CLAIMS

1. A method of locating radio-frequency identification (RFID) tags, the method comprising:

receiving, from a first RFID tag at a first unknown location, a plurality of first RFID signals, wherein receiving the plurality of first RFID signals comprises receiving at least one first RFID signal from each of a plurality of angles of arrival;

designating, based on the plurality of first RFID signals, the first RFID tag as a first virtual reference tag;

receiving, from a second RFID tag at a second unknown location, at least one second RFID signal, wherein receiving the at least one second RFID signal comprises receiving the at least one second RFID signal from a first angle of arrival in the plurality of angles of arrival; and

determining, based on the at least one second RFID signal, a position of the second RFID tag with respect to the first virtual reference tag, wherein determining the position of the second RFID tag comprises comparing a signature of the second RFID tag at the first angle of arrival to a signature of the first virtual reference tag at the first angle of arrival.

2. The method of claim 1, wherein designating the first RFID tag as the first virtual reference RFID tag comprises determining that the first RFID tag is stationary.

3. A method of of locating radio-frequency identification (RFID) tags, the method comprising:

receiving, from a first RFID tag at a first unknown location, a plurality of first RFID signals;

designating, based on the plurality of first RFID signals, the first RFID tag as a first virtual reference tag;

receiving, from a second RFID tag at a second unknown location, at least one second RFID signal; and

determining, based on the at least one second RFID signal, a position of the second RFID tag with respect to the first virtual reference tag, wherein determining the position of the second RFID tag comprises:

determining a multipath profile for the second RFID tag, the multipath profile representing RF power received by the plurality of antennas along a LOS path and at least one NLOS path from the second RFID tag to at least one RFID tag reader;

determining a multipath profile for the first virtual reference tag, the multipath profile representing RF power received by the plurality of antennas along a LOS path and at least one NLOS path from the first virtual reference tag to the at least one RFID tag reader; and

comparing the multipath signature of the second RFID tag to the multipath signature of the first virtual reference RFID tag.

4. The method of claim 3, further comprising:

receiving, from a third RFID tag at a third unknown location, a plurality of third RFID signals;

designating, based on the plurality of third RFID signals, the third RFID tag as a second virtual reference tag;

determining a multipath profile for the second virtual reference tag, the multipath profile representing RF power received by the plurality of antennas along a LOS path and at least one NLOS path from the second virtual reference tag to the at least one RFID tag reader; and

determining, based on the at least one second RFID signal, a position of the second RFID tag with respect to the second virtual reference tag based on the multipath profile for the second virtual reference tag.

5. The method of claim 4, further comprising:

determining a first error between the multipath signature of the second RFID tag and the multipath signature of the first virtual reference RFID tag;

determining a second error between the multipath signature of the second RFID tag and the multipath signature of the second virtual reference RFID tag, the second error being larger than the first error;

determining that the second RFID tag is closer to the first virtual reference tag than the second virtual reference tag based on the second error being larger than the first error.

6. The method of claim 4, further comprising:

detecting a change in an RFID signal from the first virtual reference tag;

detecting a change in an RFID signal from the second virtual reference tag;

performing a comparison of the change in the RFID signal from the first virtual reference tag to the change in the RFID signal from the second virtual reference tag; and

determining that the first virtual reference tag and the second virtual reference tag are stationary based on the comparison.

7. The method of claim 1, further comprising:

determining, based on the plurality of first RFID signals, a position of the first virtual reference tag with respect to a reference tag at a known location; and

determining, based on the position of the first virtual reference tag with respect to the reference tag and the position of the second RFID tag with respect to the first virtual reference tag, a position of the second RFID tag with respect to the reference tag.

8. A system for locating radio-frequency identification (RFID) tags, the system comprising:

a plurality of RFID tag readers to receive a plurality of first RFID signals from a first RFID tag at a first unknown location and to receive at least one second RFID signal from a second RFID tag at a second unknown location, wherein the plurality of RFID tag readers is configured to receive at least one first RFID signal in the plurality of first RFID signals from each of a plurality of angles of arrival and to receive the at least one second RFID signal from a first angle of arrival in the plurality of angles of arrival; and

a processor, operably coupled to the plurality of RFID tag readers, to designate the first RFID tag as a first virtual reference tag based on the plurality of first RFID signals and to determine a position of the second RFID tag with respect to the first virtual reference tag based on the at least one second RFID signal, wherein the processor is configured to determine the position of the second RFID tag by comparing a signature of the second RFID tag from the first angle of arrival to a signature of the first virtual reference tag at the first angle of arrival.

