmit a backward or forward main beam, wherein a direction of the transmitted main beam is determined by the specific frequency of the received transmission signal, and when the main beam is reflected back to the antenna by an object adjacent the sensor, the antenna is further configured to generate a backscattered signal based on the reflected main beam;

the divider circuit is further configured to divide the backscattered signal received from the antenna;

a six-port interferometer configured to receive, by input ports of the six-port interferometer, the reference signal and the divided-backscattered signal from the divider circuit, whereby the six-port interferometer is configured to generate, based on the received reference and divided-backscattered signals, power signals at output ports of the six-port interferometer, the power signals being used for computing relative displacement *L* between the object and the radar sensor,

whereby the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver is positioned adjacent the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver and,

whereby the VCOs of the first and second CW radar transceivers are each tuned to generate output signals that each have a different specific frequency such that a direction of a main beam of the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver and a direction of a main beam of the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver are the same.

2. The radar sensor according to claim 1 wherein the six-port interferometer comprises:

a first power divider having an input port coupled to the divider circuit to receive the reference signal;

a first directional coupler having an input port coupled to an output port of the first power divider and having two output ports;

a second directional coupler having an input port coupled to another output port of the first power divider and having two output ports;

a second power divider having an input port coupled to the divider circuit to receive the divided-backscattered signal, and having an output port coupled to an input port of a wideband phase shifter, and having another output port coupled to another input port of the second directional coupler,

wherein an output port of the wideband phase shifter is coupled to another input port of the first directional coupler.

3. The radar sensor according to claim 2 wherein gradient index (GRIN) substrates are provided at coupling regions of the first and second directional couplers.

4. The radar sensor according to any one of claims 1 to 3, wherein the divider circuit comprises:

a power divider configured to divide the output signal from the VCO equally into the reference signal and a divided output signal, and to provide the reference signal to one of the input ports of the six-port interferometer;

a rat race coupler configured to receive the divided output signal at a sum port of the rat race coupler and to generate the transmission signal at a first port of the rat race coupler; and

the rat race coupler is further configured to receive, from the antenna, the backscattered signal at the first port of the rat race coupler and to produce the backscattered signal at a difference port of the rat race coupler, whereby the difference port is coupled to another one of the input ports of the six-port interferometer.

5. The radar sensor according to claim 4, wherein a central coupling region of the rat race coupler comprises regions having varying values of permittivity.

6. The radar sensor according to any one of claims 1 to 5 wherein the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver is positioned back-to-back with the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver.

7. The radar sensor according to any one of claims 1 to 5 further comprising:

a computing module coupled to the output ports of the six-port interferometers of the first and second CW radar transceivers, the computing module being configured to use the power signals from the first and second CW radar transceivers to compute the relative displacement L between the object and the radar sensor.

8. A method for determining relative displacement *L* between an object and a radar sensor using a first and a second continuous wave (CW) radar transceiver provided within the radar sensor, whereby the method comprises:

generating, by a voltage-controlled oscillator (VCO) provided within each CW radar transceiver, an output signal having a specific frequency;

dividing, by a divider circuit provided within each CW radar transceiver, the output signal from the VCO into a reference signal and a transmission signal;

receiving, by a double periodic composite right/left hand (CRLH) substrate integrated waveguide (SIW) leaky wave antenna provided within each CW radar transceiver, the transmission signal from the divider circuit and transmitting a backward or forward main beam, wherein a direction of the transmitted main beam is determined by the specific frequency of the received transmission signal, and when the main beam is reflected back to the antenna by an object adjacent the sensor, generating, by the CRLH SIW leaky wave antenna, a backscattered signal based on the reflected main beam;

dividing, by the divider circuit, the backscattered signal received from the antenna;

receiving, by input ports of a six-port interferometer provided within each CW radar transceiver, the reference signal and the divided-backscattered signal from the divider circuit, whereby the six-port interferometer generates power signals at output ports of the six-port interferometer based on the received reference and divided-backscattered signals, the power signals being used for computing relative displacement *L* between the object and the radar sensor,

whereby the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver is positioned adjacent the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver and,

whereby the VCOs of the first and second CW radar transceivers are each tuned to generate output signals that each have a different specific frequency such that the main beam of the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver and the main beam of the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver are pointing at a same direction.

