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(54) Title: A VEHICLE RADAR SYSTEM WITH TWO TRANSCEIVER ARRANGEMENTS

(57) Abstract: The present invention relates to a vehicle radar system (3) comprising a first and second transceiver arrangement (10a, b) which are arranged to generate FMCW chirp signals. Each transceiver arrangement (10a, 10b) comprises a respective first and second oscillator (23a, 23b) that is arranged to transmit respective first and second chirp signal (4a, 4b). The transceiver arrangements (10a, 10b) are arranged to mix received signals (5a, 5b) with the respective transmitted chirp signal (4a, 4b) to obtain a respective first and second IF signal (14a, 14b) that is filtered with a certain filter bandwidth (B_f). The chirp signals (4a, 4b) comprise at least one cycle of a respective first and second plurality of frequency ramps (r, r_2). A plurality of frequency ramps in the second plurality of frequency ramps (r_2) are delayed with corresponding added times (t_a) such that at least one frequency ramp in the first plurality of frequency ramps and at least one frequency ramp in the second plurality of frequency ramps run such that the difference in frequency between them is within the filter bandwidth (B_f). The present invention also relates to a corresponding method.

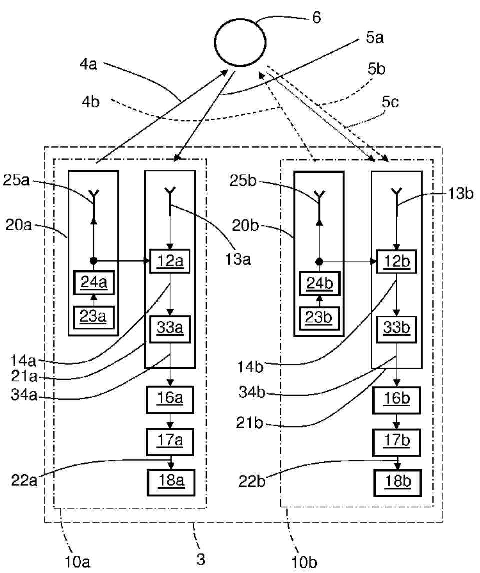

FIG. 2

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TITLE

A vehicle radar system with two transceiver arrangements

DESCRIPTION OF THE INVENTION

The present invention relates to a vehicle radar system comprising a first transceiver arrangement and a second transceiver arrangement. Each transceiver arrangement is arranged for generating FMCW (Frequency Modulated Continuous Wave) chirp signals, where the first transceiver arrangement comprises a first oscillator and is arranged to transmit a first chirp signal, and where the second transceiver arrangement comprises a second oscillator and is arranged to transmit a second chirp signal. The transceiver arrangements are arranged to receive reflected signals, mix the received signals with the respective transmitted chirp signal to obtain a respective first IF (Intermediate Frequency) signal and second IF signal, and to filter said IF signals with a certain filter bandwidth. The first chirp signal comprises at least one cycle of a first plurality of frequency ramps, and the second chirp signal comprises at least one cycle of a second plurality of frequency ramps.

The present invention also relates to a method for a vehicle radar system, where the method comprises:

- Generating FMCW (Frequency Modulated Continuous Wave) chirp signals.
- Transmitting a first chirp signal via a first transceiver arrangement, the first chirp signal having at least one cycle of a first plurality of frequency ramps.
- Transmitting a second chirp signal via a second transceiver arrangement, the second chirp signal having at least one cycle of a second plurality of frequency ramps.

- Receiving reflected signals via said transceiver arrangements.
- Mixing the received signals with the respective transmitted chirp signal to obtain a respective first IF (Intermediate Frequency) signal and second IF signal.
- Filtering said IF signals using a certain filter bandwidth.

Many vehicle radar systems comprise means for generating so-called chirp signals that are transmitted, reflected and received by means of appropriate antennas comprised in the radar system. A chirp signal is an FMCW (Frequency Modulated Continuous Wave) signal with a certain amplitude where the frequency is continuously ramped between two values, the chirp signal thus being in the form of a continuous sinusoid where the frequency varies from a first low frequency to a second high frequency over the course of the ramp. The change in frequency from start to finish may for example be of the order of 0.5% of the starting frequency.

The received signals, thus constituted by reflected radar echoes, are mixed with the transmitted chirp signal in order to convert the received signals to baseband signals. These baseband signals, or IF (Intermediate Frequency) signals, are amplified and transferred in a plurality of channels to an Analog Digital Converter (ADC) arrangement which is arranged to convert the received analog signals to digital signals. The digital signals are used for retrieving an azimuth angle of possible targets by simultaneously sampling and analyzing phase and amplitude of the received signals. The analysis is generally performed in one or more Digital Signal Processors (DSP:s) by means of Fast Fourier Transform (FFT) processing.

When a vehicle comprises two radar transceivers with an overlapping field of view, for example two radar transceivers located at the front corners of a vehicle, a transmitted signal from one radar transceiver is reflected at an object and is received by the other radar transceiver. Depending on the receiving timings, this may cause erroneous detections, which in turn may cause problems when the detections are used to control safety devices in the vehicle, such as for example automatic braking systems.

Especially when two FMCW ramps are transmitted at roughly the same time at the two radar transceivers, the risk of such erroneous detections increases, and it is thus desired to keep the ramps of the two radar transceivers separated in time. This may for example be done by means of randomized starting times for each cycle of corresponding ramps of the two radar transceivers.

US 2013/0257643 discloses a first radar apparatus that transmits triangular FMCW waveforms with a first predetermined interval interposed therebetween. Similarly, a second radar apparatus transmits triangular FMCW waveforms with a second predetermined interval interposed therebetween. The predetermined intervals are different from each other, with the intention to avoid that two waveforms are transmitted at roughly the same time.

Each radar transceiver comprises its own oscillator, each radar transceiver has its own frequency reference such as an oscillator crystal. Such crystals have small deviations from crystal to crystal due to structural differences and temperature differences. This may in turn lead to that during a cycle the FMCW ramps sequences of the radar transceivers may be mutually displaced during each cycle, which may result in that one cycle may comprise a plurality of ramps that are transmitted at roughly the same time.

