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(54) **Title:** AN AUTOMOTIVE TESTING METHOD, SYSTEM AND COMPUTER PROGRAM PRODUCT

(57) **Abstract:** The invention relates to an automotive testing method. The method comprises a step of acquiring radar sensor data responsive to a radar excitation signal generated by a radar transmitting unit. Further, the method includes a step of forwarding said radar sensor data to an electronic system of a radar receiving unit, a step of generating radar data from said radar sensor data, and a step of processing said radar data. The step of acquiring radar sensor data includes generating synthetic radar data. Further, the synthetic radar data is forwarded as radar sensor data to the electronic system of the radar receiving unit. Here, the synthetic radar data includes reflection signals, preferably all reflection signals, in a complex time series, that succeed each other and have the same temporal behaviour within a synthetic period that lasts at least an order longer than a time period of the radar excitation signal.

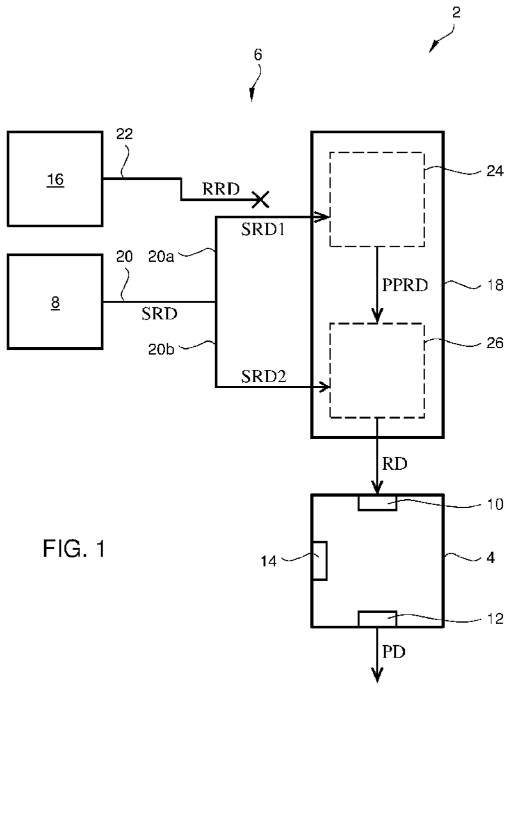

FIG. 1

WO 2017/222385 A1

Title: An automotive testing method, system and computer program product

The invention relates to an automotive testing method.

Automotive testing systems are known for the purpose of testing data acquisition units and data processing units processing sensor input data generated by said data acquisition units, thereby reducing expensive testing equipment and testing time in realistic traffic circumstances. As an example, data acquisition units can be provided with a camera unit having an optic system and an electronic system for capturing image data.

However, so far, radar systems have to be tested in realistic circumstances in order to evaluate how said systems react on radar input data. In this respect it is noted that radar systems have a high data rate relative to the time scale of the radar signals.

It is an object of the invention to provide an automotive testing method that enables testing a radar system in laboratory circumstances. Thereto, according to the invention, an automotive testing method is provided comprising the steps of:

- acquiring radar sensor data responsive to a radar excitation signal transmitted by a radar transmitting unit;
- forwarding the radar sensor data to an electronic system of a radar receiving unit;
- generating radar data from the radar sensor data, by the electronic system;
- forwarding the radar data to a data processing unit, and
- processing said radar data, by the processing unit,

wherein the step of acquiring radar sensor data includes generating synthetic radar data and wherein the said synthetic radar data is forwarded as radar sensor data to the electronic system of the radar receiving unit, the synthetic radar data including reflection signals that succeed each other and have the same temporal behaviour within a synthetic period that lasts at least an order longer than a time period of the radar excitation signal.

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The invention is at least partly based on the insight that radar data do not significantly change in the time scale of the radar signals since vehicles do not move along relevant distances during a time period of a radar excitation signal, i.e. nanoseconds.

By generating synthetic radar data including reflection signals that succeed each other and have the same temporal behaviour within a synthetic period that lasts at least an order longer than a time period of the radar excitation signal, only a reduced number of reflection signals has to be computed per synthetic period wherein the objects that are exposed to the radar excitation signal hardly move relative to each other. Then, there is substantially no loss in accuracy while, on the other hand, a considerably reduction of computational efforts is realized when carrying out a simulation of radar reflection signals. The synthetic radar data may include all reflections, in a complex time series, that have the same temporal behaviour within the synthetic period used that lasts at least an order longer than a time period of the radar excitation signal.

It is noted that, within the context of the application, the expression “synthetic radar data” is to be understood as radar data that has been generated electronically by simulating data that is normally sensed by a radar sensing element converting an incoming radar signal into an electronic signal, also referred to as raw radar data.

Advantageously, the synthetic radar data can be generated from a spectral domain radar model, e.g. using an inverse FFT routine to generate the reflection signals.

Preferably, the synthetic radar data includes a first set of radar data with temporal reflection signals to be input to a pre-processing unit that is arranged for pre-processing radar sensor data, and a second set of radar data with range-doppler domain data to be input to a digital signal processing unit for evaluating radar data in the range-doppler domain.

The invention also relates to a system.

Further, the invention relates to a computer program product. A computer program product may comprise a set of computer executable instructions stored on a data carrier, such as a flash memory, a CD or a DVD. The set of computer executable instructions, which allow a programmable computer to carry out the method as defined above, may also be available for downloading from a remote server, for example via the Internet, e.g. as an app.

Other advantageous options and embodiments according to the invention are described in the following claims.

