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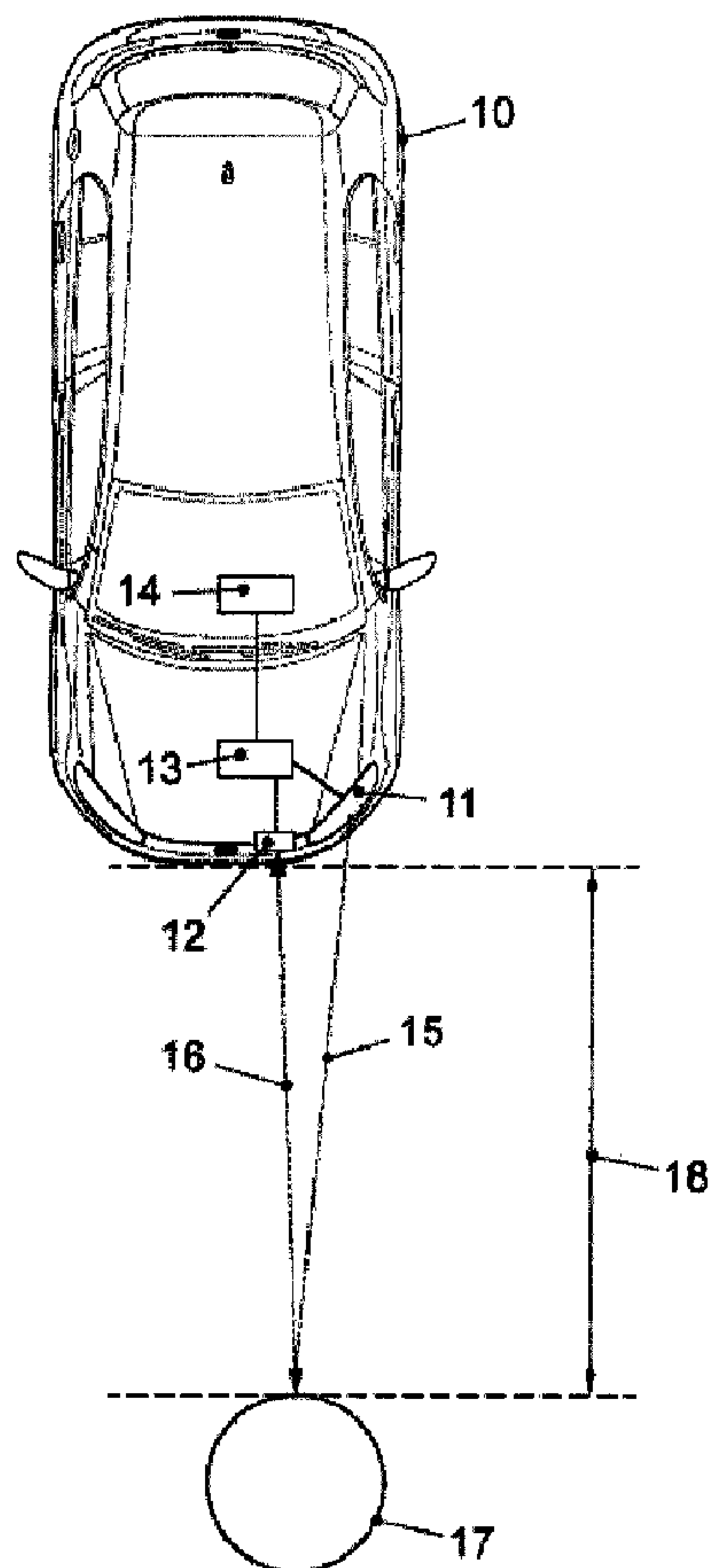
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(54) **Titre : DETERMINATION D'UN ELEMENT D'INFORMATION A DISTANCE POUR UN VEHICULE**

(54) **Title: DETERMINATION OF AN ITEM OF DISTANCE INFORMATION FOR A VEHICLE**



(57) **Abrégé/Abstract:**

The present invention relates to a method and a device for determining an item of distance information for a vehicle. In the method, a light source (11) of the vehicle (10) is actuated using a modulated signal and light (16), which was emitted by the light source (11)

(57) Abrégé(suite)/Abstract(continued):

and was reflected from an object (17) in an environment of the vehicle (10), is received. A reception signal is generated as a function of the received light (16) and a correlation signal is generated by correlating the modulated signal with the reception signal. A distance (18) to the object (17) is determined as a function of the correlation signal.

Abstract

Determination of an item of distance information for a vehicle

- 5 The present invention relates to a method and a device for determining an item of distance information for a vehicle. In the method, a light source (11) of the vehicle (10) is actuated using a modulated signal and light (16), which was emitted by the light source (11) and was reflected from an object (17) in an environment of the vehicle (10), is received. A reception signal is generated as a function of the received light (16) and a correlation signal is generated by
- 10 correlating the modulated signal with the reception signal. A distance (18) to the object (17) is determined as a function of the correlation signal.

(Figure 1)

Description

Determination of an item of distance information for a vehicle

- 5 The present invention relates to a method for a vehicle, in particular a method for determining a distance to an object in an environment of the vehicle, and also a corresponding device.

In modern vehicles, for example, passenger automobiles or trucks, a variety of so-called driver assistance systems are used to assist a driver of the vehicle when driving the vehicle. Such driver assistance systems can contribute to avoiding accidents, for example, and can relieve the driver, whereby a comfort of the driver can be increased. For example, an adaptive cruise control system can automatically maintain a suitable distance to a leading vehicle. Parking aids can assist a driver when parking in and exiting a parking space. Further assistance systems can monitor a blind spot and carry out emergency braking or control interventions depending on a traffic situation, for example. To detect a current traffic situation in an environment of the vehicle, object detection systems are therefore necessary. Typical object detection systems use technologies, for example, radar, lidar, ultrasound, or automatic image processing. Additional costs may thus arise for corresponding sensors. In addition, such sensors are to be housed at suitable locations of the vehicle, whereby additional installation space is required for these sensors.

In this context, an illumination system having driver assistance capabilities is disclosed in WO 2008/154736 A1. For this purpose, vehicle lighting modules, for example, front headlights, taillights, brake lights, and interior lights, have additional detection capabilities added, to recognize the presence of obstructions, for example, automobiles, trucks, pedestrians, and other objects, or to measure the velocity of these obstructions. These detection capabilities are made available to driver assistance applications, for example, an adaptive cruise control, a blind spot monitor, and a precrash assistant. A light-emitting diode (LED) has the capability of being used as a light source for a light, on the one hand, and to be pulsed or modulated as a source for the detection system, on the other hand.

The object of the present invention is to provide an improved distance or velocity measurement for an object in an environment of the vehicle or for multiple objects in the environment of the vehicle.

35 This object is achieved according to the present invention by a method for a vehicle according to Claim 1, a method for a vehicle according to Claim 4, a device for determining an item of

distance information for a vehicle according to Claim 9, and a vehicle according to Claim 10. The dependent claims define preferred and advantageous embodiments of the invention.

5 According to the present invention, a method for a vehicle is provided, in which a light source of the vehicle is actuated using a modulated signal. Light which has been emitted by the light source and reflected from an object in an environment of the vehicle is received and a reception signal is generated as a function of the received light. The modulated signal, using which the light source of the vehicle was actuated, is correlated with the reception signal and a corresponding correlation signal is generated. A distance to the object is determined as a
10 function of the correlation signal. For example, the modulated signal, using which the light source of the vehicle was actuated and therefore the light emitted by the light source was modulated, can be time-shifted and correlated with the reception signal. A correlation maximum results at the shifting time which is proportional to the distance of the object. In other words, the shifting time is proportional to a signal runtime from the light source to the object and back to a
15 receiver of the vehicle. Since substantially noisy signals are analysed, which can be influenced by daylight, scattered light, or light from other vehicles, for example, the level of the correlation maximum is a measure of the signal strength, so that various objects can be differentiated. A resolution in the distance can be determined by a scanning frequency of the reception signal. Long signal sequences of the modulated signal can be used by the correlation. A signal length
20 of the modulated signal is not restricted to the runtime of the signal for the distance to be measured. Furthermore, the analysis can be implemented digitally, for example, and can therefore be constructed cost-effectively.

The correlation signal can be generated, for example, by generating multiple correlation
25 coefficients, to each of which a respective shifting time is assigned. Each correlation coefficient is formed by correlating the modulated signal, which is shifted by the respective assigned shifting time, with the reception signal. In other words, the reception signal is correlated with multiple differently time-shifted modulated signals and a corresponding correlation coefficient is thus formed for each shifting time. The distance to the object is determined as a function of the
30 multiple correlation coefficients and the assigned shifting times. For this purpose, the correlation coefficients can be compared to a threshold value, for example, and if the threshold value is exceeded, it can be established that an object is present at a distance which results from the assigned shifting time.

35 The resolution in the distance to the object can be influenced by the scanning frequency of the reception signal. To achieve a high scanning rate, for example, a one-bit conversion of the reception signal can be carried out. For this purpose, the reception signal can be generated using a first signal value, for example, a 0 bit, if a level of the received light falls below a specific

intensity, and a reception signal can be generated using a second signal value, for example, a 1 bit, if the level of the received light reaches or exceeds the specific intensity. Since the significance of the correlation is in the time, no essential information is lost by this coarse one-bit conversion. The significance in the amplitude is unreliable in any case because of the amplitude modulation to be expected by way of the reflection on the object. A correlator can be constructed very simply and can process long signal sequences due to the reception signal reduced to one bit, whereby the correlation result can be improved. Since the comparison pattern for the reception signal is to be provided digitally upon the use of the one-bit conversion, it is advantageous to use a synthetic signal for the modulation of the light source, which is then generated with uniform quality as a function of the transmit clock. If the receive clock is equal to the transmit clock, clock errors, for example, as a result of temperature drifts, can be avoided. The above-described one-bit conversion can be carried out using an amplitude-limited amplifier, for example, which outputs the first signal value or the second signal value as a function of the received light.

The present invention provides a further method for a vehicle, in which a light source of the vehicle is actuated using a modulated signal and light, which was emitted by the light source and was reflected from an object in an environment of the vehicle, is received. A reception signal is generated as a function of the received light and a mixed signal is generated by mixing the modulated signal with the reception signal. A distance to the object in the environment of the vehicle is determined as a function of the mixed signal. The modulated signal can be a signal, the frequency of which changes chronologically, for example. By mixing the modulated signal with the reception signal, a mixed frequency is generated, which is proportional to a distance of an object, from which the light modulated using the modulated signal is reflected. A location resolution of multiple objects is a function of the resolution of the frequency measurement and therefore the measuring time. The method may be implemented in an integrated circuit, for example, by a corresponding analogue circuit, for example. A further advantage of this method is that both the distance to the object and the velocity of the object can be measured by the mixing of the modulated signal with the reception signal. The signals can be mixed by multiplying the modulated signal with the reception signal, for example.

The light source of the vehicle can comprise a light-emitting diode (LED) of, for example, a daytime running light, a low-beam headlight, a turn signal, a taillight, a high-beam headlight, or a reversing light of the vehicle. At typical response times of LEDs, in particular of LEDs which generate blue light, of 5-10 ns, modulation frequencies up to 100 MHz can be used, for example. By using light-emitting diodes of light sources which are available on a vehicle in any case, additional costs for corresponding light-emitting diodes for the distance measurement and a corresponding installation space can be saved. In addition, in particular upon the use of light-

emitting diodes of a daytime running light, a low-beam headlight, or a high-beam headlight of the vehicle, high-performance light-emitting diodes can be used for the distance measurement, which allow a distance measurement over several hundred metres, for example.

5 According to a further embodiment, one of the following modulation methods is used to generate the modulated signal: a frequency-modulated continuous wave method, a random frequency modulation method, a single-frequency modulation method, or a pulse modulation method.

10 In the frequency-modulated continuous wave method, which is also referred to as an FMCW method (frequency modulated continuous wave) or chirp method, a modulation frequency is changed over a specific time from a starting frequency to an end frequency. For example, the modulation frequency is continuously changed from a low starting frequency to a high end frequency and the entire procedure is repeated upon reaching the end frequency, i.e., after
15 reaching the end frequency, the modulation is continued with the starting frequency. The method can be coupled comparatively simply to a velocity measurement. In addition, the method is easily implementable by blanking out a synthetically generated waveform, for example. The light which is generated during this modulation method is well visible due to the continuous signal. The method is therefore suitable above all if an activated light source, for
20 example, a daytime running light, can be modulated. The frequency-modulated continuous wave method can be analysed with the aid of the above-described frequency mixing or with the aid of the above-described correlation, for example.

In the random frequency modulation method, which is also referred to as the RFM method
25 (random frequency modulation) a modulation frequency is changed randomly or pseudo-randomly. This method is particularly advantageous if multiple light sources illuminate a scene simultaneously and measurement is to be performed using all of them simultaneously. Each light source has a random or pseudorandom signature, which can then be differentiated. As in the frequency-modulated continuous wave method, in the random frequency modulation
30 method, the light source is continuously actuated, so that the light source is visible. Therefore, this method is also particularly suitable for a modulation of a daytime running light of the vehicle. In particular the above-described correlation method can be used to analyse the random frequency modulation method, i.e., to determine an item of distance information with the aid of the random frequency modulation method.

35 In the single-frequency modulation method, a constant modulation frequency is used. Therefore, the single-frequency modulation method can be implemented very simply. However, because it reacts very sensitively to interference due to, for example, fog, spray, dust, or foreign light

sources, it can preferably be used where such interference cannot occur due to the installation location or for applications in which a temporary failure can be tolerated. Therefore, the single-frequency modulation method can be used in the interior of the vehicle or in parking aids, for example. The single-frequency modulation also presumes a permanently activated light source and is therefore particularly suitable for use in combination with a daytime running light, for example. An analysis of the single-frequency modulation to determine the distance to an object can be carried out with the aid of a phase measurement, for example, which can be carried out in the scope of the above-described correlation method, for example.

In the pulse modulation method, short pulses are generated, for example, in the range of 10 to 100 ns. These pulses can optionally activate or deactivate the light source for the pulse duration. The measuring frequency can be in the range from 10 to 100 Hz, for example, i.e., the pulses will not be noticed by a human observer because of the low mean power. This applies both in the case of activated light sources, in which the light is deactivated for the period of time of the pulse, and for deactivated light sources, which are activated for the pulse duration. In the case of activated light sources, a "negative light pulse" therefore results, and a "positive light pulse" results in the case of deactivated light sources. An advantageous pulse modulation consists of a pulse sequence which has a high chronological significance via uneven pulse intervals. An analysis of the pulses of the pulse modulation method can be carried out using the above-described correlation method, for example, wherein a mathematical description of the pulse can also be used as a correlation pattern. Alternatively, the reception signal can be scanned over the measuring interval for the analysis of the pulse modulation method. Multiple such echograms can be recorded and added up as a distance histogram via an oversampling method. Echo pulses are then recognized using a pulse analysis and a precise distance is ascertained using a focal point determination, for example. This method is also suitable both for positive and for negative light pulses.

According to a further embodiment, an operating state of the vehicle is determined and one of the modulation methods is selected, i.e., the frequency-modulated continuous wave method, the random frequency modulation method, the single-frequency modulation method, or the pulse modulation method. The modulated signal is generated using the selected modulation method. Therefore, an optimum modulation method for the current situation can be used. The operating state of the vehicle can comprise, for example, a velocity of the vehicle, an activation state of the light source, which indicates whether or not the light source is activated to illuminate an environment of the vehicle or to emit an optical signal, a travel direction of the vehicle, a previously provided item of position information, a weather condition in the environment of the vehicle, or a type of an assistance device of the vehicle, to which the distance information is provided. For example, the single-frequency modulation method can be used at low velocities

during parking of the vehicle, while in contrast at higher velocities, the frequency-modulated continuous wave method or the random frequency modulation method is used. In addition, for example, it can be established whether the method is influenced by a source of interference and another modulation method can be selected as a function thereof. For example, because of the high precision, the frequency-modulated continuous wave method can be used and, if a source of interference is detected, it is possible to change over to the random frequency modulation method.

Furthermore, a device for determining an item of distance information for a vehicle is provided according to the present invention. The device comprises a light source for illuminating an object in an environment of or inside the vehicle, a sensor for receiving light of the light source, which was reflected from the object, and a processing unit, which is coupled to the light source and the sensor. The device is therefore suitable for carrying out one of the above-described methods or one of its embodiments and therefore also comprises the advantages described in conjunction with the method. In particular, the processing unit can be designed to generate a modulated signal and to activate the light source of the vehicle using the modulated signal and to generate a reception signal as a function of the light received using the sensor. Furthermore, the processing unit can be designed to generate a correlation signal by correlating the modulated signal with the received signal or a mixed signal by mixing the modulated signal with the received signal and to determine a distance to the object as a function of the correlation signal or the mixed signal, respectively.