The object of the present invention is thus to provide a vehicle radar system which is arranged for a decreased number of erroneous detections.

This object is obtained by means of a vehicle radar system comprising a first transceiver arrangement and a second transceiver arrangement. Each transceiver arrangement is arranged for generating FMCW (Frequency Modulated Continuous Wave) chirp signals, where the first transceiver arrangement comprises a first oscillator and is arranged to transmit a first chirp signal, and where the second transceiver arrangement comprises a second oscillator and is arranged to transmit a second chirp signal. The transceiver arrangements are arranged to receive reflected signals, mix the received signals with the respective transmitted chirp signal to obtain a respective first IF (Intermediate Frequency) signal and second IF signal, and to filter said IF signals with a certain filter bandwidth. The first chirp signal comprises at least one cycle of a first plurality of frequency ramps, and the second chirp signal comprises at least one cycle of a second plurality of frequency ramps. A plurality of frequency ramps in the second plurality of frequency ramps are delayed with corresponding added times such that at least one frequency ramp in the first plurality of frequency ramps and at least one frequency ramp in the second plurality of frequency ramps run such that the difference in frequency between them is within the filter bandwidth.

This object is also obtained by means of a method for a vehicle radar system, where the method comprises:

- Generating FMCW (Frequency Modulated Continuous Wave) chirp signals.
- Transmitting a first chirp signal via a first transceiver arrangement, the first chirp signal having at least one cycle of a first plurality of frequency ramps.
- Transmitting a second chirp signal via a second transceiver arrangement, the second chirp signal having at least one cycle of a second plurality of frequency ramps.
- Receiving reflected signals via said transceiver arrangements.
- Mixing the received signals with the respective transmitted chirp signal to obtain a respective first IF (Intermediate Frequency) signal and second IF signal.
- Filtering said IF signals using a certain filter bandwidth.
- Delaying a plurality of frequency ramps in the second plurality of frequency ramps with corresponding added times such that at least one frequency ramp in the first plurality of frequency ramps and at least one frequency ramp in the second plurality of frequency ramps run such that the difference in frequency between them is within the filter bandwidth.

According to an example, each second frequency ramp in the second plurality of frequency ramps is delayed. Alternatively, every frequency ramp in the second plurality of frequency ramps is delayed.

According to another example, one frequency ramp in the first plurality of frequency ramps and one frequency ramp in the second plurality of frequency ramps run at the same time within a margin of 1% during each cycle.

According to another example, the radar system is arranged to:

- process all ramps in a cycle by means of a first FFT, Fast Fourier Transform, to acquire target information at different ranges in a plurality of complex vectors that corresponds to the number of ramps in a cycle;
- analyze one vector element at a time for all complex vectors by means of a second FFT and then create a two-dimensional matrix in the Doppler domain comprising data regarding range and relative speed; and to
- identify erroneous detections and delete these from further processing.

Alternatively, the radar system is arranged to:

- process all ramps in a cycle individually using a first FFT, Fast Fourier Transform, to acquire target information at different ranges;
- monitor each ramp for interference signals that are determined to result from erroneous detections; and to
- remove those frequencies the ramp in question or alternatively remove the complete ramp.

Other examples are disclosed in the dependent claims.

A number of advantages are obtained by means of the present invention. Mainly, the risk of erroneous detections is reduced compared to prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described more in detail with reference to the appended drawings, where:

Figure 1 shows a schematic top view of a vehicle;

Figure 2 shows a simplified schematic of a vehicle radar system;

Figure 3a shows a first chirp signal;

Figure 3b shows a second chirp signal;

Figure 4a shows a first filtered IF signal;

Figure 4b shows a second filtered IF signal; and

Figure 5 shows a flowchart for a method according to the present invention.

DETAILED DESCRIPTION

Figure 1 schematically shows a top view of a vehicle 1 arranged to run on a road 2 in a direction D, where the vehicle 1 comprises a vehicle radar system 3 which is arranged to distinguish and/or resolve single targets from the surroundings by transmitting signals 4 and receiving reflected signals 5a, 5b and using a Doppler effect in a previously well-known manner. The vehicle radar system 3 is arranged to provide azimuth angles of possible objects 6 by simultaneously sampling and analyzing phase and amplitude of the received signals 5a, 5b.

With reference also to Figure 2, the vehicle radar system 3 comprises a first transceiver arrangement 10a and a second transceiver arrangement 10b, each transceiver arrangement 10a, 10b being arranged for generating sweep signals in the form of FMCW, Frequency Modulated Continuous Wave, chirp signals of a previously known kind. The first transceiver arrangement 10a comprises a first transmitter 20a, a first receiver 21a, a first Analog to Digital Converter (ADC) arrangement 16a, a first sampling and timing arrangement 17a and a first DSP (Digital Signal Processor) arrangement 18a. The second transceiver arrangement 10b comprises a second transmitter 20b, a second receiver 21b, a second ADC arrangement 16b, a second sampling and timing arrangement 17b and a second DSP arrangement 18b.

The first transmitter 20a comprises a first oscillator 23a, a first signal generator 24a and a first transmit antenna arrangement 25a. The second transmitter 20b comprises a second oscillator 23b, a second signal generator 24b and a second transmit antenna arrangement 25b.

The first receiver 21a comprises a first receiver mixer 12a and a first receiver antenna arrangement 13a. The second receiver 21b comprises a second receiver mixer 12b and a second receiver antenna arrangement 13b.

With reference also to Figure 3a and Figure 3b, the first transmitter 20a is arranged to transmit a first chirp signal 4a and the second transmitter 20b is arranged to transmit a second chirp signal 4b. The receivers 21a, 21b are arranged to receive reflected signals 5a, 5b, where the transmitted chirp signals 4a, 4b have been reflected by an object 6 as will be discussed more in detail below.