By way of example only, embodiments of the present invention will now be described with reference to the accompanying figures in which

Fig. 1 shows a schematic view of an automotive testing system according to the invention;

Fig. 2 shows a range-doppler diagram;

Fig. 3 shows a flow chart of a method according to the invention, and

Fig. 4 shows a diagram illustrating the matching process.

The figures merely illustrate preferred embodiments according to the invention. In the figures, the same reference numbers refer to equal or corresponding parts.

Figure 1 shows a schematic view of an automotive testing system 2 according to the invention. The system 2 comprises a data processing unit 4, a radar receiving unit 6 and a synthetic radar data generator 8.

The data processing unit 4 is provided with a data input port 10 for receiving radar data RD and a data output port 12 for transmitting processed data PD, e.g. for the purpose of feeding a control unit for generating control data based on the processed data PD transmitted by the data processing unit 4. In the shown embodiment, the processing unit 4 further comprises an additional data input port 14, e.g. for receiving further input data, e.g. camera data.

The radar receiving unit 6 is arranged for generating and forwarding the radar data RD to the data input port 10 of the data processing unit 4 responsive to a radar excitation signal. The radar receiving unit 6 includes a radar sensing unit 16 and an electronic system 18. The radar sensing unit 16 is configured for converting an incoming electromagnetic radar signal into an electronic signal, also referred to as raw radar data RRD or radar sensor data. Typically, the radar sensing unit 16 includes an antenna. The electronic system 18 is configured for generating the radar data RD based on the raw radar data RRD that are received from said radar sensing element 16, under normal conditions when installed in a vehicle. Generally, for the purpose of generating the radar data RD, the electronic system receives radar sensor data representing raw radar data received from the radar sensing element.

Further, the synthetic radar data generator 8 of the automotive testing system 1 is configured to generate and transmit synthetic radar data SRD to the radar receiving unit 6 responsive to a radar excitation signal, in consecutive radar sample periods, thus mimicking radar signals that would occur if the radar receiving unit 6 is mounted on a vehicle facing realistic traffic situations, in order to simulate common real life traffic circumstances for testing the performance of the radar receiving unit 6 and the data processing unit 4 of the automotive testing system 2. For the purpose of transmitting the synthetic radar data SRD to the radar receiving unit 6, a data transmission channel 20 is provided interconnecting the synthetic radar data generator 8 to the electronic system 18 of the radar receiving unit 6. The data transmission channel 20 can be implemented as a wired transmission channel. However, in principle, the data transmission channel

20 can be formed in another way, e.g. based on wireless transmission technology.

During regular operation of the radar receiving unit 6, in a vehicle, the radar sensing unit 16 records incoming electromagnetic radar signals, as a response to transmitted radar excitation signals, and converts said incoming radar signals into electronic signals, thus generating raw radar data RRD or radar sensor data that is forwarded to the electronic system 18 of the radar receiving unit 6, via a sensor channel 22 interconnecting the radar sensing unit 16 to the electronic system 18.

According to an aspect of the invention, the raw radar data RRD generated by the radar sensing unit 16 forms not the basis of the radar data RD forwarded to the processing unit 4. In the shown embodiment, the sensor channel 22 is disconnected from the electronic system 18 while the data transmission channel 20 transmitting synthetic radar data SRD is connected to the electronic system 18. In principle, the transmission of the raw radar data RRD generated by the radar sensing unit 16 can be terminated by physically disconnecting respective transmission channels or by functionally disabling said transmission actions, using software. Further, the radar sensing element 16 can even be removed from the radar receiving unit 6.

Then, electronic radar sensor signals are simulated by the synthetic radar data generator 8 so that the radar data generated by the radar receiving unit 6 are based on the synthetic radar data SRD transmitted to the electronic system 18 of the radar receiving unit 6. The synthetic radar data SDR may thus include a synthetic representation of real raw radar data generated by the radar sensing element 16. By generating synthetic radar data, a process of acquiring radar sensor data is performed. The synthetic radar data is forwarded as radar sensor data to the electronic system of the radar receiving unit.

By bypassing the radar sensing element 16 of the radar receiving unit 6, the electromagnetic part of the testing environment is effectively simulated thus enabling radar testing opportunities in laboratory conditions.

The synthetic radar data SDR generated by the synthetic radar data generator include reflection signals that succeed each other, in consecutive radar sample periods, and have the same temporal behaviour within a synthetic period that lasts at least an order longer than a time period of the radar excitation signal, exploiting the insight that the timescale of change in the world is much larger than the timescale of the radar signals. By rendering synthetic radar data SDR that may include successive identical reflection signals, computational efforts are reduced considerably. The synthetic period can be one order, two orders, three or even more orders greater than the time period of the radar excitation signal or radar sample period. As an example, the reflection signals in the synthetic radar data SDR are invariant during a synthetic time period corresponding to a sampling rate ranging between circa 1 Hz and circa 1 kHz. In practice, the sampling rate can be chosen in a range between circa 20 Hz and circa 60 Hz. However, other sampling rates are also possible, e.g. 10 Hz or 100 Hz.

The synthetic radar data may include all reflections, in a complex time series, that have the same temporal behaviour within the synthetic period used that lasts at least an order longer than a time period of the radar excitation signal or radar sample period. The succeeding reflection signals may have a similar time dependent shape, viz. having a similar curve over time. As an example, the reflection signal includes a reflected radar pulse that can be received after an excitation radar pulse is reflected by an object.