Finally, according to the present invention, a vehicle is provided, which comprises the above-described device, an illumination unit for illuminating an environment or an interior of the vehicle, and a driver assistance system. The illumination unit comprises the light source of the above-described device for determining the distance information. The device is coupled to the driver assistance system and the illumination unit. The device can therefore determine a distance to an object with the aid of the illumination unit of the vehicle and the sensor and can provide this distance information in the driver assistance system.

The present invention will be described hereafter in detail with reference to the drawing.

Figure 1 schematically shows a vehicle according to one embodiment of the present invention and an object in an environment of the vehicle.

Figure 2 shows steps of a method for determining a distance to an object according to one embodiment of the present invention.

Figure 3 shows steps of a method for determining a velocity of an object according to one embodiment of the present invention.

5 Figure 4 schematically shows a circuit of a light-emitting diode light source according to one embodiment of the present invention, which is designed to emit light for a distance measurement.

10 Figure 5 schematically shows the arrangement of components of the light-emitting diode light source of Figure 4 in a shared semiconductor housing.

Figure 6 shows steps of a method for determining a distance of an object according to a further embodiment of the present invention.

15 Figure 7 shows first detection regions of sensors of a device for determining the position of an object according to one embodiment of the present invention.

Figure 8 shows second detection regions of sensors of a device for determining a position of an object.

20 Figure 9 shows an overlap of the first and second detection regions of Figures 7 and 8, as are detected by sensors of a device for determining a position of an object according to one embodiment of the present invention.

25 Figure 10 shows the second detection regions of Figure 8 with additional fuzziness.

Figure 11 shows the overlap of the first and second detection regions of Figure 9 with additional fuzziness of the second detection regions.

30 Figure 12 shows transmitter segments, as are used by a light source of a device according to one embodiment of the present invention to detect a position of an object.

Figure 13 shows receiver segments, as are used by sensors of a device according to one embodiment of the present invention to determine a position of an object.

35 Figure 14 shows an overlap of the transmitter segments of Figure 12 and the receiver segments of Figure 13.

Figure 15 shows a near field view of transmitter segments which are generated according to one embodiment of the present invention by an offset arrangement of transmission diodes.

Figure 16 shows a far field view of the transmitter segments of Figure 15.

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Figure 17 shows method steps of a further method for determining items of distance information according to one embodiment of the present invention.

Figure 18 shows a scene with an object in an environment of a vehicle.

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Figure 19 shows distance histograms of rows of the scene of Figure 18.

Figure 20 shows distance histograms of columns of the scene of Figure 18.

15 Figure 21 shows a vehicle according to one embodiment of the present invention, which simultaneously measures a distance to a leading vehicle and transmits data.

Figure 22 shows steps of a method according to one embodiment of the present invention for determining a distance to an object and for transmitting transmission data.

20

Figure 1 shows a vehicle 10 having a device for determining an item of distance information. The device comprises a light source 11, which is designed to illuminate an object 17 in an environment of the vehicle 10. The light source 11 can comprise, for example, a daytime running light, a low-beam headlight, a turn signal, a taillight, a high-beam headlight, a fog light, or a reversing light of the vehicle 10. The light source can furthermore comprise one or more light-emitting diodes, which generate light to illuminate the environment of the vehicle 10 or a signal light, for example, the light of a turn signal or a brake light. The light source 11 can additionally also comprise an illumination unit for illuminating an interior of the vehicle 10, for example, a dashboard illumination, or a passenger compartment illumination. The device for determining the distance information furthermore comprises an optical sensor 12 for receiving light reflected from the object 17 and a processing unit 13, which is coupled to the light source 11 and the sensor 12. For example, in the arrangement shown in Figure 1, if the object 17 is located at a distance 18 in the region in front of the vehicle 10, light 15 which was emitted by the light source 11 is reflected from the object 17 and received as reflected light 16 by the sensor 12. The mode of operation of the device for determining an item of distance information will be described hereafter with reference to Figure 2.

35

Figure 2 shows a method 20 for the vehicle 10 for determining the distance 18 between the vehicle 10 and the object 17. In step 21, the light source 11 of the vehicle 10 is actuated using a modulated signal. The modulated signal is generated by the processing unit 13. The light 15 which was emitted by the light source 11 is reflected from the object 17 and received as reflected light 16 by the sensor 12 (step 22). In step 23, a reception signal is generated as a function of the received reflected light 16. The reception signal can comprise an analogue or digital electrical signal, for example. In step 24, the reception signal is combined with the modulated signal in the processing unit 13. For example, the modulated signal and the reception signal can be correlated or mixed, as described in detail hereafter. The distance 18 to the object 17 is determined in step 25 from a combination signal, for example, a correlation signal or a mixed signal. The distance to the object 17 thus determined can be provided to a driver assistance system 14 of the vehicle 10, for example. The driver assistance system 14 can comprise, for example, an adaptive cruise control system, a brake assistance system, a parking aid system, or a collision warning system. The object 17 can also be located in the interior of the vehicle 10 and can be illuminated by a corresponding illumination unit of the vehicle in the interior and the reflected light from the object can be received using a corresponding sensor. Distances to objects in the interior of the vehicle can thus be determined, for example, to recognize gestures of an operating system or, for example, in the event of an accident, to detect a current position of the head of an occupant in order to trigger appropriate protective mechanisms, for example, airbags.

In order that the above-described method can be used in the vehicle for different driver assistance systems, it can be necessary to use different transmission and reception methods for the different application cases. These methods can be selected depending on the required distance or application, for example. For this purpose, for example, an operating state of the vehicle 10 can be determined and a corresponding transmission and reception method can be selected as a function of the operating state of the vehicle, i.e., a corresponding modulation method for generating the modulated signal and a corresponding analysis method (for example, mixing or correlation) are selected as a function of the operating state. The modulation method can comprise, for example, a frequency-modulated continuous wave method, a random frequency modulation method, a single-frequency modulation method, or a pulse modulation method. These methods will be described in detail hereafter. The operating state of the vehicle can comprise, for example, a velocity of the vehicle, an activation state of a light source of the vehicle, which indicates whether or not the light source is activated to illuminate an environment of the vehicle or to emit an optical signal, a travel direction of the vehicle, a previously determined item of position information or distance information of an object in the environment of the vehicle, weather conditions in the environment of the vehicle, or another type of an assistance device of the vehicle, to which the distance information is provided.

In the frequency-modulated continuous wave method, which is also referred to as the FMCW (frequency modulated continuous wave) method or as the chirp method, a modulation frequency is changed over a specific time from a starting frequency to an end frequency. The modulation frequency is preferably continuously changed from the starting frequency to the end frequency. The method can be used not only for distance measurement, as described hereafter, but rather also for a velocity measurement of the object 17. The generation of modulation signals, in which a modulation frequency is changed over a specific time continuously from a starting frequency to an end frequency, is known in the prior art and therefore the method can be implemented easily, for example, by blanking out a synthetically generated waveform. Using the method, the distance 18 to the object 17 can be continuously measured, whereby the method is particularly suitable for light sources 11 which are continuously activated. By way of the continuous change of the modulation frequency and therefore the transmission frequency of the light source 11 from a starting frequency to an end frequency, a frequency ramp results. By mixing the transmission signal with the reception signal, which is received by the sensor 12, both the distance 18 and the velocity of the object 17 can be directly measured. If light-emitting diodes (LED) are used as the light source 11, which have typical response times of 5-10 ns, modulation frequencies up to at most 100 MHz can be used, for example. The FMCW modulation can therefore use, for example, the transmission frequency of 10 MHz to 100 MHz continuously over a period of time of 0.5-400 μ s, for example. The distance measurement can optionally be performed by means of frequency mixing or a correlation method if the frequency-modulated continuous wave method (FMCW) is used.

If the frequency-modulated continuous wave method is used, the transmission signal and the reception signal can be compared using a frequency mixer. An object at a specific distance generates a mixed frequency, which is proportional to the distance. The location resolution of multiple objects is a function of the resolution of the frequency measurement and therefore the measuring time. Such a frequency mixing method can be implemented as an analogue circuit in an integrated circuit, for example. For example, if a distance between 0 m and 40 m is to be measured, the light requires approximately $3.3 \text{ ns/m} \times 40 \text{ m} \times 2 = 264 \text{ ns}$ for this distance there and back along the arrows 15 and 16 of Figure 1. A useful signal length for the FMCW signal of approximately 500 ns results therefrom. A modulation down to 10 MHz for this method is therefore too low, so that a frequency deviation between 50 and 100 MHz is preferably to be used, which is changed linearly over 500 ns. At a distance 18 of 25 m, for example, between the vehicle 10 and the object 17, the reception signal is delayed by 165 ns in relation to the transmission signal. As described above, the transmission signal has a frequency deviation of $50 \text{ MHz}/500 \text{ ns} = 100 \text{ kHz/ns}$ due to the modulation. At a signal delay of the reception signal of 165 ns, the reception signal has a frequency lower by 16.5 MHz than the transmission signal.

By mixing the transmission signal with the reception signal, at the exemplary distance of 25 m, a frequency of 16.5 MHz is obtained. Expressed as a general rule, a frequency of 0.66 MHz per metre of distance results due to the mixing.

5 In the case of distance measurement by means of the frequency-modulated continuous wave method, the transmission signal and the reception signal can also be correlated with one another, to determine the distance to the object 17 on the basis of a correlation signal thus generated. For this purpose, the modulated signal which was emitted is correlated in a time-shifted manner with the reception signal. A correlation maximum results at the shifting time, 10 which is proportional to the distance 18 of the object 17. Since substantially noisy signals are analysed, the level of the correlation maximum is a measure of the signal strength, so that various objects 17 can be differentiated. The resolution in the distance can be determined by the scanning frequency of the reception signal, for example. To generate the correlation signal, multiple correlation coefficients can be generated. A respective shifting time is assigned to each 15 correlation coefficient of the multiple correlation coefficients. Each correlation coefficient is formed by correlating the modulated signal, which is shifted by the respective assigned shifting time, with the reception signal. The distance to the object is determined as a function of the multiple correlation coefficients, for example, by determining an absolute or local maximum, and the assigned shifting times. It is advantageous to use a high significance of the signal in the time 20 level by way of the continuously modulated FMCW signal, which contains many frequencies independent of one another. To achieve a high scanning rate of the reception signal, for example, a one-bit conversion can be advantageous. To generate the binary reception signal, the reception signal can be generated using a first signal value if a level of the received light falls below a specific intensity, and a reception signal can be generated using a second signal 25 value if the level of the received light reaches or exceeds the specific intensity. For this purpose, for example, an amplitude-limited amplifier can be used, which generates a reception signal having unambiguous levels, for example, a binary sequence of zeros and ones, as a function of the received light. Since the significance is in the time, hardly any information is lost by this binary conversion, since the significance in the amplitude can be unreliable as a result of the amplitude modulation to be expected due to the object 17. Due to the reception signal reduced to binary signals, a corresponding correlator can be constructed comparatively simply and can be suitable for processing long sequences. This improves the correlation result. If the reception 30 signal is provided in digital or binary form, it is advantageous that the comparison pattern of the modulated transmission signal is also digital. This can be achieved, for example, by using a synthesized digital signal to modulate the light source. This signal can be generated with uniform quality and only depending on a transmit cycle, for example. If the received cycle is equal to the transmit cycle, errors which occur, as a result of temperature drifts, for example, can be compensated for. Long signal sequences can be used due to the use of the correlation 35

method. The usable frequency deviation is therefore not restricted to the runtime of the signal for the distance to be measured. As described above, the method can be implemented solely digitally and therefore can be constructed cost-effectively. For example, a modulated signal having a length of 50 μ s – 500 μ s can be emitted and the frequency can be increased from 10 MHz to 100 MHz over this time. Such a modulated signal may be generated via a shift register in which a synthetically generated signal is stored, for example. A clock frequency with which the transmission signal can be clocked out and the reception signal can be clocked in synchronously can be 1 GHz, for example, and is therefore implementable with comparatively low expenditure. The measuring time of 50 μ s – 500 μ s is so rapid for most applications of driver assistance systems that multiplexing methods are also possible in the case of multichannel sensors. In addition, multiple measurements can be carried out and averaged to further improve the signal quality.

The modulated signal, with which the light source 11 is actuated, can furthermore be generated using a random frequency modulation method. A transmission frequency from a frequency band is randomly varied over a specific time. This method is also referred to as random frequency modulation (RFM). The above-described correlation method can be used in a comparable manner to determine the distance to the object 17. The random frequency modulation method offers a very high level of interference resistance, for example, with respect to scattered light and other measuring methods. In addition, multiple measuring channels can be measured simultaneously, since corresponding crosstalk from other measuring channels is suppressed by the correlation analysis. The modulation frequencies and the time length of the transmission signal can be selected to be comparable to those of the frequency-modulated continuous wave method. The random frequency modulation method can therefore be used in particular if multiple light sources illuminate a scene or a room simultaneously and measurement is to be performed using all of them simultaneously. For example, using the random frequency modulation method, measurements can be carried out simultaneously using all headlights of the vehicle 10. Each light source receives a separate significant signature, which can then be differentiated by the correlation method. In addition, data which are coded into the modulation signal can simultaneously be transmitted to other vehicles or receivers on the roadside. For a continuous distance measurement, a continuous actuation of the light source 11 is necessary, so that this method is particularly suitable for light sources which are continuously activated, for example, a daytime running light or a headlight when travelling at night. The above-described frequency-modulated continuous wave method and the above-described random frequency modulation method can also be used in combination. For example, the frequency-modulated continuous wave method can first be used because of the better signal quality. If sources of interference are detected, for example, light sources of other vehicles, it is possible to switch over to the random frequency modulation method. It is also possible to switch over at least

temporarily to the random frequency modulation method if a data transmission is necessary. The light source 11 and the sensor 12 can be used equally for the frequency-modulated continuous wave method and for the random frequency modulation method.

- 5 Furthermore, a single-frequency modulation method can be used to generate the modulated signal to actuate the light source 11 in the method for determining the distance to the object 17. The single-frequency modulation method uses a constant modulation frequency and is therefore particularly simple to implement. However, it can be interfered with comparatively easily by mist, spray, dust, or foreign light sources, and therefore can be used in particular in applications
10 where such interference cannot occur due to the installation location, for example, or if a temporary failure can be tolerated, for example, in the case of a distance measurement in the interior or in the case of parking aids, in which excessively close measuring does not have negative consequences and the required intervals are low due to the low velocity of the vehicle or spray development is insignificant. For a continuous distance measurement, a permanently
15 active light source is also necessary in the single-frequency method, so that the single-frequency method can preferably be used in conjunction with a daytime running light or a low-beam headlight of the vehicle, for example. A distance determination, i.e., an analysis of the single-frequency modulation method, can be reduced to a phase measurement, for example, which determines a phase difference between the modulated signal and the reception signal.
20 For example, the phase measurement can be performed digitally via an AND linkage by a comparison of the reception signal to the modulated signal. Suitable typical modulation frequencies are in the range from 5-20 MHz, for example. In this range, uniqueness of the phase analysis based on the foundation of the single-frequency modulation can be ensured.
- 25 Finally, a pulse modulation method can be used to generate the modulated signal for actuating the light source 11. Using the pulse modulation method, measurements can also be performed in particular if the light source 11 is deactivated. The short light pulses of the pulse modulation method can be formed such that they are not visible or are hardly visible to the observer. If a light source is activated, the pulse modulation method can also be used, by forming the light
30 source for the pulse duration, or, in other words, by generating "negative" light pulses. The pulse modulation method therefore suggests itself in particular where measurement is to be performed at a low measuring frequency of 10 to 100 Hz, for example, and the light for the measurement is not to be recognizable. Light sources, for example, a low-beam headlight, a turn signal light, a taillight, a brake light, or a reversing light, which are not activated at the
35 measuring time, can be activated using short pulses having a length of 10 to 100 ns, for example, which are not noticed by a human observer because of the low average power. In the case of activated light sources, the light can be deactivated for a short period of time of 10 to 100 ns, for example, whereby a negative light pulse results, which can also be detected by the

sensor 12. The determination of the distance 18 to the object 17 can be performed using the above-described correlation method, for example, if the pulse modulation method is used. In particular, a pulse modulation can be used, which consists of a pulse sequence, which has a high chronological significance via uneven pulse intervals. The reception signal, which is generated as a function of the received light, can in turn be correlated with the modulated signal or alternatively a mathematical description of the pulse can also be used as a correlation pattern for the pulse modulation. The reception signal can be scanned over the measuring interval. Multiple such echograms can be recorded and added up as a distance histogram via an oversampling method. Echo pulses can then be recognized using a pulse analysis and a precise distance 18 can be ascertained using a focal point determination, for example. The method is suitable both for positive and for negative pulses.