A chirp signal 4a, 4b is in the form of a continuous sinusoid where the frequency varies from a first frequency f_{start} to a second frequency f_{stop} over the course of a ramp, where the magnitude of the first frequency f_{start} falls below the magnitude of the second frequency f_{stop}. The change in frequency from start to finish for each ramp may for example be of the order of 0.5% of the first frequency f_{start}.

As shown in Figure 3a, the first chirp signal 4a comprises repeating cycles of a first plurality of frequency ramps r_1 and as shown in Figure 3b, the second chirp signal 4b comprises repeating cycles of a second plurality of frequency ramps r_2. As mentioned above, the frequency varies from a first frequency f_{start} to a second frequency f_{stop} over the course of each ramp r_1, r_2, where the magnitude of the first frequency f_{start} falls below the magnitude of the second frequency f_{stop}.

A cycle for the first chirp signal 4a lasts for a certain first cycle time t_{c1} and a cycle for the second chirp signal 4b lasts for a certain second cycle time t_{c2}. Each ramp lasts a certain ramp time t_r, the ramp time t_r being the same for the first chirp signal 4a and the second chirp signal 4b. The first chirp signal 4a has a first ramp period time t_{T1} and the second chirp signal 4b has a second ramp period time t_{T2}, the ramp period times t_{T1}, t_{T2} being the respective time between the starting of two consecutive ramps. Between two consecutive ramps of the first chirp signal 4a there is a first delay time t_{D1}, and between two consecutive ramps of the second chirp signal 4b there is a second delay time t_{D2}.

Referring back to Figure 2, a first transmitted signal 4a, indicated with a solid line, and a second transmitted signal 4b, indicated with a dashed line, are reflected at the object 6. The first transmitted signal 4a results in a first reflected signal 5a, indicated with a solid line, where the first reflected signal 5a is received by the first receiver 21a via the first antenna arrangement 13a. The second transmitted signal 4b results in a second reflected signal 5b, indicated with a dashed line, where the second reflected signal 5b is received by the first receiver 21b via a the second antenna arrangement 13b. The received signals 5a, 5b, thus constituted by reflected radar echoes, are mixed. In the first receiver 21a, the first received signal 5a is mixed with the first chirp signal 4a in the first receiver mixer 12a, and in the second receiver, the second received signal 5b is mixed with the first chirp signal 4a in second receiver mixer 12b.

In this way, a corresponding first IF (Intermediate Frequency) signal 14a and second IF signal 14b is acquired and filtered in a corresponding first IF filter 33a and second IF filter 33b such that a first filtered IF signal 34a and a second filtered IF signal 34b is acquired, as also shown in Figure 4a and Figure 4b. Figure 4a shows an example of the first filtered IF signal 34a, and Figure 4b shows an example of the second filtered IF signal 34b, where the filtered IF signals 34a, 34b may differ from each other more or less. Figure 4a and Figure 4b show an example of a scenario where there are no targets in the environment, such that the received signal at a certain transceiver arrangement 10a, 10b only comes from the other transceiver arrangement 10a, 10b.

The difference frequency of the filtered IF signals 34a, 34b relates to the target distance. The filtered IF signals 34a, 34b are transferred from the corresponding receiver 21a, 21b to the corresponding ADC arrangements 16a, 16b and sampling and timing arrangements 17a, 17b, where the respective IF signals 14a, 14b are sampled at a certain predetermined sampling frequency and converted to digital signals 22a, 22b. Each DSP arrangement 18a, 18b is adapted for radar signal processing of the digital signals 22a, 22b by means of a first FFT (Fast Fourier Transform) to convert the digital signals 22a, 22b to a range domain, and a second FFT to combine the results from successive chirp signal ramps into the Doppler domain in a previously known manner.

With reference to Figure 2, Figure 4a and Figure 4b, the first IF filter 33a and the second IF filter 33b are filters of a kind that have a relatively high degree of rejection of signals having frequencies exceeding a common filter bandwidth B_f; in this example 8 MHz. The filters 33a, 33b may be low-pass filters that have a respective pass band between DC, 0 MHz, and a corresponding upper frequency f_{high}, here then between about 0 – 8 MHz.

As shown in Figure 1 and Figure 2, the first transmitted signal 4a also results in a third reflected signal 5c, indicated with a dotted line, where the third reflected signal 5c is received by the second receiver 21b via the second antenna arrangement 13b. This third reflected signal 5c may cause erroneous detections which should be avoided. Although not shown, the second transmitted signal 4b may also result in reflected signals that are received by the first receiver 21a via the first antenna arrangement 13a. Such signals may also cause erroneous detections.

According to the present invention, each frequency ramp in the second plurality of frequency ramps is delayed with a certain time such that at only one frequency ramp in the first plurality of frequency ramps and only one frequency ramp in the second plurality of frequency ramps run at the same time within a margin of 1% during each cycle. In other words, the second delay time t_{D2} exceeds the first delay time t_{D1}, and the second ramp period time t_{T2} exceeds the first ramp period time t_{T1}. In this example, the second delay time t_{D2} exceeds the first delay time t_{D1} with a certain additional time t_a i.e., $t_{D2} = t_{D1}+t_a$. The additional time t_a may be fixed for a particular transceiver arrangement 10a, 10b, or may be varied from cycle to cycle.

More generally, a plurality of frequency ramps in the second plurality of frequency ramps r_2 are delayed with corresponding added times t_a such that at least one frequency ramp in the first plurality of frequency ramps and one frequency ramp in the second plurality of frequency ramps will run such that the difference in frequency between them is within the filter bandwidth B_f. For example, this may lead to the situation that these frequency ramps run at the same time within a margin of 1% during each cycle as indicated above.

In this example, with reference to Figure 3a, the measurement time for the first cycle t_{c1} is 23.55 ms, and contains 256 ramps, each having a ramp time t_r of 82 µs with a first delay time t_{D1} of 10 µs between each ramp r1. The rest of the time before the next cycle can be used only for signal processing with the RF MMICs powered off to save power. With reference to Figure 3b, the second cycle time t_{c2} is 23.6 ms, and contains 256 ramps each having a ramp time t_r of 82 µs with a second delay time t_{D2} of 10.2 µs between each ramp.