In a first exemplary embodiment, the synthetically generated reflection signals are identical during a first synthetic period, while the reflection signals during a second synthetic period, subsequent to the first synthetic period, are also mutually identical though different from the reflection signals in the first synthetic period. Then, the reflection signals, in consecutive radar sample periods, remain constant or identical during each synthetic period and can be computed by numerically evaluating a radar model at a time instant within the corresponding synthetic period.

In a second exemplary embodiment, the synthetically generated reflection signals during the first synthetic period are not identical but slightly different maintaining the same temporal behavior. Advantageously, the reflection signals may be interpolated over time, in consecutive radar sample periods, between a computed first synthetic reflection signal and a computed second synthetic reflection signal, the computed first synthetic reflection signal corresponding to a time instant within the first synthetic period, and the computed second synthetic reflection signal corresponding to a time instant within the second synthetic period following said first synthetic period. In the interpolation process, the arrival time and/or amplitudes of the reflection signal can be interpolated. The computed first and second synthetic reflection signals can be obtained by numerically evaluating a radar model at a time instant within the respective synthetic period.

When applying a ray tracing module in the radar model, reflection signals of the respective rays can be interpolated over time, in consecutive radar sample periods, between subsequent synthetic periods, each synthetic period corresponding to a step wherein rays are evaluated in the ray tracing module. A first set of evaluated rays at a first step can be matched to a second set of evaluated rays at a second, subsequent step so that a meaningful interpolation at time instants within the synthetic periods can be performed. Then, the set of evaluated rays can be updated at each ray tracing step thus providing a complete description of a simulated scene. Again, using the temporal interpolation technique, a representation of the radar field can be obtained at a time scale, in consecutive radar sample periods, that is smaller than the synthetic periods or ray tracing step period.

The process of matching the rays at subsequent ray tracing steps can be performed by introducing a physical definition determining when a ray of a first ray tracing step follows the same physical path as a ray of a second, consecutive, ray tracing step. Optionally, a heuristic can be applied to determine a probability that two rays from consecutive time steps meet the physical definition of following the same physical path. In a specific embodiment the heuristic for a multiple number or all rays from consecutive ray tracing steps are optimized using an optimization algorithm, e.g. an iterative optimization algorithm. Then, the intensity and the path length of the matched rays can be updated.

Figure 4 shows a diagram illustrating the matching process. In the top part, the diagram shows a first set of rays A0, A1, A2 etc that have been evaluated at a first ray tracing step RT step A, as well as a second set of rays B0, B1, B2 etc that have been evaluated at a second ray tracing step RT step B. The ray tracing steps are performed at a relatively low sample rate, e.g. between circa 10 Hz and circa 100 Hz. Interconnecting arrows symbolically denote a match between individual rays in the consecutive ray tracing steps. In the middle part, an exemplary overview of matching rays is shown also indicating that not all rays match. In the lower part, the diagram shows consecutive ray representations Rays To, Rays T1, Rays T2, …, Rays TN including the interpolated reflection signals, in consecutive radar sample periods, at a radar sample rate that is higher than the ray tracing sample rate, e.g. in the GHz regime.

It is noted that instead of applying a ray tracing module in the radar model, other radar models can be used, e.g. applying a finite element algorithm.

Advantageously, the synthetic radar data can be obtained through an inverse Fourier transform from data generated from a radar model in a spectral domain, e.g. in a range-doppler domain.

In the embodiment shown in Fig. 1 the electronic system 18 of the radar receiving unit 6 includes a pre-processing unit 24 and a digital signal processing unit 26. The pre-processing unit 24 is configured for pre-processing the radar sensor data representing the raw radar data, i.e. the synthetic radar data SRD, in the automotive testing system 2. Pre-processing steps may include so-called backend processing such as an analogue to digital conversion step, a sampling step and/or a noise suppressing step, finally resulting in pre-processed radar sensor data PPRD. The digital signal processing unit 26 is configured for generating the radar data RD to be forwarded to the data processing unit 4 of the automotive testing system 2, based on the pre-processed radar sensor data PPRD. Specifically, the digital signal processing unit 26 may be arranged for performing a step of object detection, a step of clustering and/or a step of tracking a cluster or object.

Generally, the radar processing steps are related to the applied type of radar signals. Various radar signal types may be applied for radar systems in vehicles including frequency modulated continuous wave FMCW, Doppler, frequency-shift keying FSK, binary frequency-shift keying BFSK, phase-shift keying PSK or differential phase-shift keying DPSK. In case of FMCW, a continuous wave signal is modulated in frequency to produce a linear sweep signal that is transmitted as an excitation signal. The echo received later is mixed with a portion of the transmitted signal to produce a beat frequency signal which is proportional with a round trip time covering the two-way distance between the radar and an object. Then, the beat frequency signal is subjected to a temporal FFT algorithm and a speed FFT algorithm. The result can be visualized in a so-called range-doppler diagram. Radar data that may be obtained using other radar principles may also be represented in a range-doppler diagram.

Figure 2 shows an example of a range-doppler diagram 50 wherein an object velocity V_+, V_- is a function of the horizontal axis, while an object range R is a function of the vertical axis. The diagram or domain 50 contains a mainly vertical band of clutter related reflection data BC. Clutter data BC is correlated to stationary objects such as buildings, trees, leaves and grass. The diagram or domain further contains reflection data of a first object A moving away from the radar and reflection data of a second object B moving towards the radar.

In the embodiment shown in Fig. 1, the data transmission channel 20 that is used for transmitting the synthetic radar data SRD from the synthetic radar data generator 8 towards the electronic system 18 of the radar receiving unit 6 is connected to both the pre-processing unit 24 and the digital processing unit 26 of the electronic system 18. The transmission channel 20 includes a first branch 20a connected to the pre-processing unit 24 for transmitting a first set of synthetic radar data SDR1 with temporal reflection signals. The transmission channel 20 further includes a second branch 20b connected to the digital processing unit 26 for transmitting a second set of synthetic radar data SDR2 with range-doppler domain data.