As already mentioned above in conjunction with the frequency-modulated continuous wave method, in addition to the distance 18 to the object 17, a velocity of the object 17 can also be determined. This will be described hereafter in detail with reference to Figure 3. Figure 3 shows a method 30 for determining a velocity of the object 17. In step 31, the light source 11 of the vehicle 10 is actuated using a frequency-modulated signal. In step 32, the reflected light 16 is received, which was emitted by the light source 11 and was reflected from the object 17 in the environment of the vehicle 11. In step 33, a reception signal is generated as a function of the received light 16. In step 34, a differential frequency between a frequency of the frequency-modulated signal, using which the light source 11 was actuated, and a frequency of the reception signal is determined by mixing the two signals. An item of velocity information of the object 17 is determined in step 35 on the basis of the mixed signal, i.e., as a function of the differential frequency. The frequency-modulated signal can be generated in particular according to the above-described frequency-modulated continuous wave method, in which the modulation frequency of the frequency-modulated signal is changed over a specific time from a starting frequency to an end frequency. As described above, an item of distance information to the object 17 can also be determined as a function of the reception signal and the frequency of the frequency-modulated signal, for example, by mixing the signals or correlating the signals. The frequency of the frequency-modulated signal is preferably in a range from 10 to 200 MHz.

The method will be described in detail hereafter as an example on the basis of a modulation with the aid of a frequency-modulated continuous wave method (FMCW). In the case of FMCW modulation, a continuous frequency deviation of, for example, 10 MHz to 100 MHz is modulated in 40 microseconds. Due to a distance of 200 metres between the vehicle 10 and the object 17, a shift by 1.32 μ s or 2.97 MHz results. A further mixed frequency results due to a relative velocity of v according to the Doppler formula:

$$f = \left(\frac{c}{c + v} \right) \cdot f_0$$

wherein f is the modulation frequency, f_0 is the frequency of the reception signal, and c is the velocity of light. In the following table, the Doppler frequency shift for various velocities of the object is shown.

Doppler frequency		Modulation frequency				
		20 MHz	40 MHz	60 MHz	80 MHz	100 MHz
Velocity	20 km/h	0.37 Hz	0.74 Hz	1.11 Hz	1.48 Hz	1.85 Hz
	40 km/h	0.74 Hz	1.48 Hz	2.22 Hz	2.96 Hz	3.70 Hz
	60 km/h	1.11 Hz	2.22 Hz	3.33 Hz	4.44 Hz	5.56 Hz
	80 km/h	1.48 Hz	2.96 Hz	4.44 Hz	5.93 Hz	7.41 Hz
	100 km/h	1.85 Hz	3.70 Hz	5.56 Hz	7.41 Hz	9.26 Hz
	120 km/h	2.22 Hz	4.44 Hz	6.67 Hz	8.89 Hz	11.11 Hz
	140 km/h	2.59 Hz	5.19 Hz	7.78 Hz	10.37 Hz	12.96 Hz
	160 km/h	2.96 Hz	5.93 Hz	8.89 Hz	11.85 Hz	14.81 Hz
	180 km/h	3.33 Hz	6.67 Hz	10.00 Hz	13.33 Hz	16.67 Hz
	200 km/h	3.70 Hz	7.41 Hz	11.11 Hz	14.81 Hz	18.52 Hz
	220 km/h	4.07 Hz	8.15 Hz	12.22 Hz	16.30 Hz	20.37 Hz
	240 km/h	4.44 Hz	8.89 Hz	13.33 Hz	17.78 Hz	22.22 Hz
	260 km/h	4.81 Hz	9.63 Hz	14.44 Hz	19.26 Hz	24.07 Hz

- 10 The table shows that the Doppler frequency is dependent on the modulation frequency. A higher modulation frequency also results in a higher Doppler frequency. The FMCW modulation can therefore be changed, for example, such that in 20 μ s, for example, the frequency of 10 MHz is modulated to 100 MHz and then the frequency of 100 MHz is maintained for a further 20 μ s. The Doppler frequency can then be measured at 100 MHz, for example. The Doppler frequency
- 15 can be directly determined by mixing the transmission frequency with the reception frequency, for example. For practical reasons, however, the Doppler frequency can alternatively be determined by mixing the reception signal with a further signal, which has a frequency deviating by a predetermined value from the frequency of the frequency-modulated transmission signal. For example, the reception signal can be compared to or mixed with a signal which has a
- 20 frequency lower by 100 kHz than the frequency-modulated transmission signal. Therefore, in the example shown in the table, frequencies between 100,000 and 100,024 Hz are obtained for the Doppler frequency for velocities between 0 and 260 km/h. These significantly higher frequencies can be measured more easily and can arise within the measuring duration of 20 μ s, for example.

As described above, the light source 11 of the vehicle 10 is to be modulated in a frequency range of 10 MHz to 100 MHz, for example. In particular, light-emitting diode light sources are suitable for this purpose, which use semiconductor light-emitting diodes to generate the light 15.

5 In particular light-emitting diodes which generate ultraviolet or blue light have such a large modulation bandwidth. For the colour conversion into white light or light components of other colours, for example, red or green light, these light-emitting diodes can additionally have phosphor coatings, which convert ultraviolet light or blue light into light of other colours. The high-frequency light for the distance measurement or velocity measurement is in particular the
10 blue light of the light-emitting diodes. The currents through the light-emitting diodes are in the range of several amperes to achieve corresponding light ranges. To achieve efficient modulation, a corresponding actuation of the light-emitting diode must be designed accordingly.

Figure 4 shows a light-emitting diode light source 40, which is also referred to as a modulation circuit and which has a corresponding layout. The light-emitting diode light source 40 comprises
15 a light-emitting diode 41, a switch element 42, and an energy storage element 43. The light-emitting diode 41 can preferably comprise a light-emitting diode which generates blue light or at least has a blue light component, as described above. The switch element 42 can comprise a transistor, for example, in particular a field-effect transistor. The energy storage element can comprise a capacitor, for example. The switch element 42 is actuated by a modulated signal 44.

20 A power supply comprises a ground terminal (GND) 45 and a power supply terminal (Vcc) 46. When the switch element 42 switches through as a result of an activation by the modulated signal 44, a current flows from the supply voltage terminal 46 through the light-emitting diode 41 to the ground terminal 45 and, in addition, a further current of a charge stored in the energy storage element 43 flows from a first terminal 47 through the switch element 42 and the light-
25 emitting diode 41 to a second terminal 48 of the energy storage element 43. As a result of the high switching frequencies, a construction having the shortest possible lines, in particular between the elements 41, 42, and 43, is to be sought, so that the inductance of the lines is as low as possible and therefore losses, susceptibility to interference, and in particular interfering radiation are as low as possible. In the blocked state of the switch element 42, the energy
30 storage element 43 is charged by the supply voltage 46 and the ground terminal 45. In the switched-through state of the switch element 42, the energy storage element provides a very large current through the light-emitting diode 41 for a short period of time. Therefore, in particular the connections between the energy storage element 43, the switch element 42, and the light-emitting diode 41 are to be kept as short as possible. If the lines in the circuit light-
35 emitting diode 41, switch 42, and energy store 43 become excessively long, they represent an inductor, which "opposes" any current change. A very high voltage is thus necessary to be able to generate a modulation, which represents a rapid current change. A few millimetres of line length can already have a substantial influence. The energy which is stored in the lines during

the modulation is partially absorbed in the lines and converted into heat and another part is emitted as interfering radiation. For example, to generate 10 W of light using the light-emitting diode 41, a current of approximately 10 A through the light-emitting diode 41 is necessary. If the light pulse is to be 50 ns long, for example, nearly 200 V are necessary in a wired construction in which the light-emitting diode 41, the switch element 42, and the capacitor 43 are arranged as separate elements on a printed circuit. Accordingly, an energy demand of $200 \text{ V} \times 10 \text{ A} \times 50 \text{ ns} = 0.1 \text{ mJ}$ is necessary. With a construction in SMD technology, for example, 60 V and 10 A are necessary, i.e., an energy demand of 30 μJ . With an optimized construction, which will be shown hereafter in conjunction with Figure 5, however, only 8 V and 10 A are necessary, i.e., an energy demand of 4 μJ . In all cases, approximately 40 W are absorbed in the light-emitting diode 41. The efficiency is thus 50% in the optimized construction, approximately 6% in the construction using SMD technology, and the efficiency is only 2% in the wired construction on a printed circuit.

Figure 5 shows the optimized construction of the light-emitting diode light source 40. The light-emitting diode light source 40 comprises the light-emitting diode 41, the switch element 42, and the energy storage element 43. The switch element 42 is coupled in a series circuit to the light-emitting diode 41. The energy storage element 43 is coupled in parallel to the series circuit of light-emitting diode 41 and switch element 42. When the switch element 42 switches through, a current path is switched through the light-emitting diode 41, which extends from a first terminal 47 of the energy storage element 43 via a first line section 50 to the switch element 42 and extends from there via a second line section 51 to the light-emitting diode 41. The current path extends to the second terminal 48 of the energy storage element 43 via a third line section 52. As shown in Figure 5, the elements 41, 42, and 43 are arranged in a shared housing 54. In other words, the semiconductor elements 41 and 42 and the capacitor 43 are housed without a separate housing in the shared housing 54. The lengths of the connections 50 to 52 can thus be designed to be correspondingly short. For example, the entire current path which connects the energy storage element 43, the light-emitting diode 41, and the switch element 42, can have a length of less than 12 mm. The length of the current path is preferably shorter than 9 mm. Each of the connections 50, 51, and 52 can be 1 to 3 mm, for example. The connections 50 to 52 can form, together with the terminals 44 to 46, a so-called lead frame, which provides the external terminals 44 to 46 of the light-emitting diode light source 40, on the one hand, and provides the connections 50 to 52 for coupling the elements 41 to 43, on the other hand. As a result of the short connection lengths of the connections 50 to 52, a high efficiency of the light-emitting diode light source 40 can be achieved. Multiple light-emitting diode light sources can be implemented in the housing 54, by correspondingly arranging multiple light-emitting diodes 41, switch elements 42, and energy stores 43 on a shared lead frame in the shared housing 54. The light-emitting diode 41 can generate light having a wavelength of less than 760 nm, preferably less

than 500 nm, i.e., blue light in particular. In addition, a phosphor coating can be provided in the housing 54, which converts ultraviolet light or blue light, which is generated by the light-emitting diode 41, into light of other colours. The light-emitting diode light source 40 or multiple of the light-emitting diode light sources 40 can be used in an illumination unit 11 of the vehicle 10, for example, to illuminate an environment of the vehicle 10 or to generate a light signal, for example, a turn signal or a brake light.

In the above-described methods and devices, existing illumination units of the vehicle, for example, headlights of a low-beam headlight, fog lights, turn signals, brake lights, or reversing headlights are used to generate a modulated light signal, which is reflected from an object in the environment of the vehicle and is received by a sensor on the vehicle. A distance or a velocity of the object can be determined from the reception signal of the sensor and the knowledge about the modulated signal, using which the illumination unit of the vehicle was actuated. Since the primary function of the illumination unit is to illuminate an environment of the vehicle or to emit a light signal, for example, a turning signal or a braking signal, a method 60 is described hereafter, which simultaneously ensures a determination of an item of distance information. For this purpose, firstly an operating state of the vehicle is detected in step 61. The operating state of the vehicle can be a setpoint state for the illumination unit of the vehicle, for example, which indicates whether the illumination unit is to be activated or deactivated. The detection of the operating state can furthermore comprise a determination of an ambient brightness in an environment or within the vehicle or a determination of a distance measuring range, for which the distance information is to be determined. In step 62, a modulated transmission signal is generated as a function of the operating state thus determined. For example, a first modulated transmission signal can be generated if the setpoint state for the illumination unit indicates that the illumination unit is to be activated. Furthermore, a second modulated transmission signal can be generated, which is converted to the first modulated transmission signal, if the setpoint state indicates that the illumination unit is to be deactivated. Thus, for example, in the case of deactivated illumination unit, a modulated transmission signal can be generated, which comprises short light pulses, the energy of which is not sufficient to be seen by an observer. Vice versa, if the illumination unit is to be activated, a modulated transmission signal can be generated which deactivates the illumination unit for short pulses, which are so short that they are not noticed by an observer and therefore the illumination unit appears to be continuously activated. In step 63, the illumination unit 11 of the vehicle 10 is actuated using the generated transmission signal. In step 64, reflected light 16 is received, which was emitted as light 15 by the illumination device 11 and was reflected from the object 17. In step 65, a reception signal is generated as a function of the received light 16. In step 66, the reception signal is combined with the transmission signal and in step 67, the distance of the object 17 is determined from the combination.

The amount of light which cannot be seen by an observer is dependent, *inter alia*, on the overall brightness of the environment of the vehicle and a contrast in the transmission plane. During the day, substantially larger amounts of light can be emitted by the illumination unit, which are not noticed by an observer, than at night. A signal-to-noise ratio is typically significantly worse during the day due to the interfering light of the sun, so that during the day higher transmission powers are necessary than at night. During the day, for example, powers of up to 2 mJ can be emitted, which are not noticed by an observer. In the method, an average power of the modulated signal can therefore be set as a function of the operating state, in particular an ambient brightness. Furthermore, the transmission power can be set as a function of a distance measuring range, for which the distance measuring information is to be determined. This is dependent on the requirement of an application, for example, which uses the distance information. A driver assistance system for adaptive cruise control or a collision avoidance system can require a greater distance measuring range than a parking system.

The modulated transmission signal can comprise a pulse-modulated signal, for example. The pulse-modulated signal can have a pulse duration in the range of 1 to 500 ns, preferably 10 to 100 ns. A frequency at which the pulses of the pulse-modulated signal are repeated can be in the range of 1 to 1000 Hz, preferably 10 to 100 Hz.

The illumination unit of the vehicle can comprise the above-described light-emitting diode light source or multiple light-emitting diodes, for example. In the case of white light-emitting diodes, the primary blue light component can be used as a modulation carrier. It is modulated at high frequency with the modulated transmission signal and remains in the spectrum of the white light-emitting diode. The phosphor of the light-emitting diode cannot follow the rapid modulation, since it is generally sluggish. A white, uniformly illuminating light thus results for human perception, while its blue component has the desired modulation.

A further illumination unit of the vehicle can be actuated as a function of the operating state of the vehicle and the modulated transmission signal. For example, the vehicle travels on a highway and a driver assistance system, for example, an adaptive cruise control, is activated. The headlights of the vehicle are deactivated. Therefore, a modulated transmission signal is generated, which comprises short-term light pulses. An item of distance information to an object in front of the vehicle can thus be provided for the adaptive cruise control system. An activation of the driving lights of the vehicle is therefore not necessary, i.e., all of the energy for all light-emitting diode lights of the headlights of the vehicle does not have to be provided, which can be advantageous in particular for an electric vehicle. In particular the adaptive cruise control system requires a long measuring range. If, as described above, the headlights are deactivated

during the day, the high-beam headlights can be used with high energy to emit measuring pulses, which have a long range. In contrast, if the vehicle travels in darkness, the high-beam headlights are modulated by briefly reducing the brightness, to allow the long measuring range. If there is an oncoming vehicle in darkness, operation of the high-beam headlights is no longer possible, in order not to dazzle the driver of the oncoming vehicle. In this case, light-emitting diodes of the low-beam headlights can be modulated by briefly reducing the brightness, to determine an item of distance information. Simultaneously, light-emitting diodes of the high-beam headlights can be modulated using short pulses, to determine an item of distance information, without dazzling the oncoming traffic. In other words, several LEDs are briefly activated (in this case LEDs of the deactivated high-beam headlights) and other light-emitting diodes are briefly deactivated (in this case light-emitting diodes of the low-beam headlights). A long measuring range can thus be made possible, without the light-emitting diodes for the high-beam headlights dazzling or annoying the oncoming vehicle.

In the above-described methods and devices, a distance of the object 17 or a velocity of the object 17 was determined while using an illumination unit 11 provided on the vehicle 10 in any case, e.g., a low-beam headlight, a daytime running light, or a high-beam headlight of the vehicle 10. It will be described hereafter how an item of position information, i.e., in addition an item of direction information of the object 17 in relation to the vehicle 10 can additionally be determined while using the above-described method.