In this way the ramps r_2 of the second chirp signal 4b are slid past the ramps r_1 of the first chirp signal 4a during a cycle such that only one frequency ramp in the first plurality of frequency ramps r_1 and the second plurality of frequency ramps r_2 run at the same time according to the above. Since it is known that only one ramp will experience this for each chirp signal, it is possible to reject the resulting erroneous detection.

To remove the false detections, two examples of possible approaches follow below.

All ramps in a cycle may be processed using the first FFT to acquire target information for the targets at different ranges. This results in a number of complex vectors, which number corresponds to the number of ramps in a cycle; in this example 256. For all complex vectors, one vector element at a time is analyzed by means of the second FFT, then creating a two-dimensional matrix in the Doppler domain comprising data regarding range and relative speed. In other words, first the first vector elements of all vectors are analyzed by means of the second FFT, then the second vector elements of all vectors, and so on. In the two-dimensional Doppler domain matrix, one would normally look for local peaks since a target will appear as a peak at a distinct range and at a distinct Doppler. A false target resulting from an erroneous detection, which is present in only one ramp according to the above, will appear at a distinct range, but would be spread and can thus be identified and deleted from further processing.

Alternatively, all ramps in a cycle may be processed individually using the first FFT to acquire target information for the targets at different ranges. Each ramp is monitored for interference signals that are determined to result from erroneous detections, and then those frequencies are deleted from the ramp in question; alternatively the complete ramp is deleted. The second FFT may then be used in the intended manner, supposedly without interference due to erroneous detection.

With reference to Figure 5, the present invention also relates to a method for a vehicle radar system 3, 3’, where the method comprises:

26: Generating FMCW (Frequency Modulated Continuous Wave) chirp signals.

27: Transmitting a first chirp signal 4a via a first transceiver arrangement 10a, where the first chirp signal 4a has at least one cycle of a first plurality of frequency ramps r_1.

28: Transmitting a second chirp signal 4b via a second transceiver arrangement 10b, where the second chirp signal 4b has at least one cycle of a second plurality of frequency ramps r_2.

29: receiving reflected signals 5a, 5b via said transceiver arrangements 10a, 10b.

30: Mixing the received signals 5a, 5b with the respective transmitted chirp signal 4a, 4b to obtain a respective first IF (Intermediate Frequency), signal 14a and second IF signal 14b.

31: Filtering said IF signals 14a, 14b using a certain filter bandwidth B_f.

32: Delaying a plurality of frequency ramps in the second plurality of frequency ramps r_2 with corresponding added times t_a such that at least one frequency ramp in the first plurality of frequency ramps and at least one frequency ramp in the second plurality of frequency ramps run such that the difference in frequency between them is within the filter bandwidth B_f.

As indicated in Figure 1, the vehicle 1 comprises a safety control unit 35 and safety means 36, for example an emergency braking system and/or an alarm signal device. The safety control unit 36 is arranged to control the safety means 36 in dependence of input from the radar system 3.

The present invention is not limited to the examples above, but may vary freely within the scope of the appended claims. For example, the ramp time t_r does not have to be the same for the first chirp signal 4a and the second chirp signal 4b; instead the ramp times could be adjusted such that the cycle time is the same for the first chirp signal 4a and the second chirp signal 4b.

Furthermore, the second delay time t_{D2} may exceed the first delay time t_{D1} with an additional time that may alter; for example every second additional time may be 0.5 µs and every other second additional time may be 0 µs. This may for example be the case where each transmitting antenna arrangement comprises two spatially separated transmitting antennas, the chirp signals comprises two consecutive ramps from one transmitting antenna at a time. The additional time of 0.5 µs is then added after a series of two transmitted ramps, one of each antenna. All times mentioned are of course only mentioned by way of example, any suitable times and timing schedules are clearly possible in a radar system according to the above.

At least a plurality of frequency ramps in the second plurality of frequency ramps r_2 are delayed with corresponding times during a cycle.

The radar system may be implemented in any type of vehicle such as cars, trucks and buses as well as boats and aircraft.

The schematics of vehicle radar systems are simplified, only showing parts that are considered relevant for an adequate description of the present invention. It is understood that the general design of radar systems of this kind is well-known in the art. For example, no devices that are arranged to use the acquired target information is shown, but many different such devices are of course conceivable; for example a warning and/or collision avoidance system.

The number of antenna arrangements, antennas within each antenna arrangement and IF signals may vary.

The ADC arrangement and the DSP arrangement should each one be interpreted as having a corresponding ADC or DSP functionality, and may each be constituted by a plurality of separate components. Alternatively, each ADC arrangement may be comprised in one ADC chip, and each DSP arrangement may be comprised in one DSP chip.

Each antenna arrangement 13a, 13b; 25a, 25b may for example comprise on or more antennas, and each antenna may be constituted by one antenna element or by an array of antenna elements.

The additional time should be added in such a way that when the corresponding pluralities of frequency ramps r_1, r_2 in the chirp signals 4a, 4b overlap, at least one frequency ramp in the first plurality of frequency ramps r1 and at least one frequency ramp in the second plurality of frequency ramps r2 run at the same time within a margin of 1%, during each cycle.

In the example shown, there has only been one receiver channel. Of course, a receiver in this context may be arranged for a plurality of channels.

Generally, the hardware used to generate the radar signal may be active only for part of the cycle period and powered down for the rest of the cycle, i.e. when it is not needed.

The first delay time t_{D1} may be changed every N cycles, where N is an integer. The first delay time t_{D1} is previously known or shared by all transceiver arrangements 10a, 10b within the same vehicle 1. This may reduce possible interference by a similar radar system in a nearby vehicle. If all radar sensors used the same value for the first delay time t_{D1}, external radars may be synchronous to within 1% of the victim radar for all ramps, resulting in undesired interference. Varying the first delay time t_{D1} according to the above would reduce such interference. When t_{D1} is changed, t_a and hence t_{D2} may also vary.