The above-mentioned second set of synthetic radar data SDR2 includes clustered radar data representing an ensemble of reflecting objects. Preferably, the clustered radar data are related to clutter signals.

Then, the first set of synthetic radar data SDR1 relates to a temporal representation of radar response signals caused by non-clutter objects such as the first object A and the second object B in the range-doppler diagram 50 moving away from and towards the radar, respectively. The second set of synthetic radar data SDR2 relates to a spectral representation of radar response signals caused by clutter objects associated with the clutter data BC in the range-doppler diagram 50. The first set of synthetic radar data SDR1 is transmitted to the pre-processing unit 24 while the second set of synthetic radar data SDR2 is transmitted to the digital signal processing unit 26.

As indicated above, the synthetic radar SDR may be generated from a spectral domain radar model. Advantageously, the second set of synthetic radar data SDR2 is directly generated using said spectral domain radar model. Then, a transformation of data to another computational domain might be superfluous, thereby even further reducing computation efforts. Further, any computation of large clutter areas in the time domain, which is inherently computationally demanding especially when performed at a radar timescale of nanoseconds, might be avoided. Again, the insight is exploited that radar reflection signals do not change substantially during the time period of the radar excitation signal because vehicles do not change position that fast.

Further, a step of clustering data can be performed in the spectral domain as well, i.e. a step of combining reflection signal contributions caused by different reflecting objects in order to process said combined signal contributions together. In the above-described implementation the clustered data relate to reflection signals caused by different clutter objects such as buildings, trees, leaves and grass or other stationary or static objects. The clutter objects typically are well known parts of a scene and/or the clutter objects are static or stationary in such a way that the results of processing the associated reflection signals from the time domain into the spectral domain are known in advance. By forwarding the processed data in the range-doppler domain, the computation of corresponding time domain radar data becomes superfluous, thereby saving computation efforts. Generally, computation time can be saved if the result of processing steps resulting in spectral data is known in advance, viz. by inserting these spectral data as range-doppler domain data.

Alternatively, the synthetic radar data SDR may include a synthetic representation of cluster data that is related to a specific object or specific objects, e.g. the object A moving away from the radar, said second synthetic radar data SDR2 being transmitted to the digital signal processing unit 26. Further, almost all synthetic radar data SDR may relate to cluster data in the range-doppler domain, all said synthetic radar data SDR being transmitted to the digital signal processing unit 26. Otherwise, all synthetic radar data SDR may simulate time-domain raw radar data that is transmitted to the pre-processing unit 24. Then, no synthetic radar data SDR is transmitted directly to the digital signal processing unit 26.

It is noted that the data processing unit 4 may receive further radar data and/or other sensor signals such as laser signals, infrared signals, radar signals, acoustic signals, ultrasonic signals, pressure signals or electronic signals received in a wired or wireless way and representing any type of measured physical signals associated with automotive conditions or parameters. The signals may relate to automotive conditions or parameters of a vehicle in which the sensor unit is mounted or automotive conditions or parameters of other vehicles forwarding such signals to the sensor unit. It is further noted that the automotive testing system may include a multiple number of acquisition units such as the described radar receiving unit wherein sensor data are simulated using synthetic radar data. By providing multiple sensor data, a realistic process of processing sensor data may be simulated.

Optionally, synthetic radar data simulating radar reflections of a car or another curved surface can be generated using a ray tracing method wherein, via interpolation, a smoothly varying surface normal vector is taken into account when computing reflection caused by an elementary polygon cell in the exterior of said car. Here, the surface normal and the radii of curvature between the vertices of the meshes are interpolated so that the surface can be meshed in a relatively coarse way saving computation efforts. Generally, the exterior of a car has a curved shape. By meshing the exterior of said car, or at least a portion of said car exterior receiving an incident radar beam, into a multiple number of elementary polygon cells, the entire reflection can be computed by evaluating the partial reflections caused by the individual polygon cells, e.g. using a ray tracing method, and combining these partial reflections coherently. Advantageously, when smoothly varying the surface normal vector of the individual polygon cells, in an interpolating manner, a relatively accurate radar reflection can be computed while computational efforts remain relatively moderate as the exterior surface of the car can be meshed in a relatively coarse manner. As a result, computational efficiency and accuracy can be improved and any reduction of accuracy caused by the coarse mesh can at least partially be corrected. Said optional method of simulating radar reflections from curved surfaces is in itself known from another field of visualization, namely 3D computer graphics, viz. as Phong shading.

Figure 3 shows a flow chart of an embodiment of a method according to the invention. The method 100 is used for automotive testing, and comprises a step of acquiring 110 radar sensor data responsive to a radar excitation signal transmitted by a radar transmitting unit, a step of forwarding 120 the radar sensor data to an electronic system of a radar receiving unit, a step of generating 130 radar data from the radar sensor data, by the electronic system, a step of forwarding 140 the radar data to a data processing unit, and a step of processing 150 said radar data by the processing unit, wherein the step of acquiring 110 radar sensor data includes generating 112 synthetic radar data and wherein the synthetic radar data is forwarded as radar sensor data to the electronic system of the radar receiving unit, the synthetic radar data including reflection signals, preferably all reflection signals, in a complex time series, that succeed each other and have the same temporal behaviour within a synthetic period that lasts at least an order of magnitude longer than a time period of the radar excitation signal.By generating synthetic radar data using a synthetic radar data generator, and forwarding said synthetic radar data to an electronic system of the radar receiving unit as radar sensor data a simulation of real sensor data is performed, bypassing a radar sensing element that during normal operation conditions of the radar receiving unit converts an incoming radar signal into an electronic signal for transmission to the electronic system as raw radar data.

