[CLAIMS]

1. A radio wave arrival angle detection device comprising:

a carrier wave decomposition unit configured to decompose, for each of a first carrier wave received by a first antenna and a second carrier wave received by a second antenna, which are carrier waves obtained by multiplexing a plurality of subcarrier waves having different frequencies, a partial signal extracted from a single unit signal among a plurality of unit signals constituting signals transmitted by the first carrier wave and the second carrier wave into a subcarrier wave group composed of a plurality of the subcarrier waves;

an arrival angle calculation unit configured to calculate an arrival angle of the first carrier wave to the first antenna or an arrival angle of the second carrier wave to the second antenna on the basis of a geometric relationship between a phase difference of a first subcarrier wave selected from a first subcarrier wave group obtained by decomposing the first carrier wave by the carrier wave decomposition unit and a second subcarrier wave having the same frequency as the first subcarrier wave, which is selected from a second subcarrier wave group obtained by decomposing the second carrier wave by the carrier wave decomposition unit, and a disposition position of the first antenna and the second antenna;

an intermediate frequency band conversion unit configured to convert a frequency of the carrier wave into an intermediate frequency; and

a sampling unit configured to sample three or more partial signals of a predetermined length from a carrier wave converted by the intermediate frequency band conversion unit

with the elapse of time,

wherein the carrier wave decomposition unit is configured to decompose each of three or more partial signals sampled from the first carrier wave by the sampling unit into a first subcarrier wave group corresponding to each partial signal, and is configured to decompose each of three or more partial signals sampled by the second carrier wave into a second subcarrier wave group corresponding to each partial signal, and

the arrival angle calculation unit is configured to compare arrival angle calculated values calculated using the first subcarrier wave selected from the first subcarrier wave group and the second subcarrier wave having the same frequency as the first subcarrier wave, which is selected from the second subcarrier wave group, in each pair for all pairs of the first subcarrier wave group and the second subcarrier wave group having the same sampling time, and calculates the arrival angle on the basis of a plurality of arrival angle calculated values having differences of the arrival angle calculated values within a predetermined range.

2. The radio wave arrival angle detection device according to Claim 1, further comprising:

a smoothing unit that selects a set of the first sub-carrier wave and the second sub-carrier wave which have the same frequency with respect to a plurality of frequencies, and smooths an arrival angle obtained through calculation by the arrival angle calculation unit for each of the frequencies.

3. The radio wave arrival angle detection device according to any one of Claims 1 to 2, further comprising:

a signal processing unit that calculates the arrival angle of the carrier wave on the basis of signal processing with respect to an amplitude and a phase of the sub-carrier wave included in the carrier wave that is received by a plurality of antenna elements of an array antenna.

4. The radio wave arrival angle detection device according to any one of Claims 1 to 3, further comprising:

a position estimation unit that calculates a transmission position of the carrier wave by using reception time or radio wave intensity of the carrier wave that is received by each of two or greater antennas,

wherein the arrival angle calculation unit calculates the arrival angle by using an arrival angle of the carrier wave based on the transmission position that is represented by a positional relationship between the transmission position and the first antenna or the second antenna.

5. The radio wave arrival angle detection device according to any one of Claims 1 to 4, further comprising:

an angle calculation execution determination unit that determines whether or not to

perform calculation of the arrival angle on the basis of a magnitude of a phase difference or a difference in signal level which is obtained through comparison between a plurality of the sub-carrier waves,

wherein the arrival angle calculation unit performs calculation of an arrival direction only in a case where the angle calculation execution determination unit makes a determination as execution of calculation of the arrival direction.

6. The radio wave arrival angle detection device according to Claim 5,

wherein when the magnitude of the phase difference or the difference in signal level between the first sub-carrier wave and the second sub-carrier wave, which have the same frequency, is greater than a predetermined threshold value, the angle calculation execution determination unit makes a determination as non-execution of calculation of the arrival angle.

7. The radio wave arrival angle detection device according to Claim 5 or 6,

wherein with respect to at least one of the first sub-carrier wave group and the second sub-carrier wave group, the angle calculation execution determination unit compares signal levels between a plurality of sub-carrier waves included in the sub-carrier wave group, and makes a determination as non-execution of calculation of the arrival angle when a magnitude of the difference in signal level is greater than a predetermined threshold value.