The filter bandwidth B_f may comprise the effect of digital filters (not shown) in the respective transceiver arrangement 10a, 10b.

CLAIMS

1. A vehicle radar system (3) comprising a first transceiver arrangement (10a) and a second transceiver arrangement (10b), each transceiver arrangement (10a, 10b) being arranged for generating FMCW, Frequency Modulated Continuous Wave, chirp signals, where the first transceiver arrangement (10a) comprises a first oscillator (23a) and is arranged to transmit a first chirp signal (4a) and where the second transceiver arrangement (10b) comprises a second oscillator (23b) and is arranged to transmit a second chirp signal (4b), where the transceiver arrangements (10a, 10b) are arranged to:

receive reflected signals (5a, 5b);

mix the received signals (5a, 5b) with the respective transmitted chirp signal (4a, 4b) to obtain a respective first IF, Intermediate Frequency, signal (14a) and second IF signal (14b); and to

filter said IF signals (14a, 14b) with a certain filter bandwidth (B_f);

where the first chirp signal (4a) comprises at least one cycle of a first plurality of frequency ramps (r_1) and the second chirp signal (4b) comprises at least one cycle of a second plurality of frequency ramps (r_2) **characterized in** that a plurality of frequency ramps in the second plurality of frequency ramps (r_2) are delayed with corresponding added times (t_a) such that at least one frequency ramp in the first plurality of frequency ramps and at least one frequency ramp in the second plurality of frequency ramps run such that the difference in frequency between them is within the filter bandwidth (B_f).

2. A vehicle radar system (3) according to claim 1, **characterized in** that each second frequency ramp in the second plurality of frequency ramps (r_2) is delayed.

3. A vehicle radar system (3) according to claim 1, **characterized in** that every frequency ramp in the second plurality of frequency ramps (r_2) is delayed.

4. A vehicle radar system (3) according to any one of the preceding claims, **characterized in** that one frequency ramp in the first plurality of frequency ramps (r_1) and one frequency ramp (r_2) in the second plurality of frequency ramps run at the same time within a margin of 1% during each cycle.

5. A vehicle radar system (3) according to any one of the preceding claims, **characterized in** that the radar system (3) is arranged to provide input to a safety control unit (35) that in turn is arranged to control safety means (36), where the radar system (3), the safety control unit (35) and the safety means (36) are comprised in a vehicle (1).

6. A vehicle radar system (3) according to any one of the preceding claims, **characterized in** that the radar system (3) is arranged to:

- process all ramps in a cycle by means of a first FFT, Fast Fourier Transform, to acquire target information at different ranges in a plurality of complex vectors that corresponds to the number of ramps in a cycle;
- analyze one vector element at a time for all complex vectors by means of a second FFT and then create a two-dimensional matrix in the Doppler domain comprising data regarding range and relative speed; and to
- identify erroneous detections and delete these from further processing.

7. A vehicle radar system (3) according to any one of the claims 1-5, **characterized in** that the radar system (3) is arranged to:

- process all ramps in a cycle individually using a first FFT, Fast Fourier Transform, to acquire target information at different ranges;
- monitor each ramp for interference signals that are determined to result from erroneous detections; and to
- remove those frequencies the ramp in question or alternatively remove the complete ramp.

8. A method for a vehicle radar system (3), where the method comprises:

(26) generating FMCW, Frequency Modulated Continuous Wave, chirp signals;

(27) transmitting a first chirp signal (4a) via a first transceiver arrangement (10a), the first chirp signal (4a) having at least one cycle of a first plurality of frequency ramps (r_1);

(28) transmitting a second chirp signal (4b) via a second transceiver arrangement (10b), the second chirp signal (4b) having at least one cycle of a second plurality of frequency ramps (r_2);

(29) receiving reflected signals (5a, 5b) via said transceiver arrangements (10a, 10b);

(30) mixing the received signals (5a, 5b) with the respective transmitted chirp signal (4a, 4b) to obtain a respective first IF, Intermediate Frequency, signal (14a) and second IF signal (14b); and

(31) filtering said IF signals (14a, 14b) using a certain filter bandwidth (B_f);

characterized in that the method further comprises:

(32) delaying a plurality of frequency ramps in the second plurality of frequency ramps (r_2) with corresponding added times (t_a) such that at least one frequency ramp in the first plurality of frequency ramps and at least one frequency ramp in the second plurality of frequency ramps run such that the difference in frequency between them is within the filter bandwidth (B_f).

9. A method according to claim 8, **characterized in** that each second frequency ramp in the second plurality of frequency ramps (r_2) is delayed.

10. A method according to claim 8, **characterized in** that every frequency ramp in the second plurality of frequency ramps (r_2) is delayed.

11. A method according to any one of the claims 8-10, **characterized in** that one frequency ramp in the first plurality of frequency ramps (r_1) and one frequency ramp (r_2) in the second plurality of frequency ramps run at the same time within a margin of 1% during each cycle.

12. A method according to any one of the claims 8-11, **characterized in** that the method comprises:

- processing all ramps in a cycle by means of a first FFT, Fast Fourier Transform, to acquire target information at different ranges in a plurality of complex vectors that corresponds to the number of ramps in a cycle;
- analyzing one vector element at a time for all complex vectors by means of a second FFT and then creating a two-dimensional matrix in the Doppler domain comprising data regarding range and relative speed; and
- identifying erroneous detections and deleting these from further processing.

13. A method according to any one of the claims 8-11, **characterized in** that the method comprises:

- processing all ramps in a cycle individually using a first FFT, Fast Fourier Transform, to acquire target information at different ranges;
- monitoring each ramp for interference signals that are determined to result from erroneous detections; and to
- deleting those frequencies from the ramp in question or alternatively deleting the complete ramp.