According to one embodiment, the sensor 12 of the vehicle 10 comprises at least two first sensors for receiving light, which was generated by the light source 11 of the vehicle and was reflected from a scene, which comprises the object 17, in the environment of the vehicle. A respective first detection region of the scene is assigned to each of the at least two sensors. The first detection regions are arranged in a row in a first direction. Figure 7 shows 15 first detection regions, which are assigned to 15 first sensors. The 15 first detection regions are arranged in a horizontal direction. Two of the 15 first detection regions are identified with the reference signs 71 and 72. The sensor 12 furthermore comprises at least two second sensors for receiving light reflected from the scene, wherein a respective second detection region of the scene is assigned to each of the at least two second sensors. The second detection regions are arranged in a second direction in a row. The second direction is different from the first direction. In Figure 8, two second detection regions 81 and 82 are shown, which are arranged in a vertical direction in a row. In addition, further detection regions are shown in Figure 8, which are also arranged in pairs in the vertical direction in a row, for example, the two third detection regions 83 and 84. The processing unit 13 is designed to determine a position of the object 17 in the environment of the vehicle 10 as a function of signals of the first and second sensors. One of the first detection regions, for example, the region 71, partially overlaps one of the second

detection regions, for example, the region 81. The one of the first detection regions, i.e., the region 71, can additionally partially overlap a further one of the second detection regions, for example, the region 82, as shown in Figure 9. The third detection regions 83, 84, which are monitored by corresponding third sensors, can be arranged in such a manner that one of the first detection regions, for example, the detection region 71, partially overlaps one of the second detection regions, for example, the region 81, a further one of the second detection regions, for example, the region 82, one of the third detection regions, for example, the region 83, and a further one of the third detection regions, for example, the region 84.

The position determination of the object 17 with the aid of the overlapping detection regions, as were described above, will be described in detail hereafter. In comparison thereto, it is to be noted here, that in the case of non-overlapping detection regions, using five detection regions, for example, only five different position regions can be differentiated for the object 17. By way of the overlap of the detection regions, as shown in Figure 9, however, eight different position regions for the object 17 can be differentiated using the detection regions 71 and 81-84. If only the sensor which is assigned to one of the detection regions 81-84 detects the object 17, the object 17 is located in a region which is assigned to the corresponding sensor and which the region which is assigned to the sensor 71 does not overlap. Therefore, four different regions can already be differentiated for the object 17. If the object 17 is detected in one of the regions 81-84 and additionally in the region 71, the object 17 must be located in one of the four overlapping regions, which result due to the overlap of the region 81 with the region 71, the region 82 with the region 71, the region 83 with the region 71, or the region 84 with the region 71. Four further position regions can thus be differentiated for the object 17. If the sensors are arranged in such a manner that the detection regions shown in Figures 7 and 8 can be monitored separately, by way of the overlap shown in Figure 9, a total of 56 different regions, in which the object 17 can be detected separately, can be implemented using the required 15 first sensors for the regions of Figure 7 and the 16 sensors for the regions of Figure 8.

The second detection regions can additionally in turn be overlapping in the vertical direction and can additionally be overlapping in the horizontal direction with further detection regions, for example, the third overlapping regions 83, 84. This can be achieved, for example, by a so-called "fuzziness" of the assigned sensors. Figure 10 shows the above-described overlap of the second, third, and further detection regions. In combination with the first detection regions of Figure 7, a variety of different regions can therefore be provided for the position determination of the object 17, as shown in Figure 11. By overlapping the first detection regions with one another, the resolution of the position determination of the object 17 can be increased further, which is not shown in Figure 11 for reasons of comprehensibility, however. Furthermore, Figures 9 and 11 show that in particular in the centre, i.e., in the region in which the horizontally

arranged detection regions and the vertically arranged detection regions overlap, a particularly high resolution of the position determination of the object 17 can be achieved. This can be advantageously used for many driver assistance systems of a vehicle, since in particular in the straight-ahead direction of the vehicle, a high resolution is advantageous, while a lower resolution can generally be tolerated in the edge region.

The detection regions of Figures 7-11 are perpendicular to the measuring direction, i.e., perpendicular to the arrow 16 of Figure 1.

A further possibility for determining an item of position information of the object 17 in relation to the vehicle 10 will be described in conjunction with Figures 12-14.

The illumination unit 11 of the vehicle 10 has at least one first light source and one second light source. The first and second light sources are activatable independently of one another. The first light source is designed to illuminate a first illumination region of a scene in an environment of or inside the vehicle 10. The second light source is designed to illuminate a second illumination region of the scene. The first illumination region is different from the second illumination region. In Figure 12, multiple illumination regions 121-127 are shown. For example, the first illumination region can be the region 121 and the second illumination region can be the region 122. The sensor 12 comprises at least one first sensor and one second sensor for receiving light reflected from the scene. A first detection region of the scene is assigned to the first sensor and a second detection region of the scene is assigned to the second sensor. The first detection region is different from the second detection region. Six detection regions 131-136 are shown in Figure 13. For example, the first detection region can be the region 131 and the second detection region can be the region 132. The processing unit 13 activates the first and second light source and optionally further light sources to generate the illumination regions 123-127 and determines a position of the object 17 in the environment of the vehicle 10 as a function of signals of the first and second sensors and optionally further sensors, which are assigned to the detection regions 133-136, and as a function of the activation of the light sources. The regions 121-127 and 131-136 are in the plane of the arrows 15 and 16 of Figure 1, for example.

The detection regions can be arranged aligned with the illumination regions, for example, i.e., the detection region 131 substantially corresponds to the illumination region 121, the detection region 132 substantially corresponds to the illumination region 122, etc. Each of the detection regions can have a predetermined angle range, for example, 10° , or, as shown in Figures 12 and 13, 20° . The segments thus formed can be scanned successively in a so-called time multiplexing method. Since distance measurements can be carried out within a segment within a very short time, for example, within $50 \mu\text{s}$ using the above-described distance measuring

methods, in particular using the frequency-modulated continuous wave method or random frequency modulation method, the entire angle range which is covered by the segments can be scanned in a very short time. For example, if an angle range of 120° is to be scanned in 10° segments, the entire angle range can be scanned in $600\ \mu\text{s}$ at a measuring time of $50\ \mu\text{s}$ per segment. The entire angle range of 120° can be scanned in $6\ \text{ms}$ even at a longer measuring time of $500\ \mu\text{s}$. Typical applications of driver assistance systems require measuring times in the range of $30\ \text{ms} - 50\ \text{ms}$, so that sufficiently rapid scanning is possible. The resolution of the scanning can be improved by not equipping every angle segment with a corresponding transmitter and receiver, but rather by using segments which respectively overlap by half. Figure 14 shows such an overlap of the illumination regions 121-127 with the detection regions 131-136. Both the illumination regions and the detection regions respectively comprise an angle range of 20° . Due to the offset overlap of the illumination regions 121-127 with the detection regions 131-136, twelve 10° segments result, which can be scanned using seven light sources and six sensors. The segments can be arranged adjacent to one another, since a time multiplexing method is used and therefore crosstalk from one segment to an adjacent segment is not relevant. Only one pair composed of transmitter and receiver is always operated at one point in time, so that it can be established unambiguously in which segment a signal occurs. In other words, the first detection region 131 overlaps a subregion of the first illumination region 121 and a subregion of the second illumination region 122. The second detection region 132 comprises a further subregion of the second illumination region 122. The second detection region 132 is separate from the first illumination region 121.

In addition, an item of information for a visual range estimation can be obtained from the arrangement of illumination regions and detection regions described above in conjunction with Figures 12-14, if detection regions which are not assigned to an illumination region at all are simultaneously also analysed. For example, for a distance measurement, the light source for the illumination region 121 and the sensor for the detection region 131 are operated. A measuring segment results in the overlap region between the illumination region 121 and the measuring region 131. Simultaneously or also in a time multiplexing method, a sensor is queried, which is assigned to the detection region 136. If this sensor also reports a distance signal as a result of the light output for the illumination region 121, this can only arise from secondary scattered light. If signals occur here in the case of very remote illumination regions and detection regions, this is because of very thick fog, for example. If the segments are closer together, for example, if the detection region 133 delivers a distance signal, measurable secondary scattering thus already occurs at lower particle densities. By analysing regions at different distances, the fog can be evaluated in a very well graduated manner. A current visual range can be estimated therefrom.

For the segmented illumination of the environment of the vehicle 10, multiple light sources are necessary, as described above. For this purpose, for example, multiple light-emitting diodes of a low-beam headlight or in particular of a daytime running light, which has a linear structure, can be used, for example. In order to achieve a uniform appearance in particular in the case of a linear daytime running light, for example, light-emitting diodes arranged spaced apart in the daytime running light can be interconnected in groups and illuminate a respective illumination region. Interposed light-emitting diodes can illuminate further illumination regions. In other words, for example, the first light source, which is used to generate the illumination region 121, can comprise at least one first light-emitting diode and one second light-emitting diode. A second light source, which illuminates the illumination region 122, can also comprise at least one light-emitting diode or multiple light-emitting diodes. The first and the second light-emitting diodes of the first light source and the light-emitting diode of the second light source are arranged in a row, wherein the light-emitting diode of the second light source is arranged between the first and second light-emitting diodes of the first light source. Since the brightness of the light-emitting diodes can vary during the distance measurement, due to this offset arrangement, these brightness differences cannot be perceived by an observer. Alternatively, however, an interesting design effect can thus also be provided, if the brightness differences are visible to an observer.

Figure 15 shows a near field of illumination regions as a result of an offset arrangement of light-emitting diodes. A strip light 151 comprises 21 light-emitting diodes. The strip light 151 can be a strip light of a daytime running light, for example, and can have a length of 42 cm, for example. Seven illumination regions or segments having an angle of respectively 20° are illuminated using the strip light 151. Each segment is generated by respectively three light-emitting diodes at a distance of 14 cm. Figure 15 shows the segments which can be illuminated by the individual light-emitting diodes. The far field of the segments generated by the light-emitting diodes of the strip light 151 is shown in Figure 16. The illumination regions 121-127, which approximately comprise 20° , are clearly recognizable here.

Various assistance systems of a vehicle can require an item of information of the environment of the vehicle, which provides a high resolution of an image of a scene in front of the vehicle from the viewpoint of the vehicle, wherein each region or pixel of the item of image information is assigned a corresponding distance value to an object in this region. This item of image information can be necessary to be able to detect obstructions above or below a specific region, for example, such as obstructions located on the roadway, such as barriers, which cannot be driven over. Figure 17 shows a method 170 for determining such items of distance information. In step 171, the scene in the environment of the vehicle is illuminated. The method 170 is usable not only outside the vehicle, but rather also inside the vehicle, to be able to recognize

gestures of a driver, for example. The light reflected from the scene is received using the sensor 12 of the vehicle 10. In step 172, multiple first distance histograms are determined as a function of the received light. A respective first strip-shaped region of the scene is assigned to a respective first distance histogram of the multiple first distance histograms. The first distance histogram comprises a strength of reflections in a distance range due to objects in the assigned first strip-shaped region. In step 173, multiple second distance histograms are determined as a function of the received light. A respective second strip-shaped region of the scene is assigned to a respective second distance histogram of the multiple second distance histograms. The second distance histogram comprises a strength of reflections in a distance range due to objects in the assigned second strip-shaped region. In step 174, a distance is determined as a function of the multiple first distance histograms and the multiple second distance histograms for a region of the scene. The region of the scene comprises an intersection region of one of the first strip-shaped regions with one of the second strip-shaped regions. The first strip-shaped regions are preferably parallel to one another along the longitudinal direction thereof and the second strip-shaped regions are preferably parallel to one another along the longitudinal direction thereof. The longitudinal direction of the first strip-shaped regions is preferably perpendicular to the longitudinal direction of the second strip-shaped regions. The first strip-shaped regions can comprise rows of the scene in front of the vehicle or inside the vehicle and the second strip-shaped regions can comprise columns of the scene. To determine the multiple first distance histograms and the multiple second distance histograms, the sensor 12 can comprise a receiver matrix, in which rows and columns can optionally be interconnected, so that a reception signal arises either from the sum of all elements in one column or from the sum of all elements of one row. All rows and columns can be individually measured. The distance measurements can be carried out using one of the above-described methods, for example, by modulating the light source of the vehicle appropriately and correlating or mixing the reception signal from one of the rows or columns with the transmission signal for the illumination unit 11. The receiver matrix can have 300 rows and 700 columns, for example, i.e., a total of 1000 rows and columns. At a measuring time per row or column of 50 μ s, for example, these 1000 measurements can be performed in 50 ms. Only one distance-resolved echogram is available per row or column, respectively, a so-called distance histogram. This can be processed using a method similarly as in a computer tomograph to form a pixel-resolved image. To reduce the processing expenditure, a specific region of interest can be selected using the same method. The corresponding reception elements of the receiver matrix are interconnected for this region and only this region is observed and analysed.

It is possible to change over dynamically between different regions to be analysed and thus to adapt to various driving situations.

The above-described method will be described hereafter with reference to Figures 18 to 20 on the basis of an example. Figure 18 shows a scene in an environment of the vehicle. A vehicle 182 is located on a roadway 181. The scene is subdivided in the form of a matrix into a plurality of regions. In the example shown in Figure 18, the scene is subdivided into 14 rows and 19 columns, so that a total number of 266 regions results. This small number of rows and columns was selected for reasons of comprehensibility in Figures 18 to 20. Practical implementations can have at least 100 rows and at least 200 columns, for example, preferably 300 rows and 700 columns. The sensor 12 accordingly preferably comprises a sensor matrix having a corresponding row and column resolution. The illumination unit 11 of the vehicle 10 illuminates the scene shown in Figure 18, preferably using a light-emitting diode light source, and an analysis is performed using one of the above-described modulation methods, for example, the frequency-modulated continuous wave method, the random frequency modulation method, the single-frequency modulation method, or the pulse modulation method. By interconnecting the receiver matrix in rows or columns, distance-resolved echograms are generated for the rows and columns.

Figure 19 shows corresponding distance-resolved echograms for the 14 rows of the scene of Figure 18. The echogram for the fifth row from the bottom of the scene of Figure 18 is to be described hereafter in detail as an example. The echogram for this fifth row is identified in Figure 19 with the reference sign 191. As is apparent from Figure 19, the echogram has an elevated signal level in the range from 60 to 110 metres. Vice versa, essentially no signal level is present in the range from 10 to 60 metres and in the range from 110 to 150 metres. This means that at least one object is located in the range from 60 to 110 m in the fifth column. However, multiple objects can be present in this region. It is not apparent from the echogram of Figure 19 where the object is located in the horizontal direction, i.e., in which column region the object is located.

Figure 20 shows corresponding echograms for the 19 columns of the scenes of Figure 18. Reference is made as an example in this context to the column 6 from the left of Figure 18, which is identified in Figure 20 with the reference sign 201. The echogram 201 of the sixth column shows that one object or multiple objects is/are located in the range of 60 to 110 metres distance. The echogram of the columns again contains no information about the distribution of the objects within the column.

A corresponding item of distance information to objects in the scene can be determined from the entirety of the echograms for each of the 266 individual regions of the scene of Figure 18. An item of region-specific information can be obtained with the aid of a two-dimensional Fourier transform, for example, from the distance-resolved echograms of the rows and columns.

The distance-resolved echograms in Figures 19 and 20 are dimensionless and can indicate a relative size, for example, which indicates what percentage of the surface region in the form of rows and columns has a respective distance to the vehicle.

5

Both with pulse modulation and with the random frequency modulation method (RFM), it is possible to encode an item of information in the emitted signal 15, which can be decoded by a receiver. This information can be used, for example, for communication between vehicles, so-called car-to-car communication, or for communication between the vehicle 10 and an infrastructure object, for example, a traffic signal or a traffic control system. Figure 22 shows a method 220, using which items of digital information can be transmitted simultaneously with a distance measurement. Figure 21 shows the vehicle 10 and a further vehicle 210 and an infrastructure object 211. Using the method 220 described in Figure 22, a distance between the vehicles 10 and 210 can be measured and an item of information, in particular an item of digital information, can be transmitted to the vehicle 210 or the infrastructure object 211 simultaneously.

In step 221, a modulated signal is generated as a function of transmission data, which are to be transmitted by the vehicle 10. In step 222, the light source 11 of the vehicle 10 is actuated using the modulated signal. In step 223, light 16, which was emitted as light 15 by the light source 11 and was reflected from the vehicle 210 or another object in the environment of the vehicle 10, is received. In step 224, a reception signal is generated as a function of the received light. The reception signal can comprise an analogue electrical signal or a digital signal, for example. In step 225, the reception signal is combined with the modulated signal, for example, with the aid of the above-described correlation method, and in step 226, the distance between the vehicle 10 and the vehicle 210 is determined from a combination signal of this combination. The modulation method for generating the modulated signal can comprise in particular a random frequency modulation method or a pulse modulation method. In the frequency modulation method, a modulation frequency is changed as a function of the transmission data. In the pulse modulation method, a pulse interval or a pulse length is changed as a function of the transmission data. The modulated signal can additionally be generated as a function of random data.