9. The system of claim 8, wherein the processor is configured to designate the first RFID tag as the first virtual reference RFID tag in response to determining that the first RFID tag is stationary.

10. A system for locating radio-frequency identification (RFID) tags, the system comprising:

a plurality of RFID tag readers configured to receive a plurality of first RFID signals from a first RFID tag at a first unknown location and to receive at least one second RFID signal from a second RFID tag at a second unknown location; and

a processor operably coupled to the plurality of RFID tag readers and configured to:

determine a multipath profile for the second RFID tag, the multipath profile representing RF power received by the plurality of antennas along a LOS path and at least one NLOS path from the second RFID tag to at least one RFID tag reader;

determine a multipath profile for the first virtual reference tag, the multipath profile representing RF power received by the plurality of antennas along a LOS path and at least one NLOS path from the first virtual reference tag to the at least one RFID tag reader;

compare the multipath signature of the second RFID tag to the multipath signature of the first virtual reference RFID tag; and

determine a position of the second RFID tag with respect to the first virtual reference tag based on comparing the multipath signature of the second RFID tag to the multipath signature of the first virtual reference tag.

11. The system of claim 10, wherein:

the plurality of RFID readers is configured to receive a plurality of third RFID signals from a third RFID tag at a third unknown location, and

the processor is configured to:

designate the third RFID tag as a second virtual reference tag based on the plurality of third RFID signals,

determine a multipath profile for the second virtual reference tag, the multipath profile representing RF power received by the plurality of antennas along a LOS path and at least one NLOS path from the second virtual reference tag to the at least one RFID tag reader; and

determine, based on the at least one second RFID signal, a position of the second RFID tag with respect to the second virtual reference tag based on the multipath profile for the second virtual reference tag.

12. The system of claim 11, wherein the processor is configured to:

determine a first error between the multipath signature of the second RFID tag and the multipath signature of the first virtual reference RFID tag;

determine a second error between the multipath signature of the second RFID tag and the multipath signature of the second virtual reference RFID tag, the second error being larger than the first error; and

determine that the second RFID tag is closer to the first virtual reference tag than the second virtual reference tag based on the second error being larger than the first error.

13. The system of claim 11, wherein the processor is configured to:

detect a change in an RFID signal from the first virtual reference tag;

detect a change in an RFID signal from the second virtual reference tag;

perform a comparison of the change in the RFID signal from the first virtual reference tag to the change in the RFID signal from the second virtual reference tag; and

determine that the first virtual reference tag and the second virtual reference tag are stationary based on the comparison.

14. The system of claim 8, wherein the processor is configured to determine a position of the first virtual reference tag with respect to a reference tag at a known location based on the plurality of first RFID signals and to determine a position of the second RFID tag with respect to the reference tag based on the position of the first virtual reference tag with respect to the reference tag and the position of the second RFID tag with respect to the first virtual reference tag.

15. The method of claim 3, wherein designating the first RFID tag as the first virtual reference RFID tag comprises determining that the first RFID tag is stationary.

16. The method of claim 3, further comprising:

determining, based on the plurality of first RFID signals, a position of the first virtual reference tag with respect to a reference tag at a known location; and

determining, based on the position of the first virtual reference tag with respect to the reference tag and the position of the second RFID tag with respect to the first virtual reference tag, a position of the second RFID tag with respect to the reference tag.

17. The system of claim 11, wherein the processor is further configured to designate the first RFID tag as the first virtual reference RFID tag in response to determining that the first RFID tag is stationary.

18. The system of claim 11, wherein the processor is further configured to determine a position of the first virtual reference tag with respect to a reference tag at a known location based on the plurality of first RFID signals and to determine a position of the second RFID tag with respect to the reference tag based on the position of the first virtual reference tag with respect to the reference tag and the position of the second RFID tag with respect to the first virtual reference tag.