14. A method according to any one of the claims 8-13, **characterized in** that the hardware used to generate the radar signal is only active for part of the cycle period and powered down for the rest of the cycle.

15. A method according to any one of the claims 8-14, **characterized in** that the first delay time t_{D1} is changed every N cycles, where N is an integer.

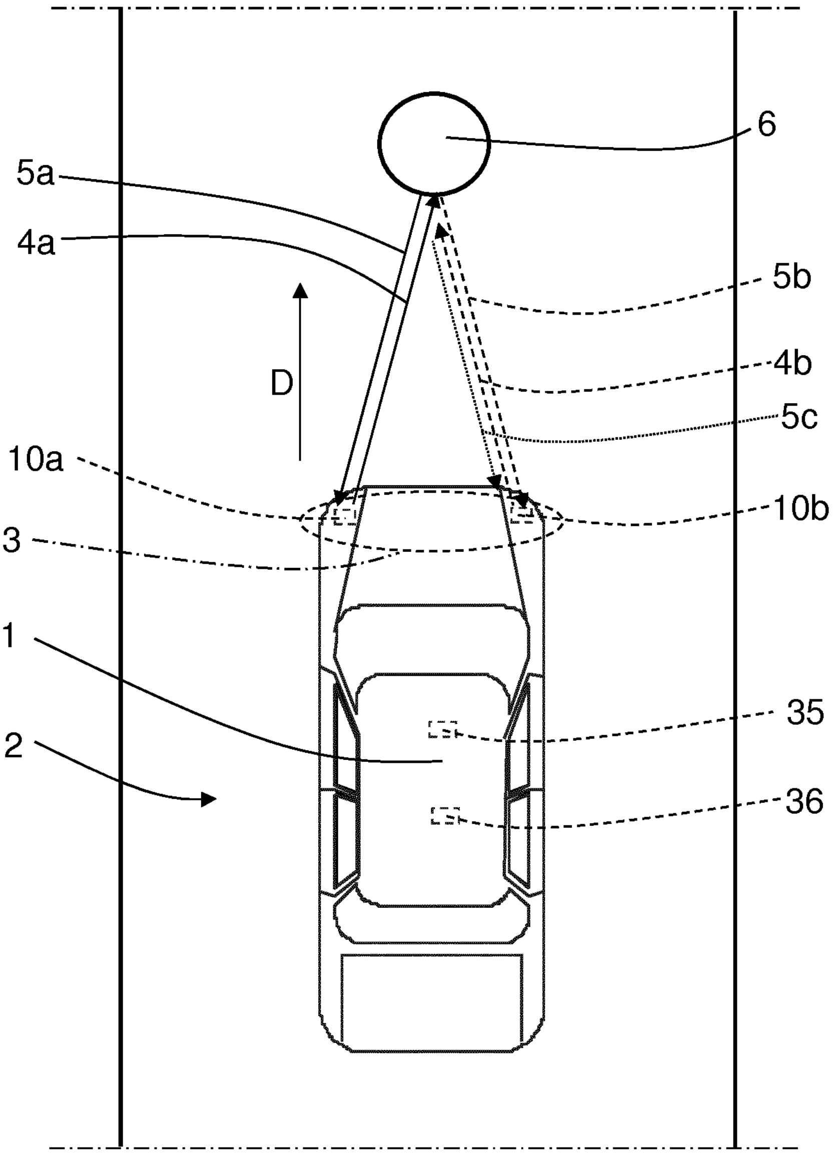

FIG. 1

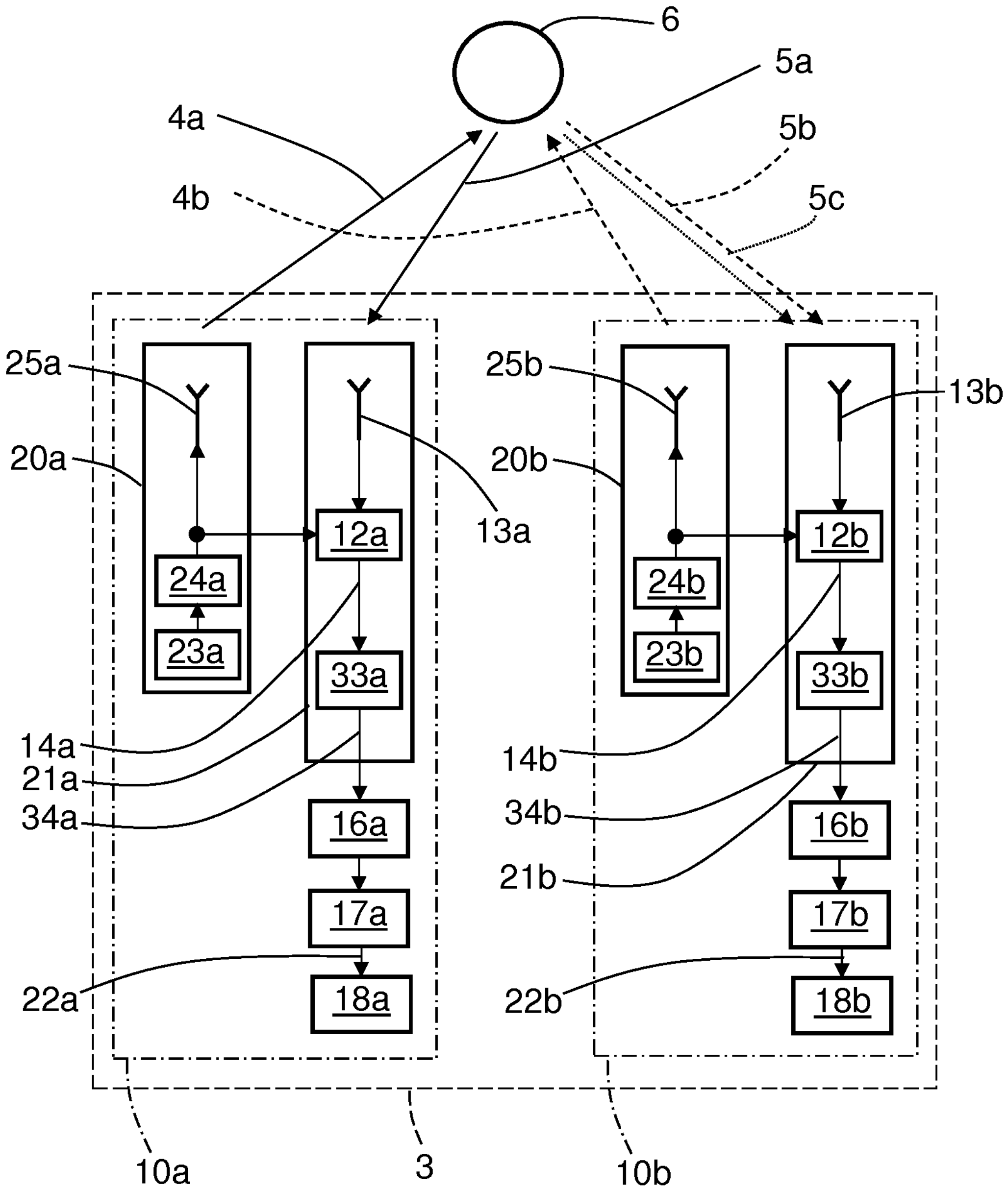
6
5a
4a
5b
4b
5c
25a
20a
13a
12a
24a
23a
33a
14a
21a
34a
16a
17a
22a
18a
25b
13b
20b
12b
24b
23b
33b
14b
34b
16b
21b
17b
22b
18b
10a
3
10b