The method of automotive testing can be facilitated using dedicated hardware structures, such as computer servers. Otherwise, the method can also at least partially be performed using a computer program product comprising instructions for causing a processor of a computer system to facilitate automotive testing. All (sub)steps can in principle be performed on a single processor. However, it is noted that at least one step can be performed on a separate processor. A processor can be loaded with a specific software module. Dedicated software modules can be provided, e.g. from the Internet.

The invention is not restricted to the embodiments described herein. It will be understood that many variants are possible.

It is noted that the electronic system 23 of the radar receiving unit 6 may include a single or a multiple number of units for processing radar data.

It is further noted that generating synthetic radar data simulating radar reflections of a car using a ray tracing method wherein the surface normal and the radii of curvature between the vertices of the meshes are interpolated, so that an interpolating smoothly varying surface normal vector is taken into account when computing reflection caused by an elementary polygon cell in the exterior of a car or another curved surface, can not only be used in the claimed automotive testing method, but more generally in automotive testing, comprising the steps of acquiring radar sensor data and processing said radar sensor data.

These and other embodiments will be apparent for the person skilled in the art and are considered to fall within the scope of the invention as defined in the following claims. For the purpose of clarity and a concise description features are described herein as part of the same or separate embodiments. However, it will be appreciated that the scope of the invention may include embodiments having combinations of all or some of the features described.

Claims

1. An automotive testing method, comprising the steps of:
- acquiring radar sensor data responsive to a radar excitation signal transmitted by a radar transmitting unit;
- forwarding the radar sensor data to an electronic system of a radar receiving unit;
- generating radar data from the radar sensor data, by the electronic system;
- forwarding the radar data to a data processing unit, and
- processing said radar data, by the processing unit,

wherein the step of acquiring radar sensor data includes generating synthetic radar data and wherein the said synthetic radar data is forwarded as radar sensor data to the electronic system of the radar receiving unit, the synthetic radar data including reflection signals that succeed each other and have the same temporal behaviour within a synthetic period that lasts at least an order longer than a time period of the radar excitation signal.

2. A method according to claim 1, wherein the reflection signals succeed each other in consecutive radar sample periods.

3. A method according to claim 1 or 2, wherein the succeeding reflection signals have a similar time dependent shape.

4. A method according to any of the preceding claims, further comprising a step of computing a first synthetic reflection signal corresponding to a time instant within a first synthetic period and computing a second synthetic reflection signal corresponding to a time instant within a second synthetic period consecutive to the first synthetic period, further comprising a step of interpolating the reflection signals over time between the first and second synthetic reflection signals.

5. A method according to claim 4, wherein the first and second synthetic reflection signals are computed by numerically evaluating a radar model applying a ray tracing module wherein each synthetic period corresponds to a step wherein rays are evaluated in the ray tracing module.

6. A method according to claim 5, further comprising a step of matching a first set of evaluated rays at a first ray tracing step to a second set of evaluated rays at a second, subsequent ray tracing step.

7. An automotive testing method according to any of the preceding claims, wherein the synthetic radar data include all reflection signals, in a complex time series, that succeed each other and have the same temporal behaviour within a synthetic period that lasts at least an order longer than a time period of the radar excitation signal.

8. An automotive testing method according to any of the preceding claims, wherein the synthetic period corresponds to a sampling rate ranging between circa 1 Hz and circa 1 kHz.

9. An automotive testing method according to any of the preceding claims, wherein the step of transmitting said synthetic radar data to the electronic system of the radar receiving unit includes bypassing a radar sensing element that is arranged for converting an incoming radar signal into raw radar data.

10. An automotive testing method according to any of the preceding claims, wherein the synthetic radar data are generated from a spectral domain radar model.

11. An automotive testing method according to any of the preceding claims, wherein the synthetic radar data includes a first set of radar data with temporal reflection signals.

12. An automotive testing method according to any of the preceding claims, wherein the synthetic radar data includes a second set of radar data with range-doppler domain data.

13. An automotive testing method according to claim 12, wherein the second set of radar data includes clustered radar data representing an ensemble of reflecting objects.

14. An automotive testing method according to claim 13, wherein the clustered radar data includes clutter signals.

15. An automotive testing method according to any of the preceding claims, wherein synthetic radar data simulating radar reflections of a car are generated including the steps of:

- meshing the exterior surface of the car coarsely, and
- applying a using a ray tracing method while interpolating the surface normal and the radii of curvature between vertices of the meshes.

16. An automotive testing system, comprising a radar transmitting unit for transmitting a radar excitation signal, a radar receiving unit including an electronic system for generating radar data from radar sensor data that has been acquired responsive to said radar excitation signal, and a data processing unit provided with a data input port for receiving radar data from the electronic system of the radar receiving unit and a data output port for transmitting processed data, wherein the testing system further comprises a synthetic radar data generator that is configured for generating synthetic radar data and for forwarding said synthetic radar data as radar sensor data to the electronic system of the radar receiving unit, the synthetic radar data including reflection signals that succeed each other and have the same temporal behaviour within a synthetic period that lasts at least an order longer than a time period of the radar excitation signal.