The data which are to be transmitted from the vehicle 10 are therefore transmitted in the modulation of the transmission signal. For example, as shown in Figure 21, a bit sequence 213 can be transmitted with the aid of the modulated transmission signal from the vehicle 10 both to the vehicle 210 travelling ahead and to the infrastructure object 211, as shown by the light propagation arrows 15 and 212. Receivers in the vehicle 210 or in the infrastructure object 211,

respectively, can receive and demodulate the modulated transmission signal and thus reclaim and process the transmission data 213. The encoding of the transmission data 213 in the modulated transmission signal will be described hereafter in detail as an example for a pulse modulation method and a random frequency modulation method (RFM).

5

In the pulse modulation method, light pulses are transmitted at a pulse repetition rate. This is typically long in comparison to the pulse length of the light pulses. Since it is unfavourable for the distance measurement if the pulse repetition rate is constant, the interval between the pulses can be varied in a certain range to avoid beat states, for example. To transmit data, for example, this variation of the interval between the pulses can be subdivided into a static component and a systematic component. For example, pulses having a length of 50 ns and a pulse repetition rate of 25 kHz, i.e., 40 μ s, can be used. To measure a distance in the range of up to 250 m, for example, the pulse interval should not fall below $250 \text{ m} \times 6.6 \text{ ns/m} \times 2 = 3.3 \mu\text{s}$. It is therefore possible to vary the pulse interval between 3.3 μ s and 76 μ s. In a system having a runtime distance measurement and a base timing of 25 ns, 2936 possible variations result. Of these, 512 can be used, for example, to transmit 9 bits. Of these, for example, 6 bits can comprise the transmission data to be transmitted and the remaining 3 bits can be randomly varied. The interval between the pulses therefore varies by 12.8 μ s from 33.6 to 46.6 μ s. Therefore, 6 bits of transmission data can be transmitted every 40 μ s, whereby a net data rate of 150 kb per second is achieved.

20

In random frequency modulation (RFM), for example, frequencies can be varied from 10 MHz to 100 MHz within 40 μ s. In a random frequency modulation method without data transmission, multiple frequencies are statically selected randomly from this frequency band, which are then modulated successively and thus result in a frequency train which is significant for the measurement. For the transmission of the transmission data, the frequency selection is no longer carried out randomly, but rather comprises at least one systematic component. For example, frequencies can be synthesized in frequency steps of 10 kHz from the band from 10 to 100 MHz. Therefore, 9000 different frequencies are possible. Of these, for example, 512 can again be used as significant frequencies, so that a frequency interval of approximately 175 kHz results for each item of information. A typical frequency modulation receiver can differentiate frequencies by 50 kHz without problems, so that the transmitted items of information can easily be decoded if a frequency interval of 50 kHz or more is maintained. For the random variation to reduce interfering influences, 125 kHz or ± 62.5 kHz still remains.

35

List of reference numerals

	10	vehicle
	11	light source
5	12	optical sensor
	13	processing unit
	14	driver assistance system
	15	light
	16	reflected light
10	17	object
	18	distance
	20	method
	21-25	step
	30	method
15	31-35	step
	40	light-emitting diode light source
	41	light-emitting diode
	42	switch element
	43	energy storage element
20	44	modulated signal
	45	ground terminal
	46	power supply terminal
	47	first terminal
	48	second terminal
25	50-52	connections
	54	housing
	60	method
	61-67	step
	71, 72	detection region
30	81-84	detection region
	121-127	illumination region
	131-136	detection region
	151	strip light
	170	method
35	171-174	step
	181	roadway
	182	vehicle
	191	echogram

	201	echogram
	210	vehicle
	211	infrastructure object
	212	light propagation arrow
5	213	transmission data
	220	method
	221-226	step

10

Patent Claims

1. Method for a vehicle, comprising:

- actuating a light source (11) of the vehicle (10) using a modulated signal,
- 5 - receiving light (16), which was emitted by the light source (11) and was reflected from an object (17) in an environment of the vehicle (10), and
- generating a reception signal as a function of the received light (16), characterized by:
- generating a correlation signal by correlating the modulated signal with the reception signal, and
- 10 - determining a distance (18) to the object (17) as a function of the correlation signal.

2. Method according to Claim 1, characterized in that the generation of the correlation signal comprises a generation of multiple correlation coefficients, wherein a respective shifting time is assigned to each correlation coefficient of the multiple correlation coefficients, wherein each
15 correlation coefficient is formed by correlating the modulated signal, which is shifted by the respective assigned shifting time, with the reception signal, wherein the distance (18) to the object (17) is determined as a function of the multiple correlation coefficients and the assigned shifting times.

20 3. Method according to Claim 1 or 2, characterized in that the generation of the reception signal comprises a generation of the reception signal using a first signal value if a level of the received light (16) falls below a specific intensity, and a generation of the reception signal using a second signal value if the level of the received light (16) reaches or exceeds the specific intensity.

25 4. Method for a vehicle, comprising:

- actuating a light source (11) of the vehicle (10) using a modulated signal,
- receiving light (16), which was emitted by the light source (11) and was reflected from an object (17) in an environment of the vehicle (10), and
- generating a reception signal as a function of the received light (16), characterized by:
- 30 - generating a mixed signal by mixing the modulated signal with the reception signal, and
- determining a distance (18) to the object (17) as a function of the mixed signal.

5. Method according to Claim 4, characterized by:

- determining a velocity of the object (17) as a function of the mixed signal.

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6. Method according to any one of the preceding claims, characterized in that the light source (11) comprises a light-emitting diode of

- a daytime running light of the vehicle (10),

- a low-beam headlight of the vehicle (10),
- a turn signal of the vehicle (10),
- a taillight of the vehicle (10),
- a high-beam headlight of the vehicle (10), and/or
- 5 - a reversing light of the vehicle (10).

7. Method according to any one of the preceding claims, characterized in that a modulation method for generating the modulated signal comprises:

- a frequency-modulated continuous wave method, in which a modulation frequency is
- 10 changed over a specific time from a starting frequency to an end frequency,
- a random frequency modulation method, in which a modulation frequency is changed randomly,
- a single-frequency modulation method, in which a modulation frequency is constant, and/or
- 15 - a pulse modulation method.

8. Method according to one of the preceding claims, further comprising:

- determining an operating state of the vehicle (10),
- selecting a modulation method as a function of the operating state of the vehicle (10),
- 20 wherein the modulation method comprises a frequency-modulated continuous wave method, a random frequency modulation method, a single-frequency modulation method, and/or a pulse modulation method, and
- generating the modulated signal using the selected modulation method.

25 9. Device for determining an item of distance information for a vehicle, comprising:

- a light source (11), which is implemented to illuminate an object (17) in an environment of or inside the vehicle (10),
 - a sensor (12) for receiving light (16) of the light source (11) reflected from the object (17), and
 - 30 - a processing unit (13), which is coupled to the light source (11) and the sensor (12),
- characterized in that the device for carrying out the method is implemented according to any one of the preceding claims.

10. Vehicle comprising:

- 35 - a device according to Claim 9,
- an illumination unit (11) for illuminating an environment or an interior of the vehicle (10), wherein the illumination unit (11) comprises the light source, and
- a driver assistance system (14),

wherein the device is coupled to the driver assistance system (14) and the illumination unit (11).

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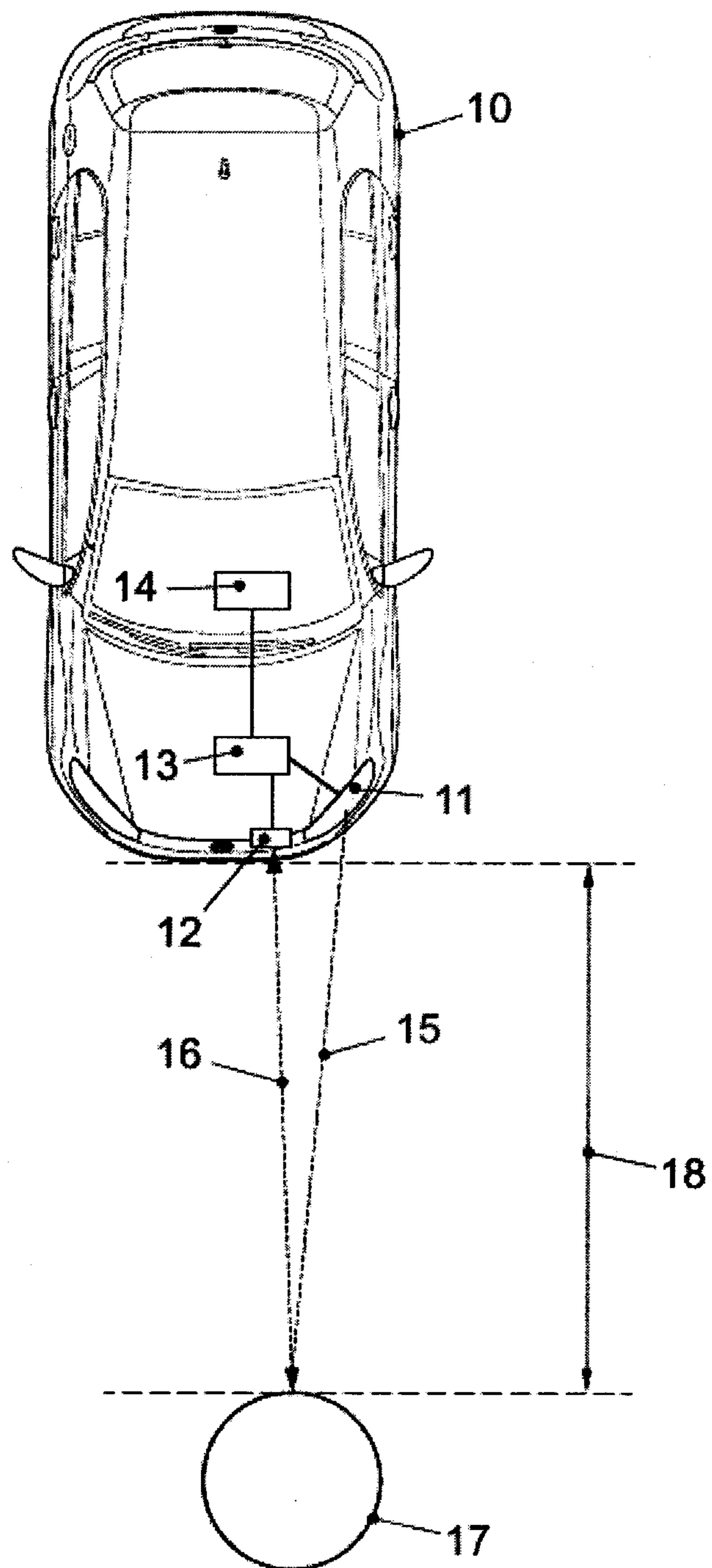


FIG. 1

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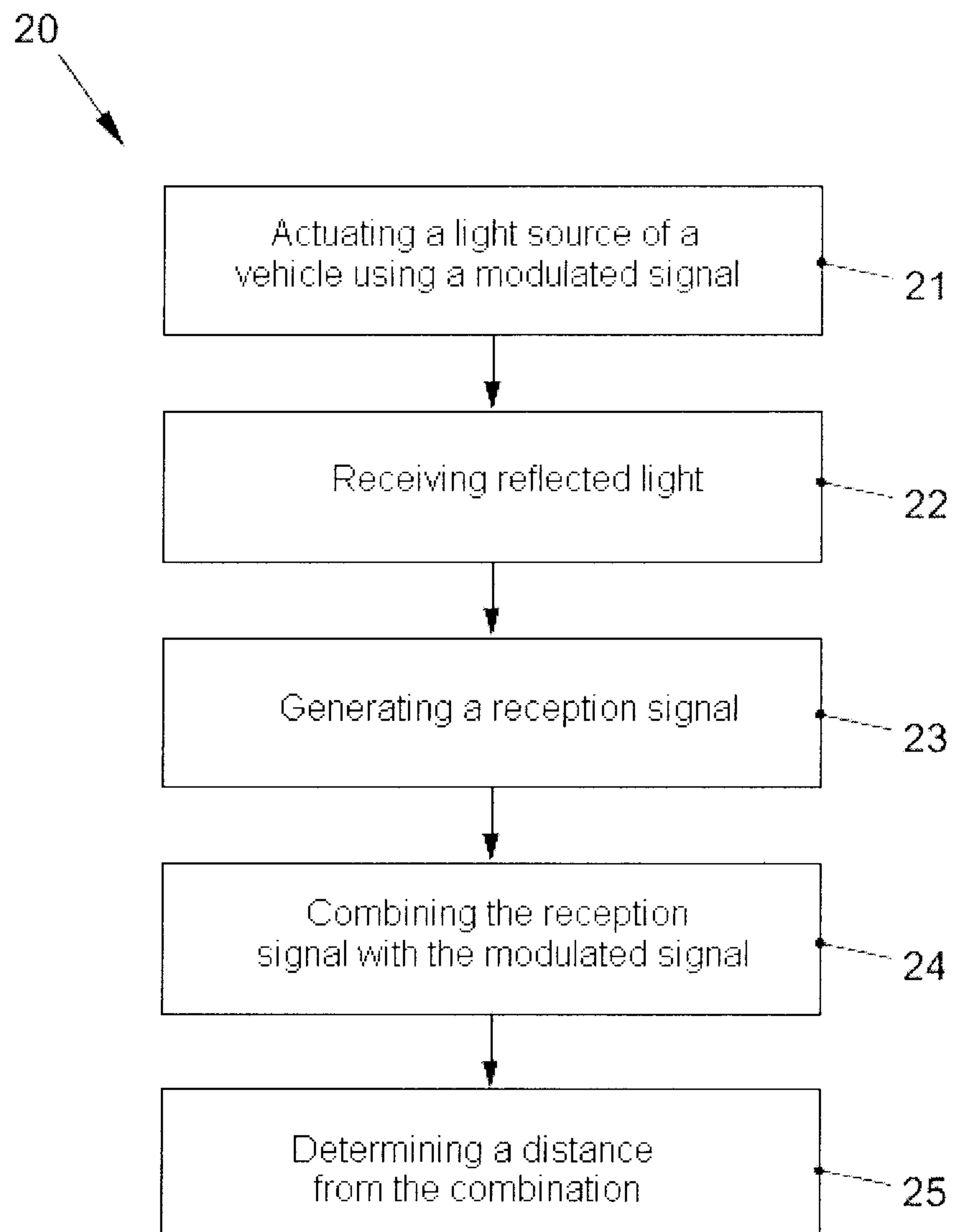