8. A vehicle detection system, comprising:

the radio wave arrival angle detection device according to any one of Claims 1 to 7; and

an erroneous detection prevention device,

wherein the erroneous detection prevention device includes an erroneous detection determination unit that determines whether or not the arrival angle calculated by the radio wave arrival angle detection device is included in a predetermined angle range corresponding to a position at which a vehicle to be detected exists.

9. A vehicle detection system comprising:

a radio wave arrival angle detection device which includes a carrier wave decomposition unit configured to decompose, for each of a first carrier wave received by a first antenna and a second carrier wave received by a second antenna, which are carrier waves obtained by multiplexing a plurality of subcarrier waves having different frequencies, a partial signal extracted from a single unit signal among a plurality of unit signals constituting a signal transmitted by the first carrier wave and the second carrier wave into a subcarrier wave group composed of the plurality of subcarrier waves, and

an arrival angle calculation unit configured to calculate an arrival angle of the first carrier wave to the first antenna or an arrival angle of the second carrier wave to the second antenna on the basis of a geometric relationship between a phase difference of a first

subcarrier wave selected from a first subcarrier wave group obtained by decomposing the first carrier wave by the carrier wave decomposition unit and a second subcarrier wave having the same frequency as the first subcarrier wave, which is selected from a second subcarrier wave group obtained by decomposing the second carrier wave by the carrier wave decomposition unit, and a disposition position of the first antenna and the second antenna;

a false detection prevention device which includes a false detection determination unit configured to determine whether an arrival angle calculated by the radio wave arrival angle detection device is included in a range of a predetermined angle corresponding to a position at which a vehicle is present; and

a third antenna and a fourth antenna disposed to be above and below with respect to ground in a vertical direction and a fifth antenna disposed to be parallel to the fourth antenna with respect to the ground in a horizontal direction, which are antennas that communicate with a vehicle-mounted device mounted on a vehicle and are provided above a lane along which the vehicle travels,

wherein the radio wave arrival angle detection device calculates an arrival angle of the second carrier wave to the second antenna when the third antenna is set as the first antenna and the fourth antenna is set as the second antenna, and calculates an arrival angle of the second carrier wave to the second antenna when the fifth antenna is set as the first antenna and the fourth antenna is set as the second antenna.

10. A radio wave arrival angle detection method comprising:

a step of decomposing, for each of a first carrier wave received by a first antenna and a second carrier wave received by a second antenna, which are carrier waves obtained by multiplexing a plurality of subcarrier waves having different frequencies, a partial signal extracted from a single unit signal among a plurality of unit signals constituting signals transmitted by the first carrier wave and the second carrier wave into a subcarrier wave group composed of a plurality of the subcarrier waves;

a step of calculating an arrival angle of the first carrier wave to the first antenna or an arrival angle of the second carrier wave to the second antenna on the basis of a geometric relationship between a phase difference of a first subcarrier wave selected from a first subcarrier wave group obtained by decomposing the first carrier wave and a second subcarrier wave having the same frequency as the first subcarrier wave, which is selected from a second subcarrier wave group obtained by decomposing the second carrier wave, and a disposition position of the first antenna and the second antenna; and

a step of converting a frequency of the carrier wave into an intermediate frequency and sampling three or more partial signals of a predetermined length from this converted carrier wave with an elapse of time,

wherein each of three or more partial signals sampled from the first carrier wave in the step of sampling three or more partial signals along an elapse of time is decomposed into a first subcarrier wave group corresponding to each partial signal, and each of three or more

partial signals sampled from the second carrier wave in the step of sampling three or more partial signals along an elapse of time is decomposed into a second subcarrier wave group corresponding to each partial signal in the step of decomposing an extracted partial signal into a subcarrier wave group, and

arrival angle calculated values calculated using the first subcarrier wave selected from the first subcarrier wave group and the second subcarrier wave having the same frequency as the first subcarrier wave, which is selected from the second subcarrier wave group, in each pair are compared for all pairs of the first subcarrier wave group and the second subcarrier wave group having the same sampling time, and the arrival angle is calculated on the basis of a plurality of arrival angle calculated values having differences of the arrival angle calculated values within a predetermined range in the step of calculating an arrival angle.

11. A vehicle false detection prevention method comprising:

calculating an arrival angle according to the radio wave arrival angle detection method described in claim 10; and

determining whether the calculated arrival angle is included in a range of a predetermined angle corresponding to a position at which a vehicle to be detected is present.