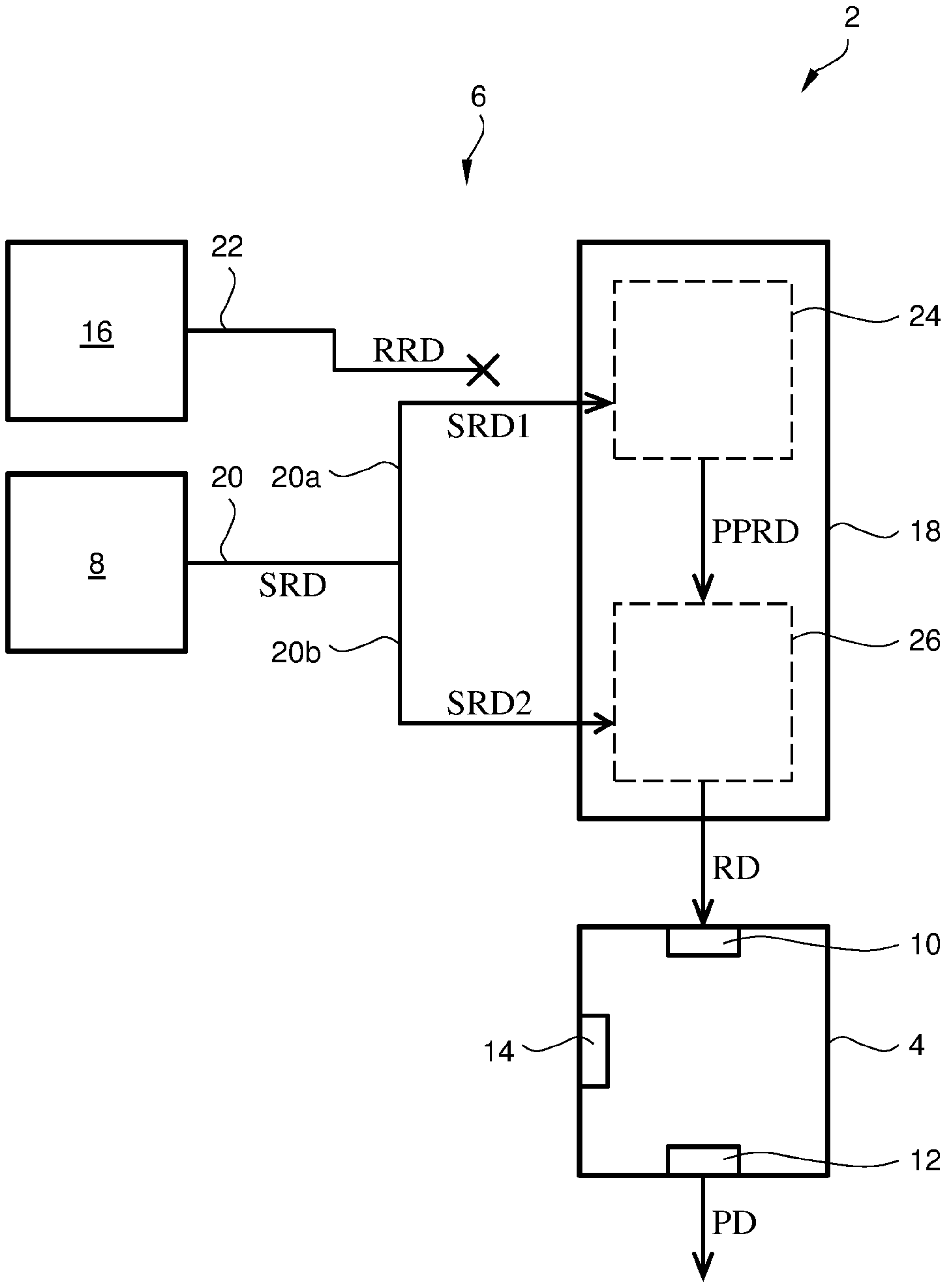
17. An automotive testing system according to claim 16, wherein the electronic system is arranged for generating the radar data based on radar sensor data representing raw radar data received from a radar sensing element converting an incoming radar signal into an electronic signal, and wherein the testing system further comprises a data transmission channel

interconnecting the synthetic radar data generator to the electronic system of the radar receiving unit.

18. An automotive testing system according to claim 17, wherein the electronic system of the radar receiving unit comprises a pre-processing unit for pre-processing the radar sensor data, and a digital signal processing unit for generating, based on the pre-processed radar sensor data, the radar data to be forwarded to the data processing unit, and
wherein the data transmission channel includes a first branch connected to the pre-processing unit of the electronic system.

19. An automotive testing system according to claim 18, wherein the data transmission channel includes a second branch connected to the digital signal processing unit of the electronic system.

20. A computer program product for automotive testing, the computer program product comprising computer readable code for causing a processor to perform the steps of:
- generating synthetic radar data and forwarding said synthetic radar data is radar sensor data to the electronic system of the radar receiving unit the automotive testing system according to claim 16.