9. The method according to claim 8 wherein the six-port interferometer comprises:

a first power divider having an input port coupled to the divider circuit to receive the reference signal;

a first directional coupler having an input port coupled to an output port of the first power divider and two output ports;

a second directional coupler having an input port coupled to the output port of the first power divider and two output ports;

a second power divider having an input port coupled to the divider circuit to receive the divided-backscattered signal, and having an output port that is coupled to an input port of a wideband phase shifter, and another output port that is coupled to another input port of the second directional coupler,

wherein an output port of the wideband phase shifter is coupled to another input port of the first directional coupler.

10. The method according to claim 9 wherein gradient index (GRIN) substrates are provided at coupling regions of the first and second directional couplers.

11. The method according to any one of claims 8 to 10, wherein dividing by the divider circuit comprises:

dividing, by a power divider provided within each CW radar transceiver, the output signal from the VCO equally into the reference signal and a divided output signal, and providing the reference signal to one of the input ports of the six-port interferometer;

receiving, by a rat race coupler provided within each CW radar transceiver, the divided output signal at a sum port of the rat race coupler and generating the transmission signal at a first port of the rat race coupler; and

receiving from the antenna, by the rat race coupler, the backscattered signal at the first port of the rat race coupler and producing the backscattered signal at a difference port of the rat race coupler, whereby the difference port is coupled to another one of the input ports of the six-port interferometer.

12. The method according to claim 11, wherein a central coupling region of the rat race coupler comprises regions having varying values of permittivity.

13. The method according to any one of claims 8 to 12 wherein the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver is positioned back-to-back with the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver.

14. The method according to any one of claims 8 to 13 further comprising:

computing, by a computing module that is provided within each of the first and second CW radar transceivers and that is coupled to the output ports of the six-port interferometer provided within each of the first and second CW radar transceivers, the relative displacement *L* between the object and the radar sensor based on the power signals received from the six-port interferometers of the first and second CW radar transceivers.

CLAIMS:

1. A radar sensor comprising:

a first and a second continuous wave (CW) radar transceiver, whereby each CW radar transceiver comprises:

a voltage-controlled oscillator (VCO) configured to generate an output signal having a specific frequency;

a divider circuit configured to divide the output signal from the VCO into a reference signal and a transmission signal;

a double periodic composite right/left hand (CRLH) substrate integrated waveguide (SIW) leaky wave antenna configured to:

receive the transmission signal from the divider circuit;

transmit a backward or forward main beam, wherein a direction of the transmitted main beam is determined by the specific frequency of the received transmission signal, and when the main beam is reflected back to the antenna by an object adjacent the sensor, the antenna is further configured to generate a backscattered signal based on the reflected main beam;

the divider circuit is further configured to divide the backscattered signal received from the antenna;

a six-port interferometer configured to receive, by input ports of the six-port interferometer, the reference signal and the divided-backscattered signal from the divider circuit, whereby the six-port interferometer is configured to generate, based on the received reference and divided-backscattered signals, power signals at output ports of the six-port interferometer, the power signals being used for computing relative displacement L between the object and the radar sensor,

whereby the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver is positioned adjacent the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver and,

whereby the VCOs of the first and second CW radar transceivers are each tuned to generate output signals that each have a different specific frequency such that a direction of a main beam of the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver and a direction of a main beam of the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver are the same.

2. The radar sensor according to claim 1 wherein each six-port interferometer comprises:

a first power divider having an input port coupled to the divider circuit to receive the reference signal;

a first directional coupler having an input port coupled to an output port of the first power divider and having two output ports;

a second directional coupler having an input port coupled to another output port of the first power divider and having two output ports;

a second power divider having an input port coupled to the divider circuit to receive the divided-backscattered signal, and having an output port coupled to an input port of a wideband phase shifter, and having another output port coupled to another input port of the second directional coupler,

wherein an output port of the wideband phase shifter is coupled to another input port of the first directional coupler.

3. The radar sensor according to claim 2 wherein gradient index (GRIN) substrates are provided at each coupling region of the first and second directional couplers.