FIG. 2

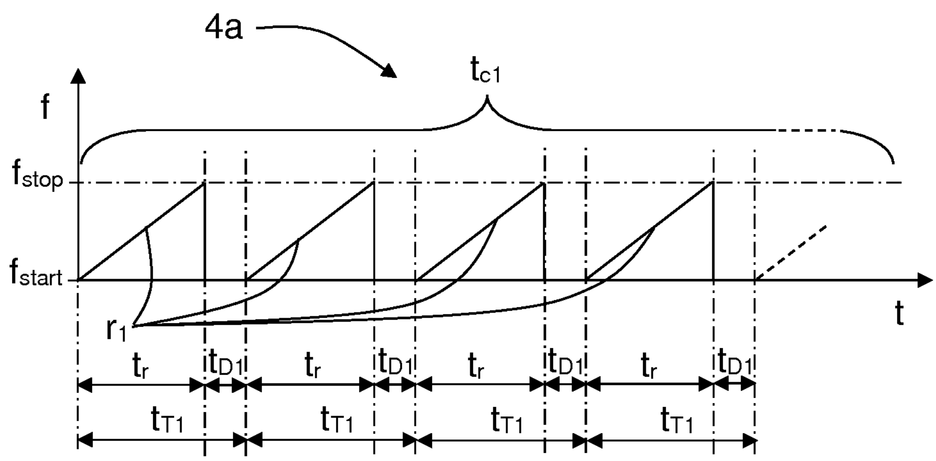
4a
t_{c1}
f
f_{stop}
f_{start}
t
r_1
t_r
t_{D1}
t_{T1}

FIG. 3a

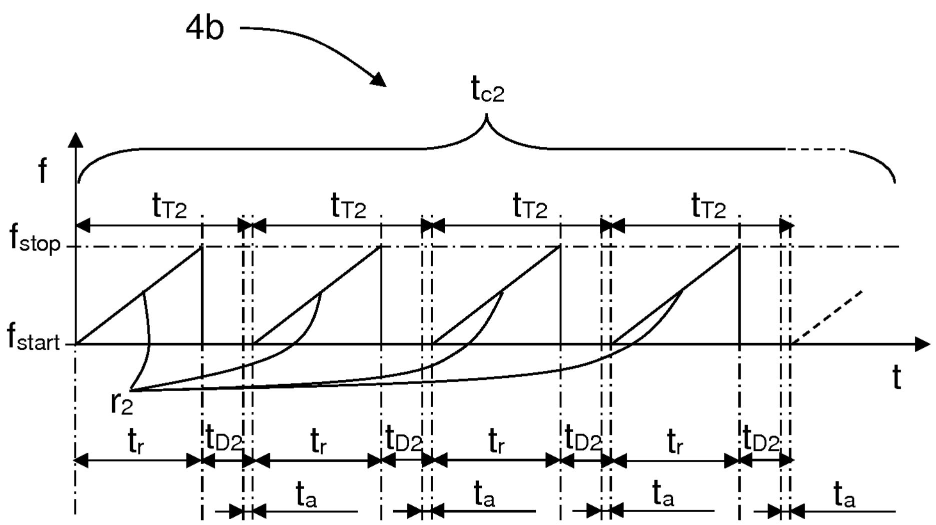
4b
t_{c2}
f
t_{T2}
f_{stop}
f_{start}
t
r_2
t_r
t_{D2}
t_a