FIG. 2

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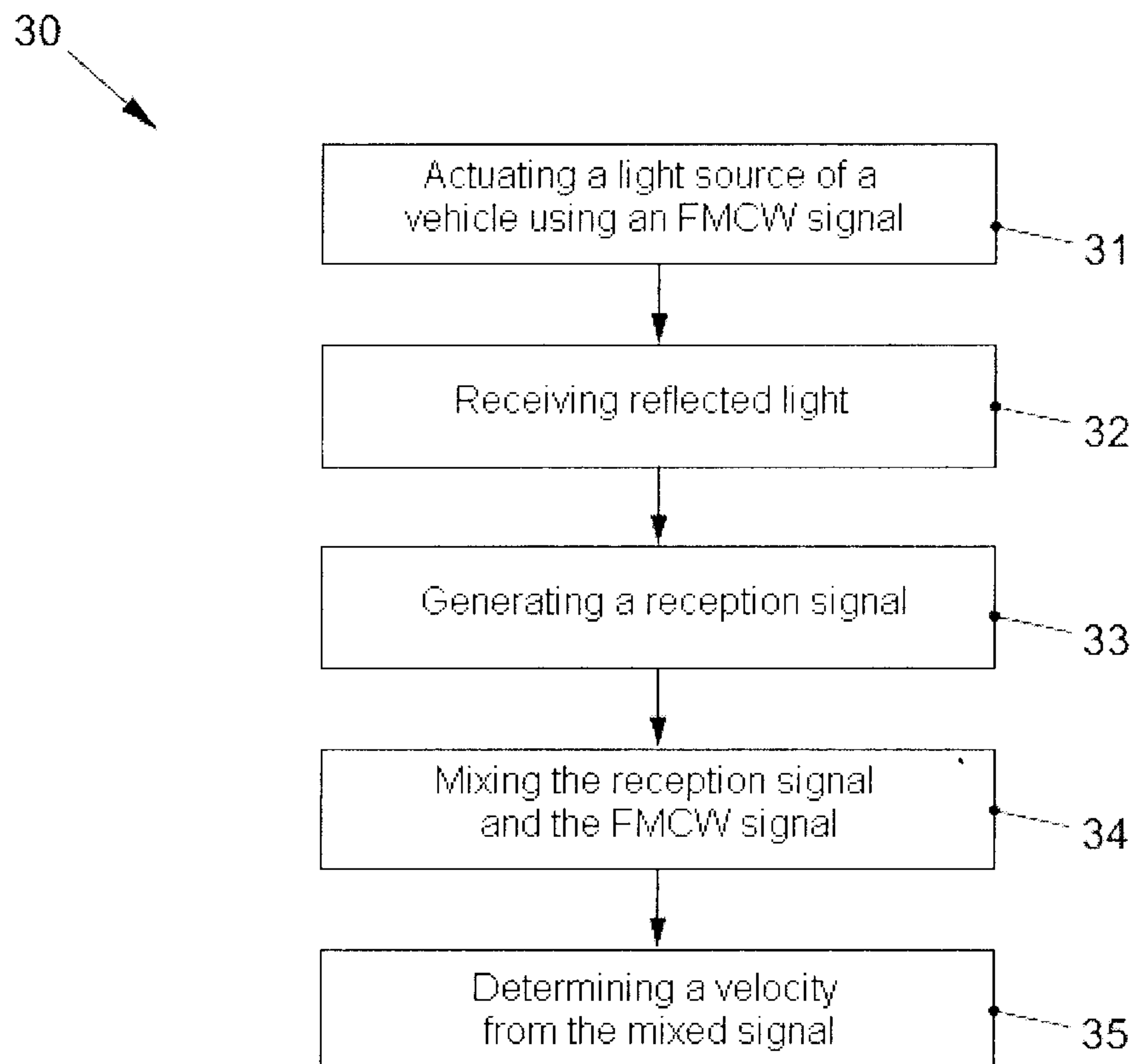


FIG. 3

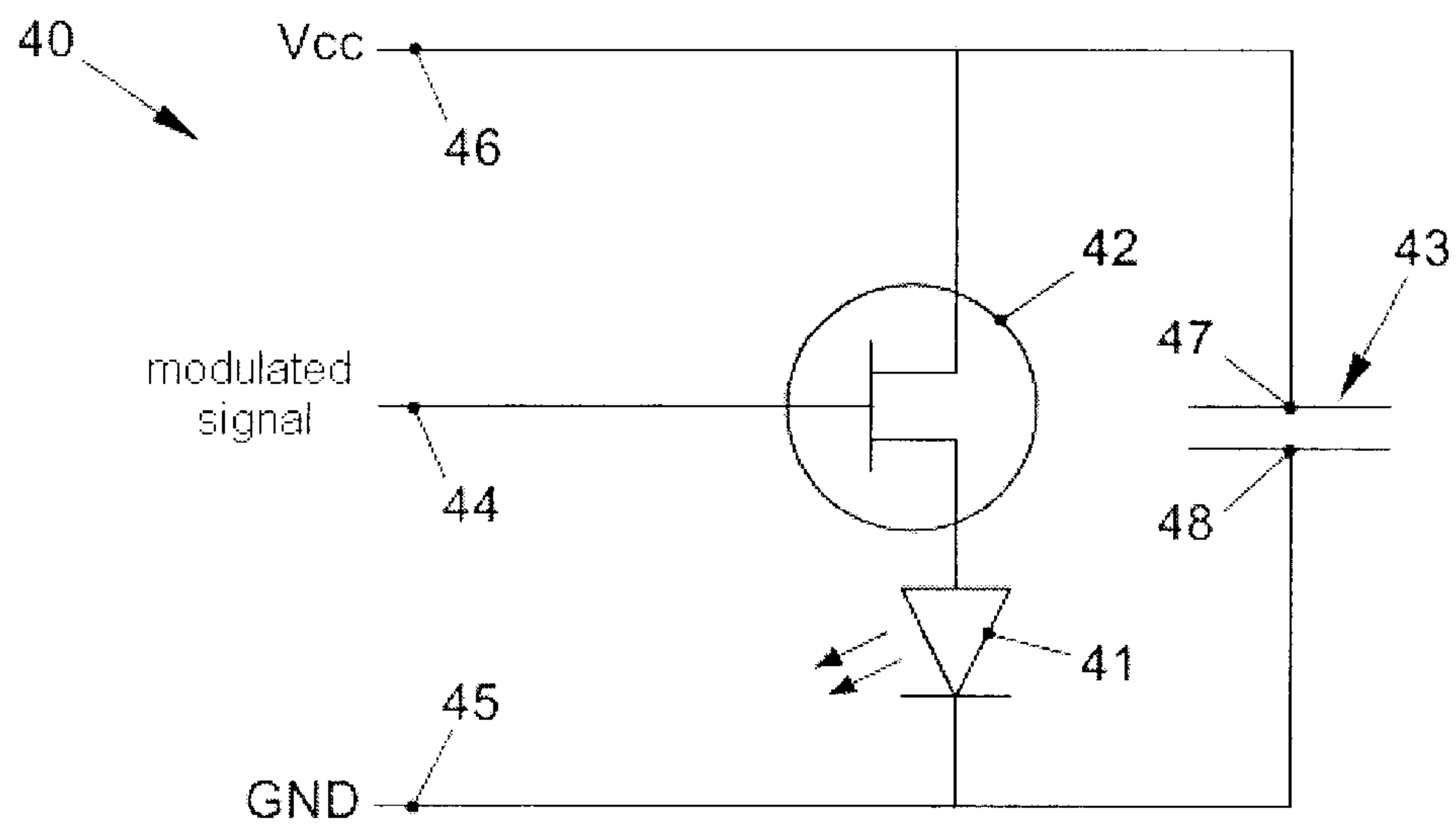


FIG. 4

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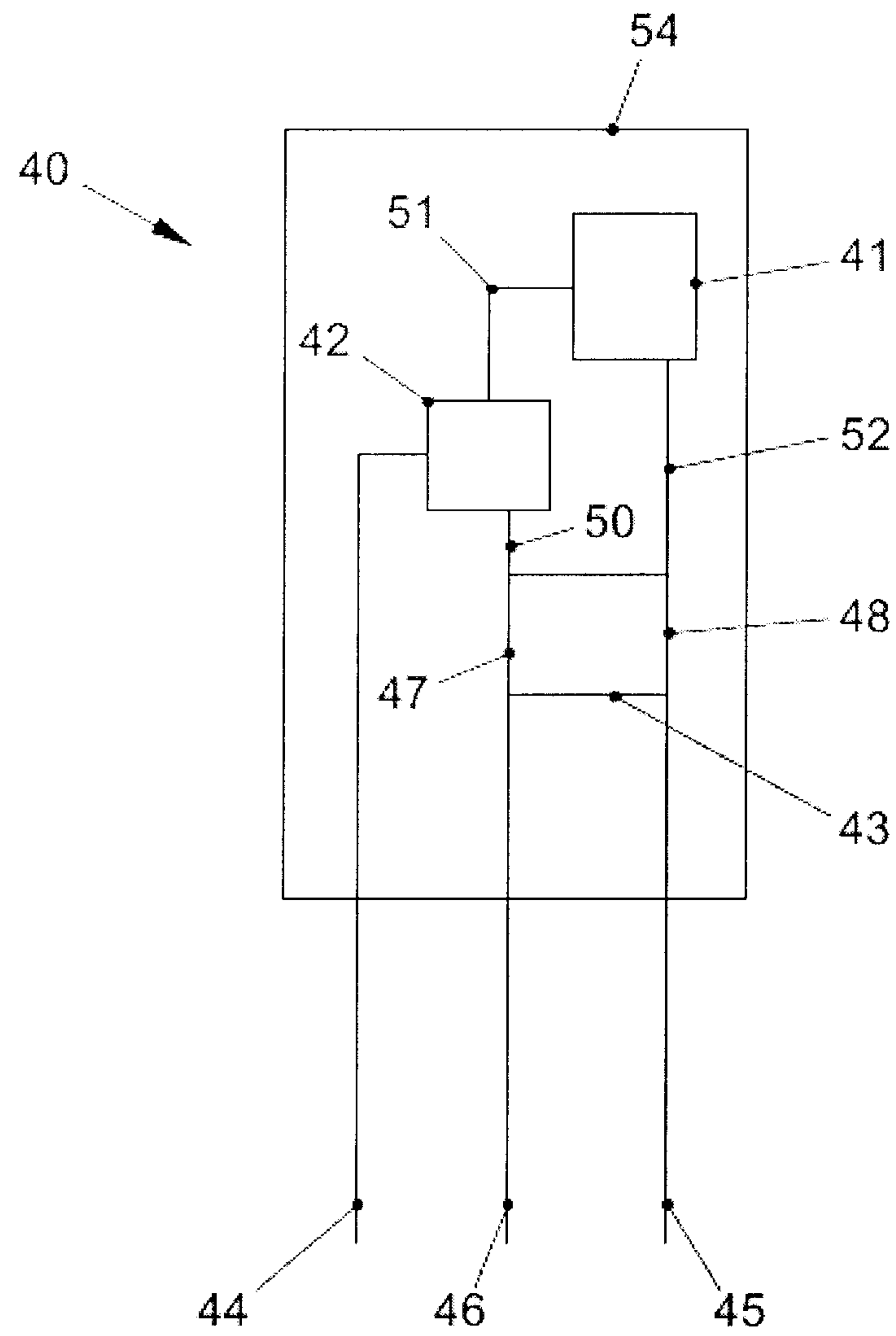


FIG. 5

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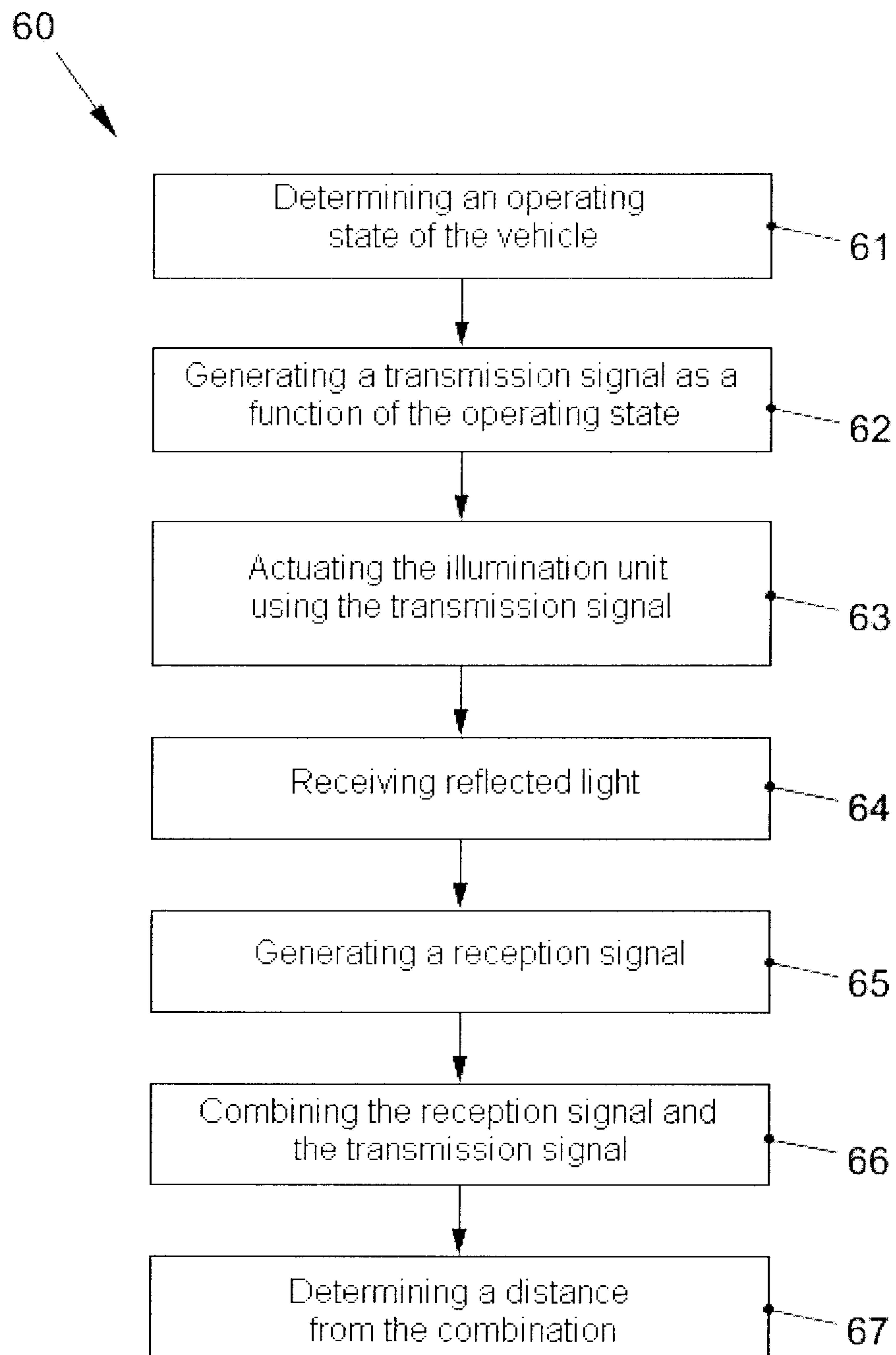


FIG. 6

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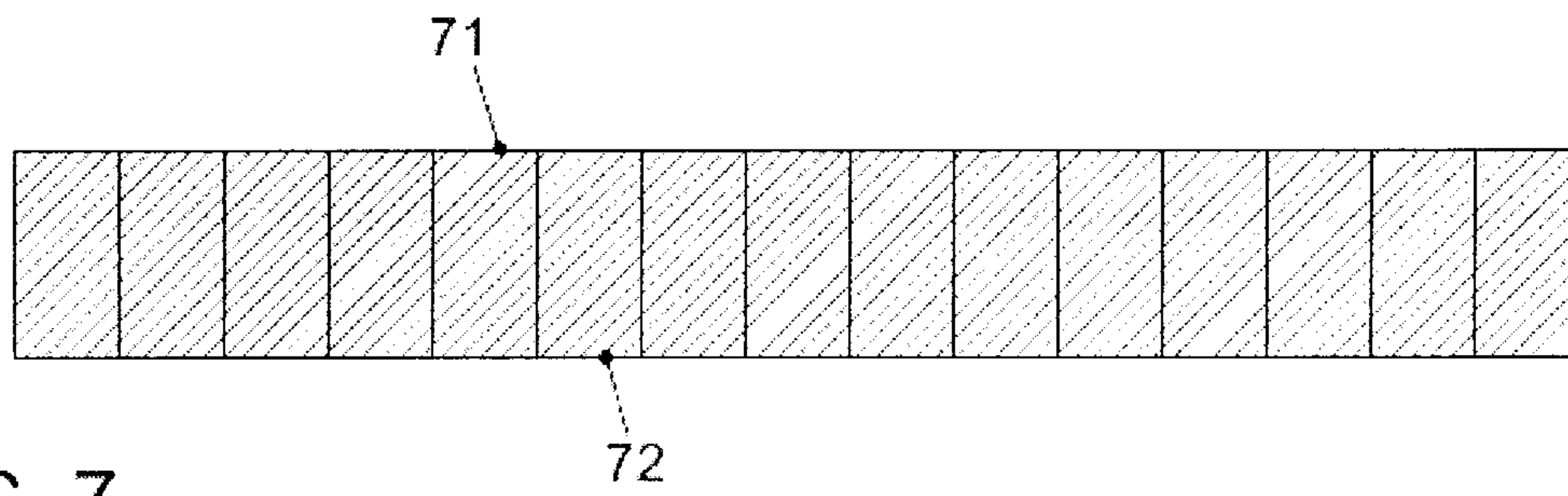