2
6
16
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RRD
SRD1
24
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20a
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SRD
PPRD
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20b
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SRD2
RD
10
14
4
12
PD

FIG. 1

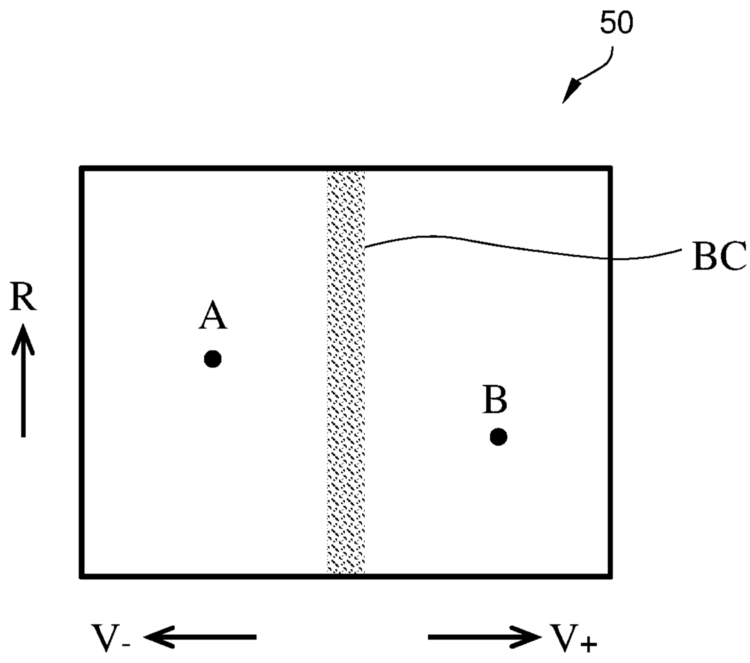

FIG. 2

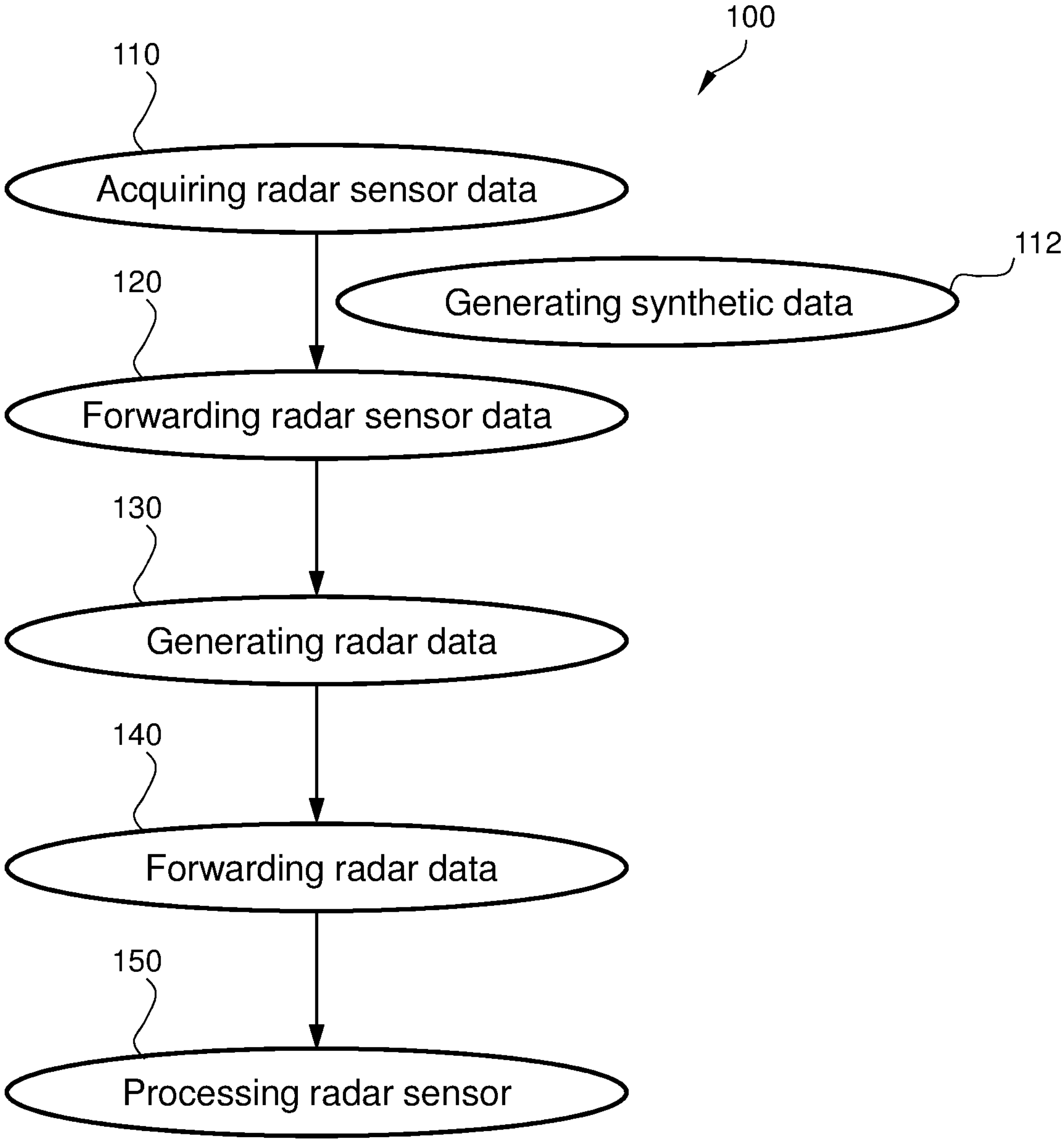
100
110
Acquiring radar sensor data
112
Generating synthetic data
120
Forwarding radar sensor data
130
Generating radar data
140
Forwarding radar data
150
Processing radar sensor