FIG. 3b

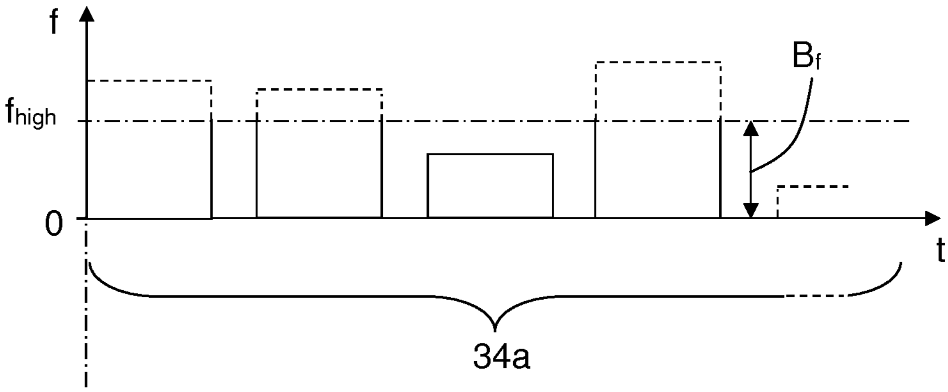

FIG. 4a

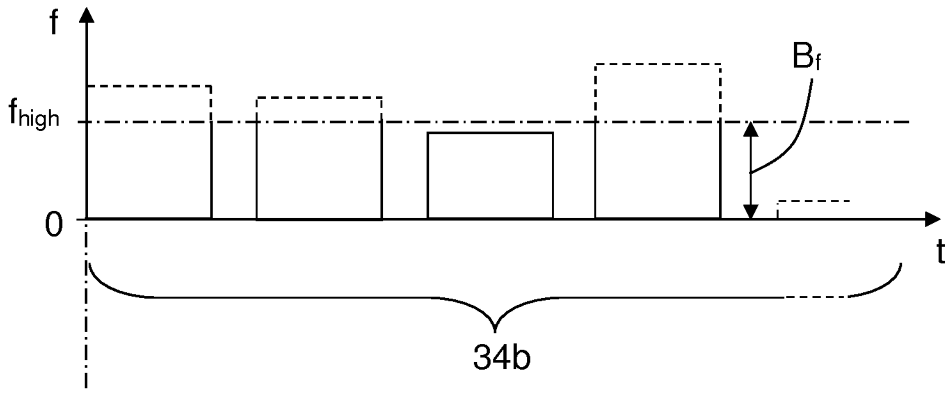

FIG. 4b

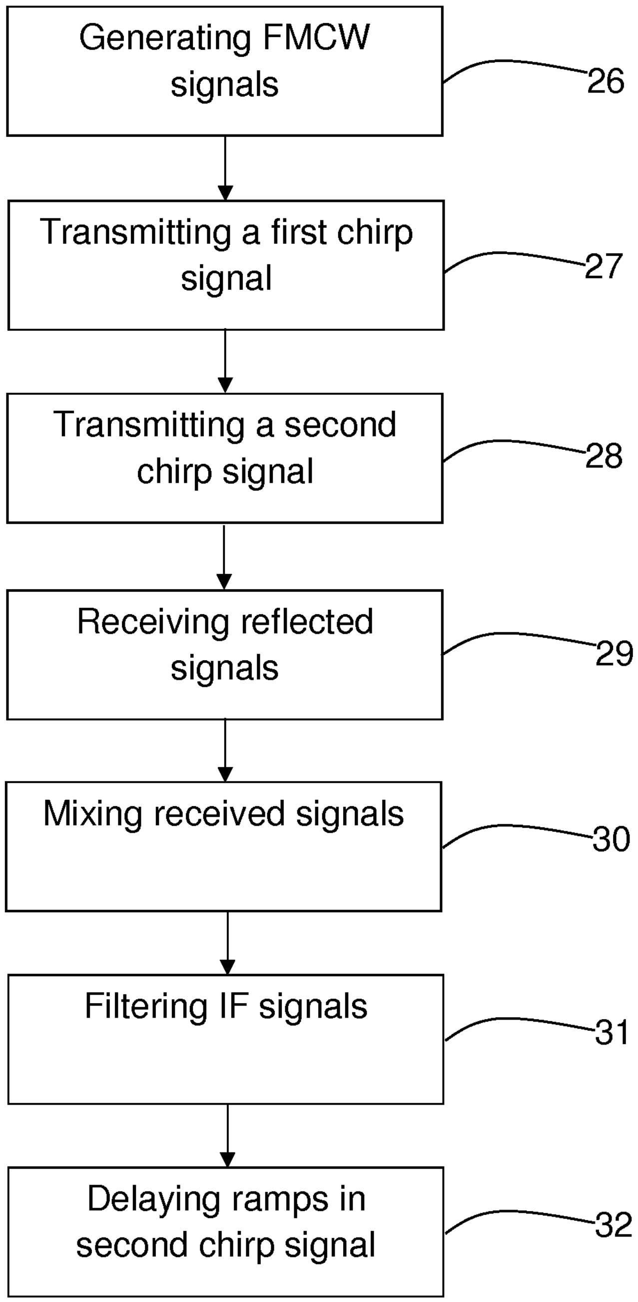
Generating FMCW signals
26
Transmitting a first chirp signal
27
Transmitting a second chirp signal
28
Receiving reflected signals
29
Mixing received signals
30
Filtering IF signals
31
Delaying ramps in second chirp signal
32

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/052350

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S7/02 G01S7/35 G01S13/34 G01S13/93
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 653 887 A1 (THALES SA [FR]) 23 October 2013 (2013-10-23)	1,2,4,5, 8,9,11, 14,15
Y	paragraphs [0018], [0050], [0042], [0051] - [0054], [0025], [0032], [0006]; figures 1-4	3,6,7, 10,12,13
Y	US 2012/176266 A1 (LEE JAE EUN [KR] ET AL) 12 July 2012 (2012-07-12) paragraphs [0034] - [0036]; figure 2	3,10
Y	DE 10 2013 210256 A1 (BOSCH GMBH ROBERT [DE]) 4 December 2014 (2014-12-04) paragraphs [0007], [0044], [0047], [0083] - [0085], [0098]; figure 3	6,7,12, 13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 May 2016	18/05/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Metz, Carsten

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/052350

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2653887 A1	23-10-2013	CN 103376448 A	30-10-2013
		EP 2653887 A1	23-10-2013
		FR 2989782 A1	25-10-2013
US 2012176266 A1	12-07-2012	CN 102608581 A	25-07-2012
		DE 102012000319 A1	12-07-2012
		KR 20120081735 A	20-07-2012
		US 2012176266 A1	12-07-2012
DE 102013210256 A1	04-12-2014	CN 105264400 A	20-01-2016
		DE 102013210256 A1	04-12-2014
		EP 3004918 A1	13-04-2016
		US 2016124075 A1	05-05-2016
		WO 2014195046 A1	11-12-2014