FIG. 8

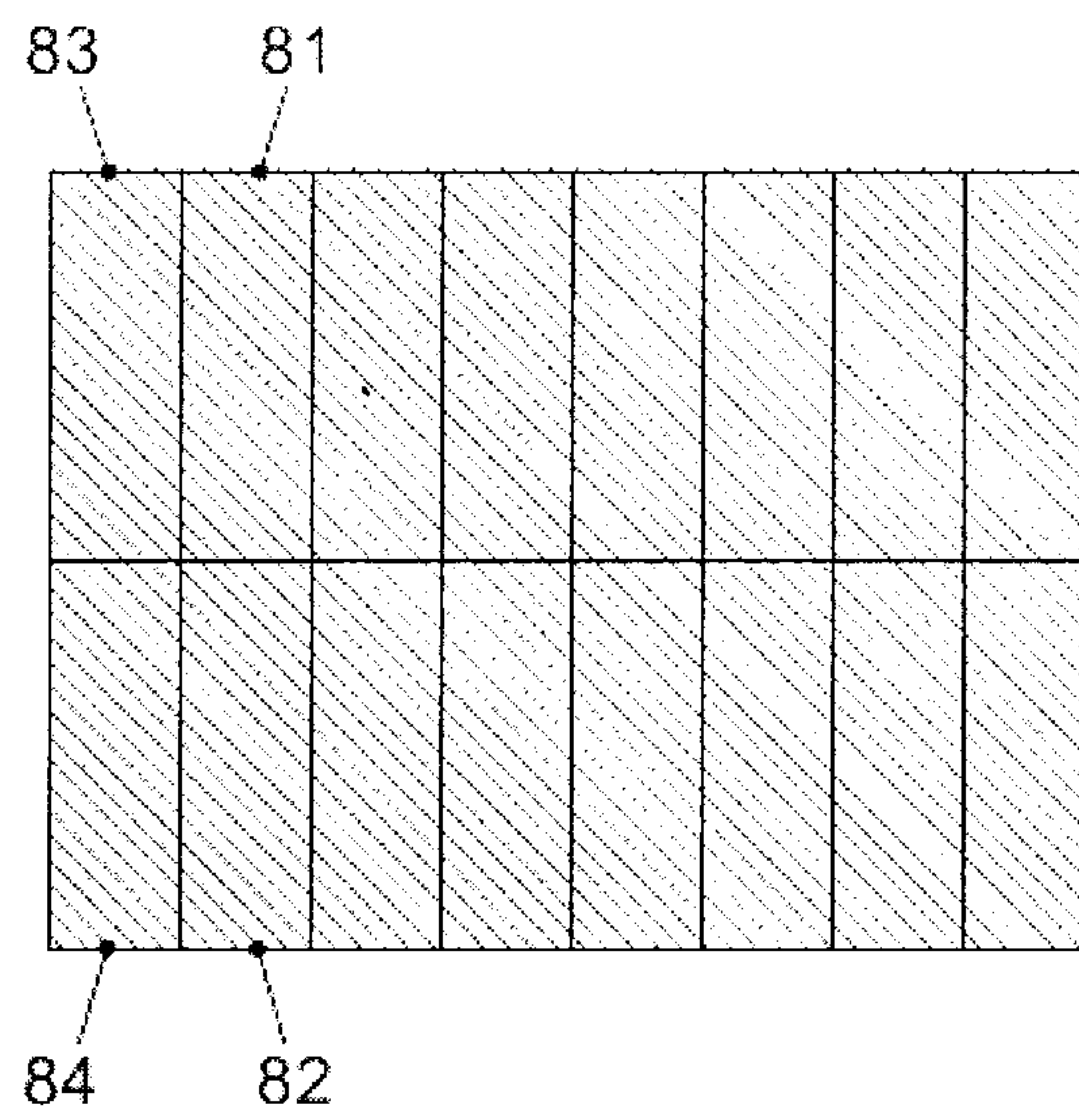
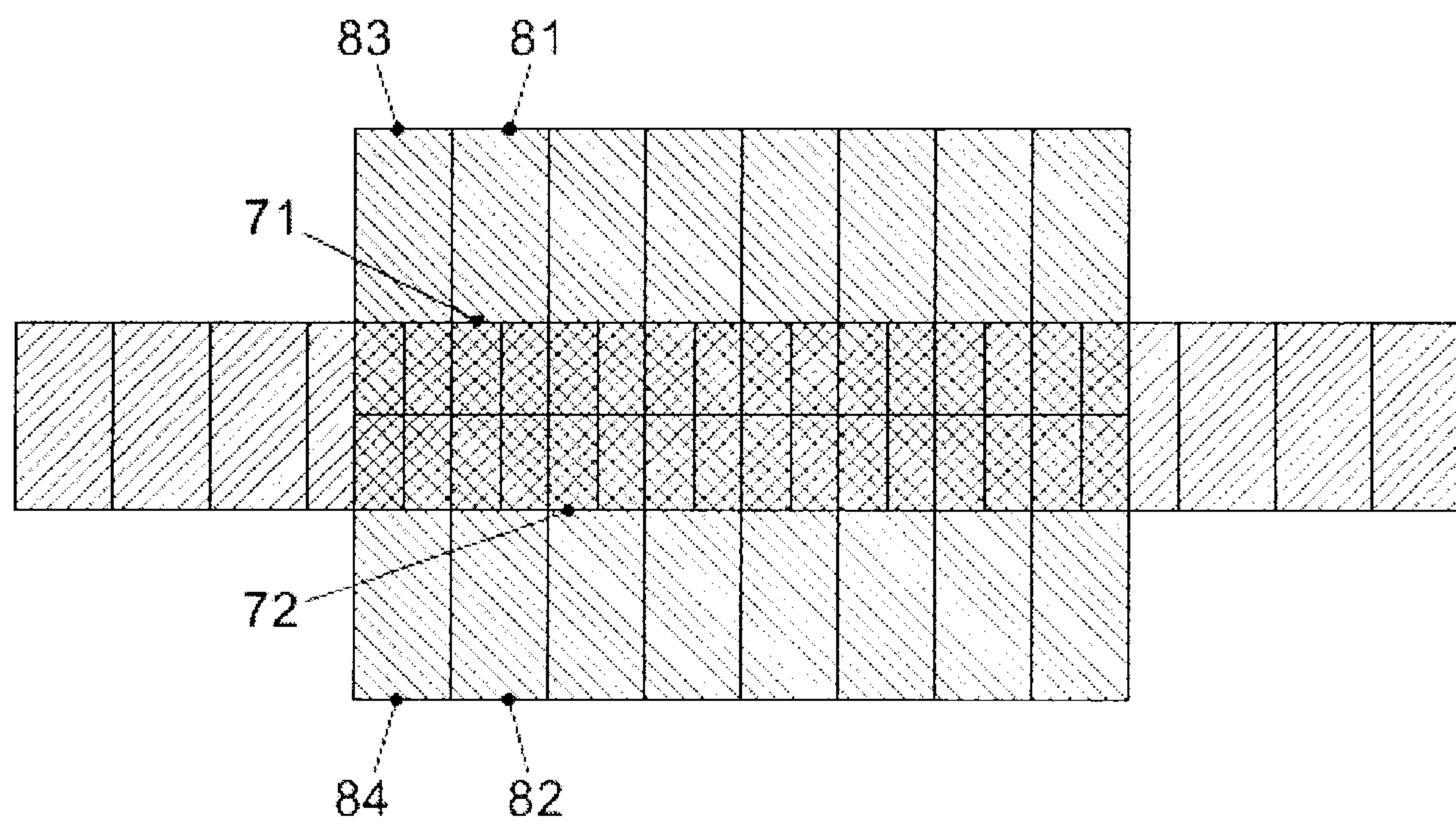


FIG. 9



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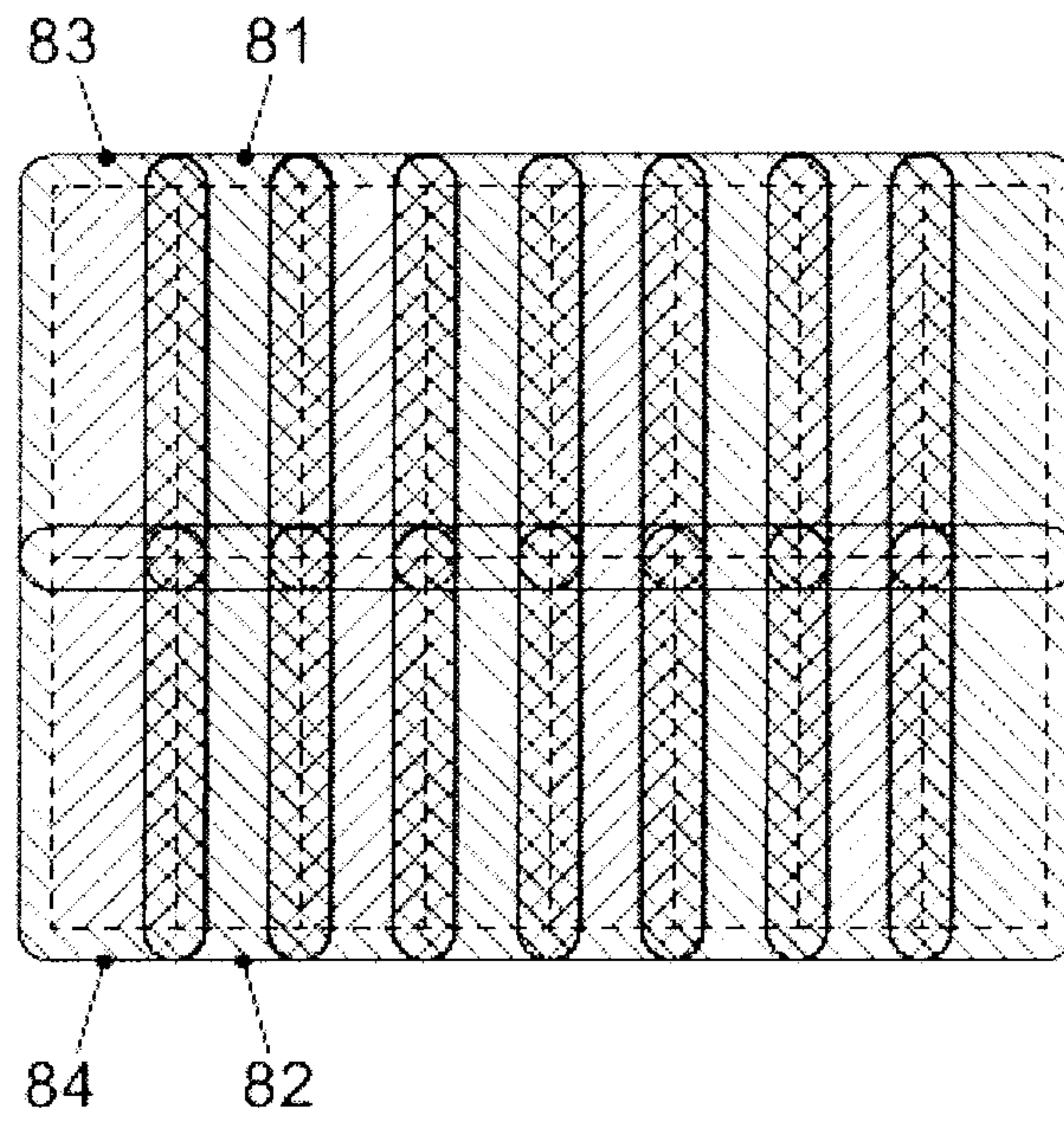


FIG. 10

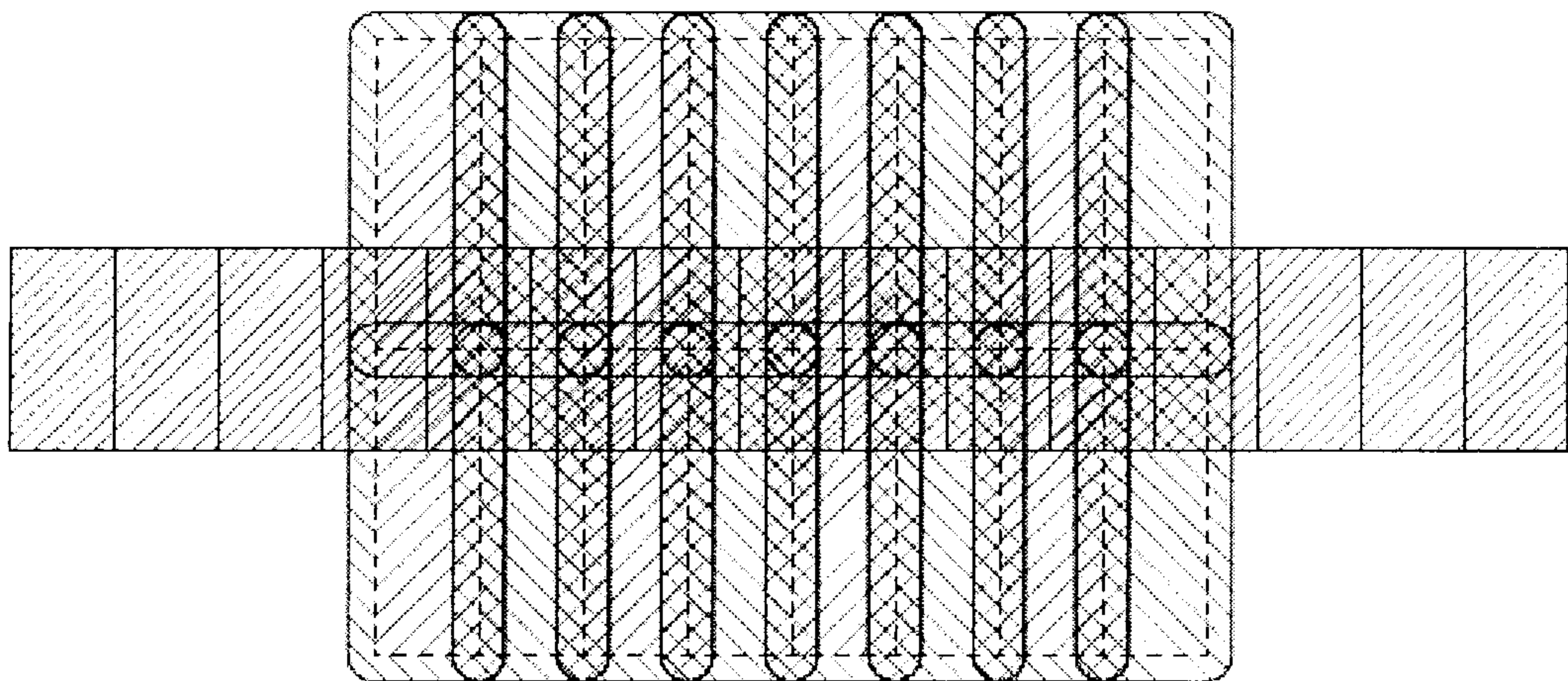


FIG. 11

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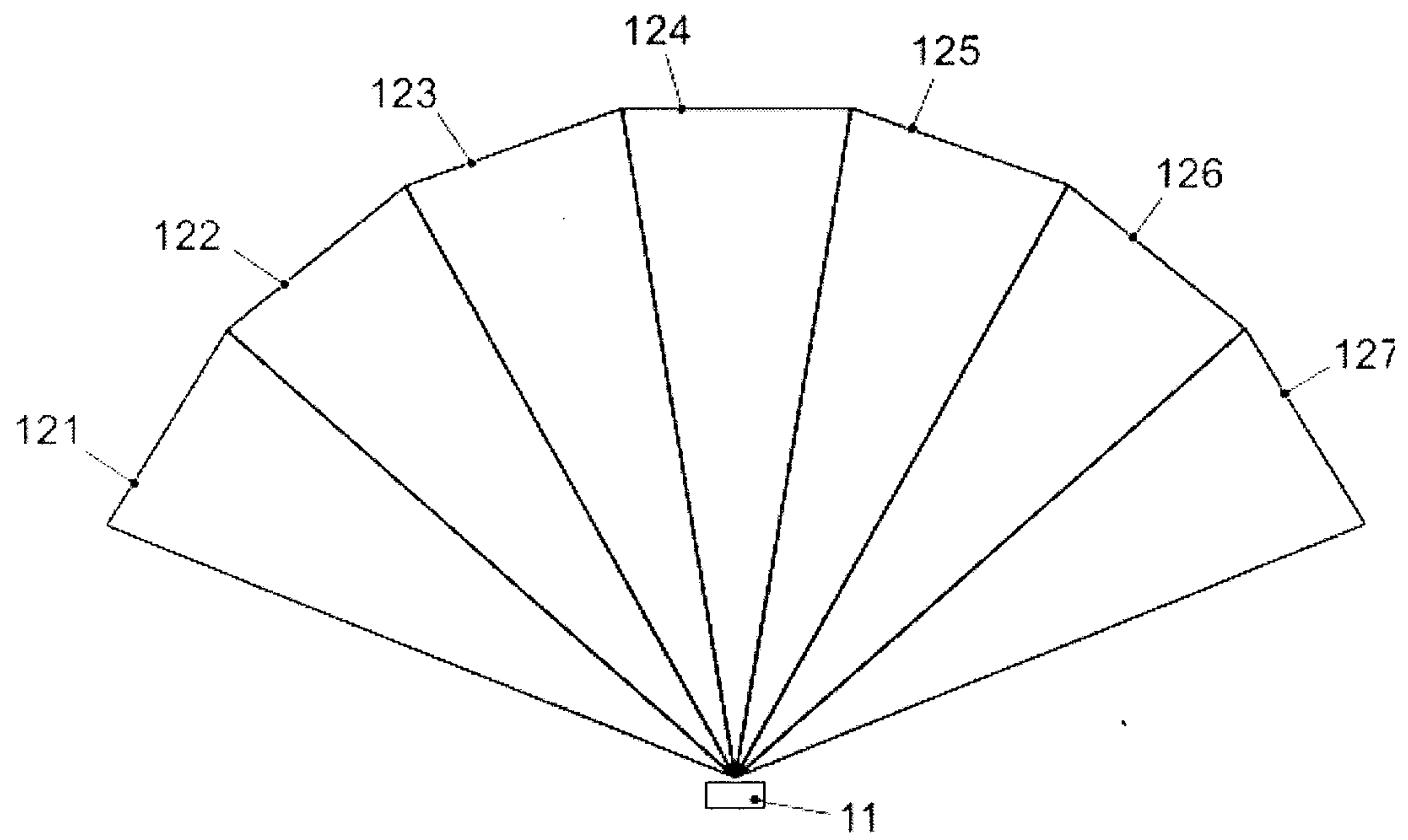