4. The radar sensor according to claim 1, wherein each divider circuit comprises:

a power divider configured to divide the output signal from the VCO equally into the reference signal and a divided output signal, and to provide the reference signal to one of the input ports of the six-port interferometer;

a rat race coupler configured to receive the divided output signal at a sum port of the rat race coupler and to generate the transmission signal at a first port of the rat race coupler; and

the rat race coupler is further configured to receive, from the antenna, the backscattered signal at the first port of the rat race coupler and to produce the backscattered signal at a difference port of the rat race coupler, whereby the difference port is coupled to another one of the input ports of the six-port interferometer.

5. The radar sensor according to claim 4, wherein a central coupling region of each rat race coupler comprises regions having varying values of permittivity.

6. The radar sensor according to claim 1 wherein the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver is positioned back-to-back with the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver.

7. The radar sensor according to claim 1 further comprising:

a computing module coupled to the output ports of the six-port interferometers of the first and second CW radar transceivers, the computing module being configured to use the power signals from the first and second CW radar transceivers to compute the relative displacement L between the object and the radar sensor.

8. A method for determining relative displacement L between an object and a radar sensor using a first and a second continuous wave (CW) radar transceiver provided within the radar sensor, whereby the method comprises:

generating, by a voltage-controlled oscillator (VCO) provided within each CW radar transceiver, an output signal having a specific frequency;

dividing, by a divider circuit provided within each CW radar transceiver, the output signal from the VCO into a reference signal and a transmission signal;

receiving, by a double periodic composite right/left hand (CRLH) substrate integrated waveguide (SIW) leaky wave antenna provided within each CW radar transceiver, the transmission signal from the divider circuit and transmitting a backward or forward main beam, wherein a direction of the transmitted main beam is determined by the specific frequency of the received transmission signal, and when the main beam is reflected back to the antenna by an object adjacent the sensor, generating, by each CRLH SIW leaky wave antenna, a backscattered signal based on the reflected main beam;

dividing, by each divider circuit, the backscattered signal received from the antenna;

receiving, by input ports of a six-port interferometer provided within each CW radar transceiver, the reference signal and the divided-backscattered signal from the divider circuit, whereby the six-port interferometer generates power signals at output ports of the six-port interferometer based on the received reference and divided-backscattered signals, the power signals being used for computing relative displacement L between the object and the radar sensor,

whereby the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver is positioned adjacent the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver and,

whereby the VCOs of the first and second CW radar transceivers are each tuned to generate output signals that each have a different specific frequency such that the main beam of the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver and the main beam of the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver are pointing at a same direction.

9. The method according to claim 8 wherein each six-port interferometer comprises:

a first power divider having an input port coupled to the divider circuit to receive the reference signal;

a first directional coupler having an input port coupled to an output port of the first power divider and two output ports;

a second directional coupler having an input port coupled to the output port of the first power divider and two output ports;

a second power divider having an input port coupled to the divider circuit to receive the divided-backscattered signal, and having an output port that is coupled to an input port of a wideband phase shifter, and another output port that is coupled to another input port of the second directional coupler,

wherein an output port of the wideband phase shifter is coupled to another input port of the first directional coupler.

10. The method according to claim 9 wherein gradient index (GRIN) substrates are provided at each coupling region of the first and second directional couplers.

11. The method according to claim 8, wherein dividing by each divider circuit comprises:

dividing, by a power divider provided within each CW radar transceiver, the output signal from the VCO equally into the reference signal and a divided output signal, and providing the reference signal to one of the input ports of the six-port interferometer;

receiving, by a rat race coupler provided within each CW radar transceiver, the divided output signal at a sum port of the rat race coupler and generating the transmission signal at a first port of the rat race coupler; and

receiving from the antenna, by the rat race coupler, the backscattered signal at the first port of the rat race coupler and producing the backscattered signal at a difference port of the rat race coupler, whereby the difference port is coupled to another one of the input ports of the six-port interferometer.

12. The method according to claim 11, wherein a central coupling region of each rat race coupler comprises regions having varying values of permittivity.

13. The method according to claim 8 wherein the double periodic CRLH SIW leaky wave antenna of the first CW radar transceiver is positioned back-to-back with the double periodic CRLH SIW leaky wave antenna of the second CW radar transceiver.

14. The method according to claim 8 further comprising:

computing, by a computing module that is provided within each of the first and second CW radar transceivers and that is coupled to the output ports of the six-port interferometer provided within each of the first and second CW radar transceivers, the relative displacement L between the object and the radar sensor based on the power signals received from the six-port interferometers of the first and second CW radar transceivers.