FIG. 3

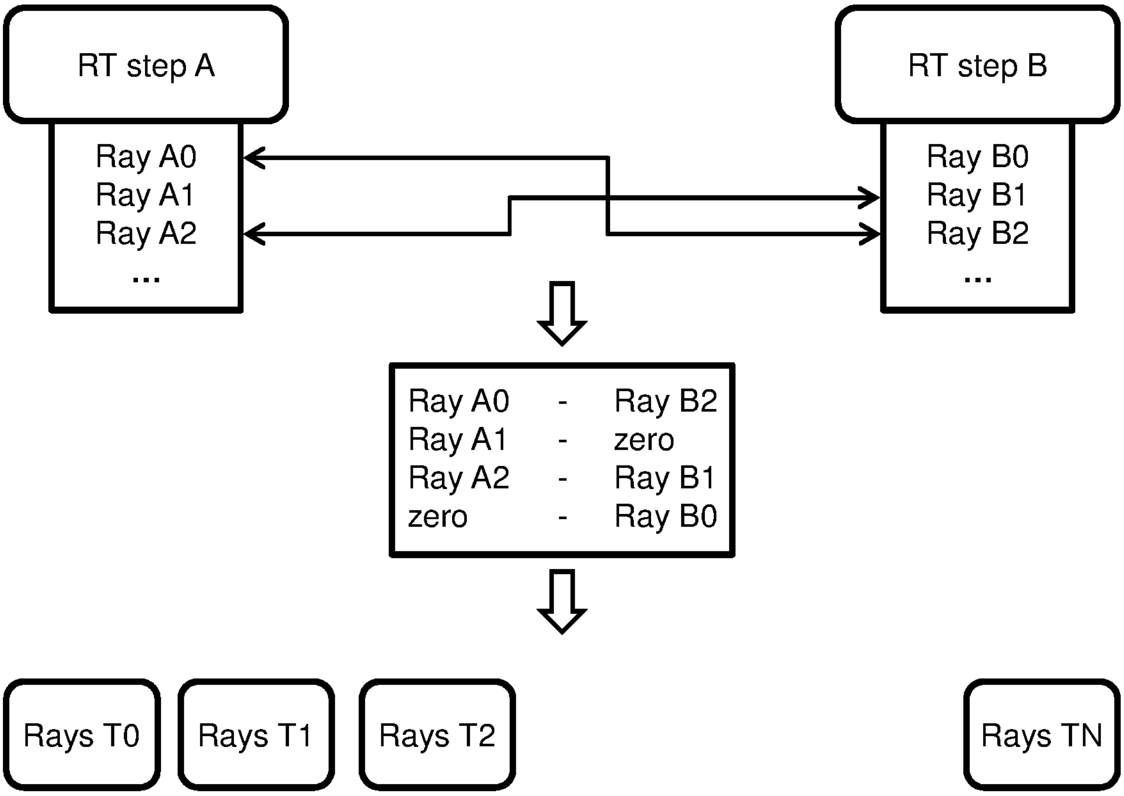
RT step A
Ray A0
Ray A1
Ray A2
...
RT step B
Ray B0
Ray B1
Ray B2
...
Ray A0 - Ray B2
Ray A1 - zero
Ray A2 - Ray B1
zero - Ray B0
Rays T0
Rays T1
Rays T2
Rays TN

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2017/050425

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S7/40 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 G06T

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, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 223 840 A (CRONYN WILLARD M [US]) 29 June 1993 (1993-06-29) column 2, paragraph 41 - paragraph 42; figure 1 column 5, paragraphs 16-17,53 - paragraph 64 -----	1-3,7-20
X,P	US 2017/115378 A1 (HAGHIGHI KASRA [SE] ET AL) 27 April 2017 (2017-04-27) paragraphs [0001], [0106] - paragraphs [0109], [0121], [0130]; figures 2, 5 -----	1-20
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 September 2017	11/10/2017

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	Beer, Mark

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Marco Weiskopf ET AL: "Integrationslösung zur Absicherung eines realen Radarsensors im Systemverbund mit der Hardware-in-the-Loop Testtechnologie", , 16 April 2015 (2015-04-16), XP055325566, Retrieved from the Internet: URL:http://subs.emis.de/LNI/Proceedings/Proceedings240/29.pdf [retrieved on 2016-12-02] sections 4 and 5; figures 2-6 -----	1-3,7-20
X	US 5 457 463 A (VENCEL LESLIE J [AU] ET AL) 10 October 1995 (1995-10-10) column 4, line 30 - column 6, line 10; figures 1, 3, 4, 5 column 8, line 9 - line 46 -----	1-20
X	ERGEZER HALIT ET AL: "Hardware-in-the-loop radar test simulator", 2014 4TH INTERNATIONAL CONFERENCE ON SIMULATION AND MODELING METHODOLOGIES, TECHNOLOGIES AND APPLICATIONS (SIMULTECH), SCITEPRESS, 28 August 2014 (2014-08-28), pages 666-673, XP032768670, sections 2 and 3; figures 1, 6 -----	1-20
X	HAO HUANG ET AL: "Hardware-in-the-loop simulation technology of wide-band radar targets based on scattering center model", CHINESE JOURNAL OF AERONAUTICS, vol. 28, no. 5, 1 October 2015 (2015-10-01), pages 1476-1484, XP055325574, AMSTERDAM, NL ISSN: 1000-9361, DOI: 10.1016/j.cja.2015.07.006 section 2; figure 5 -----	1-20
A	US 7 567 205 B1 (LEE CHUL J [US]) 28 July 2009 (2009-07-28) column 1, line 5 - line 58 -----	15
A	US 4 660 041 A (MAPLES VANCE H [US] ET AL) 21 April 1987 (1987-04-21) column 2, line 12 - line 48; figure 7 -----	1,16,20

1

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Information on patent family members

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PCT/NL2017/050425

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			SE	1750342	A1	23-04-2017
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