FIG. 12

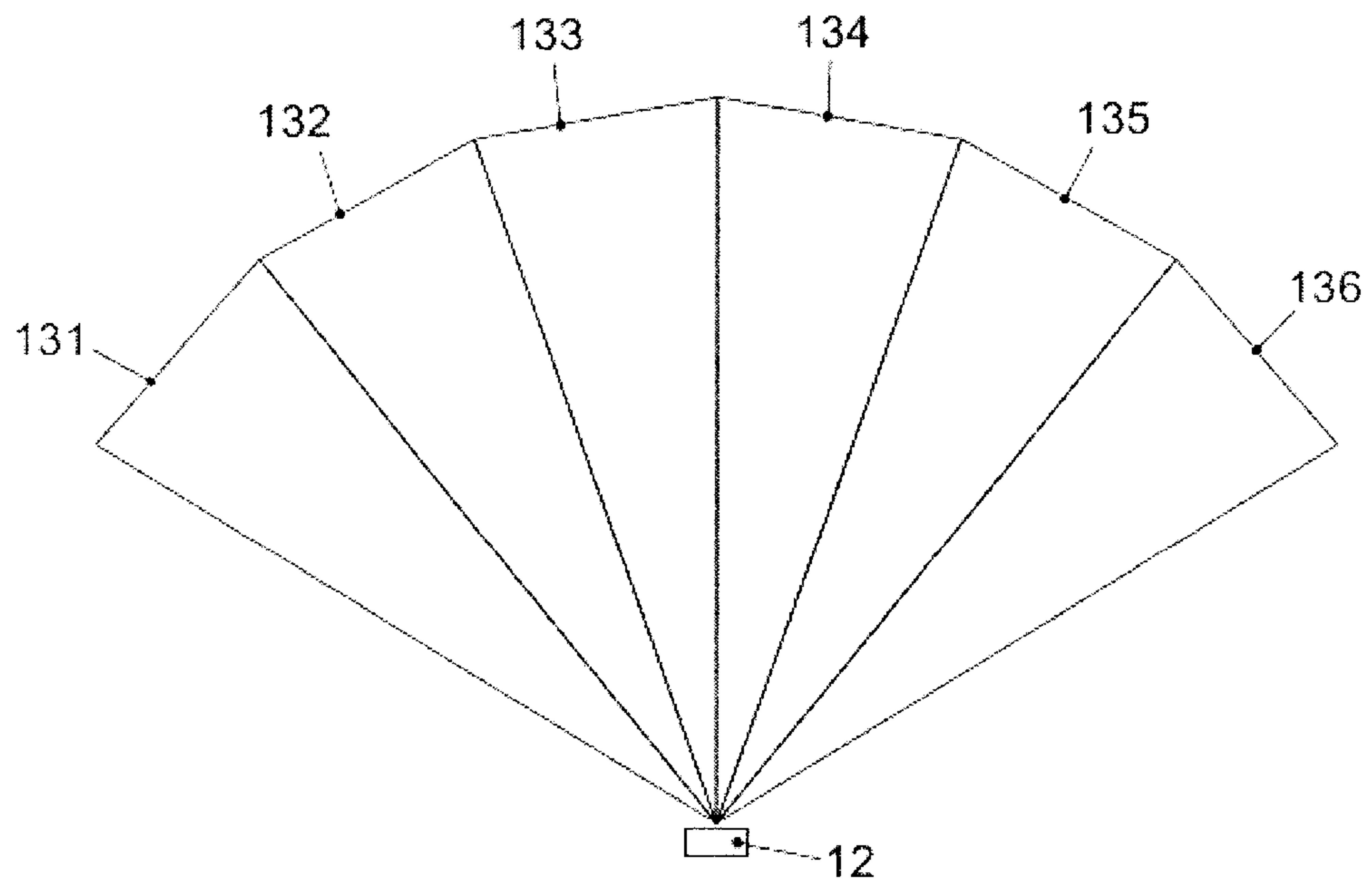


FIG. 13

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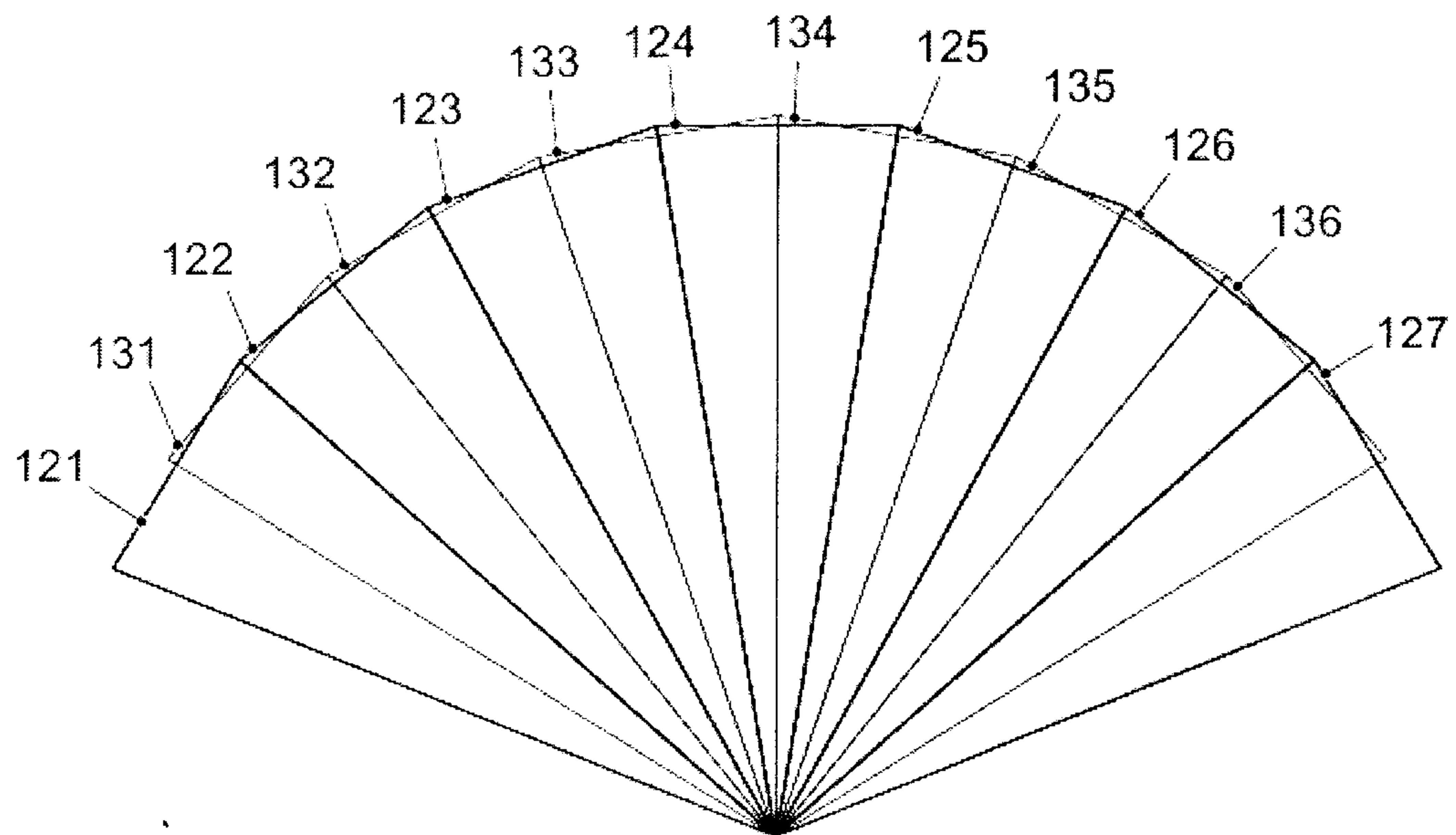


FIG. 14

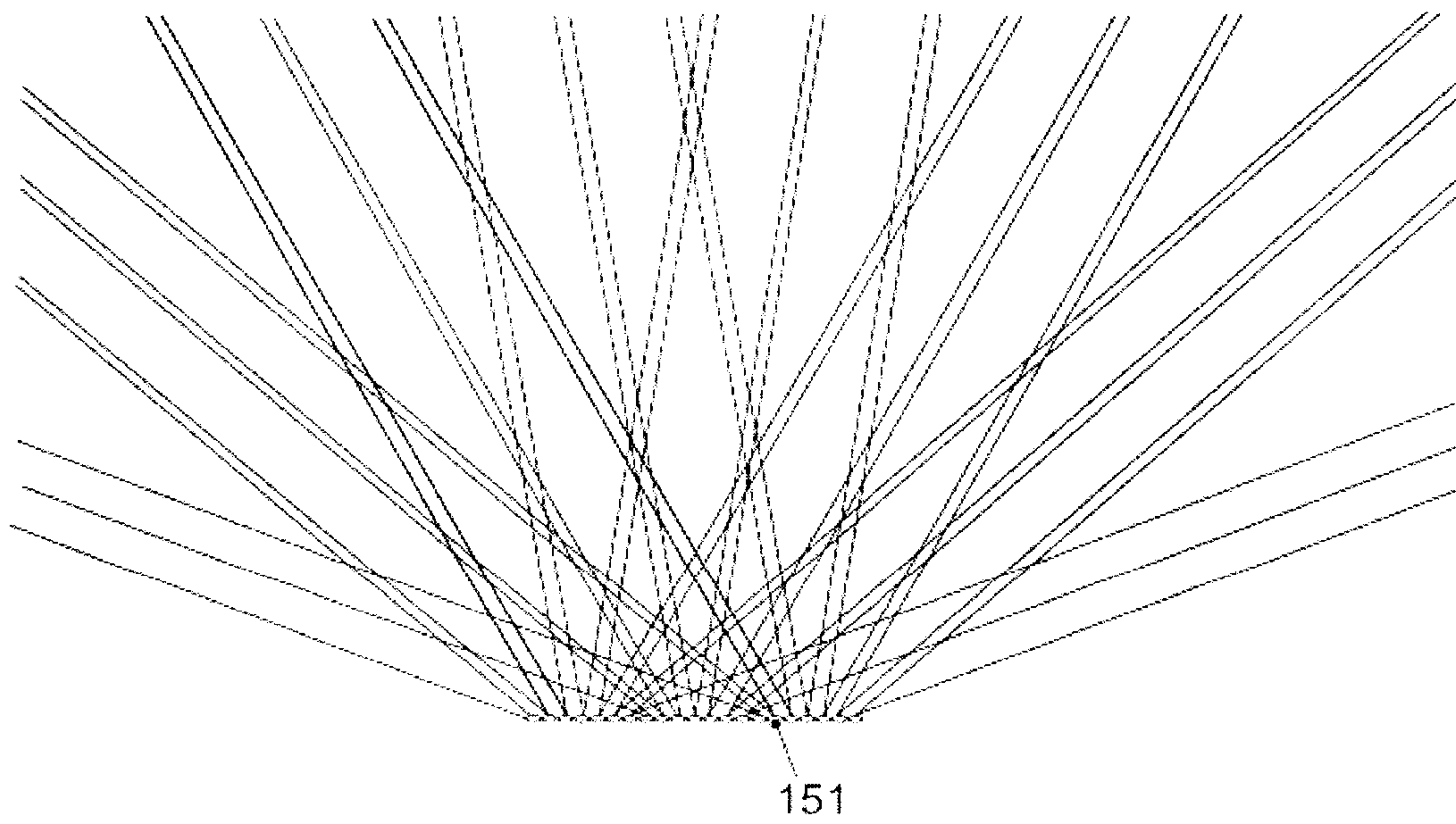


FIG. 15

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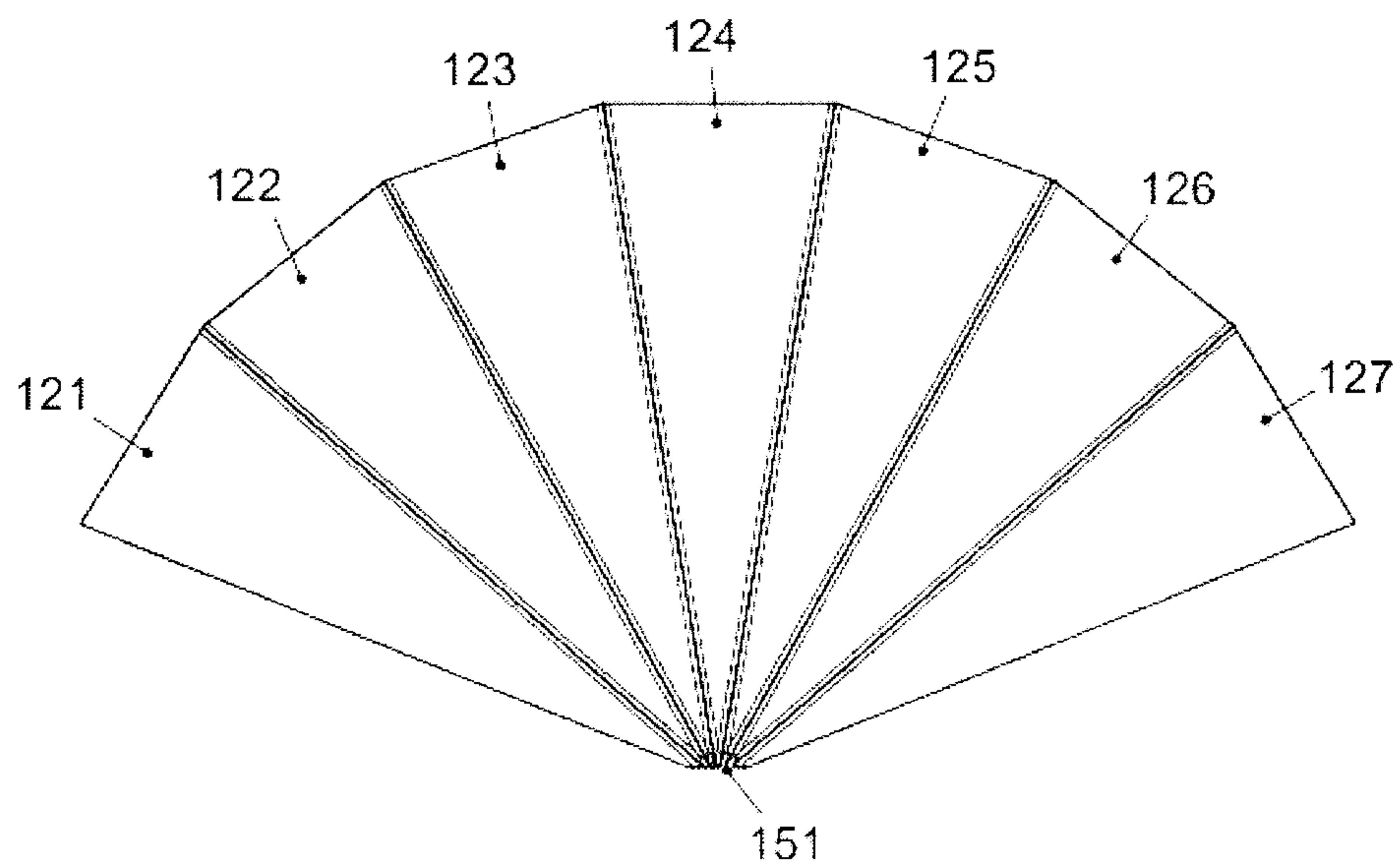


FIG. 16

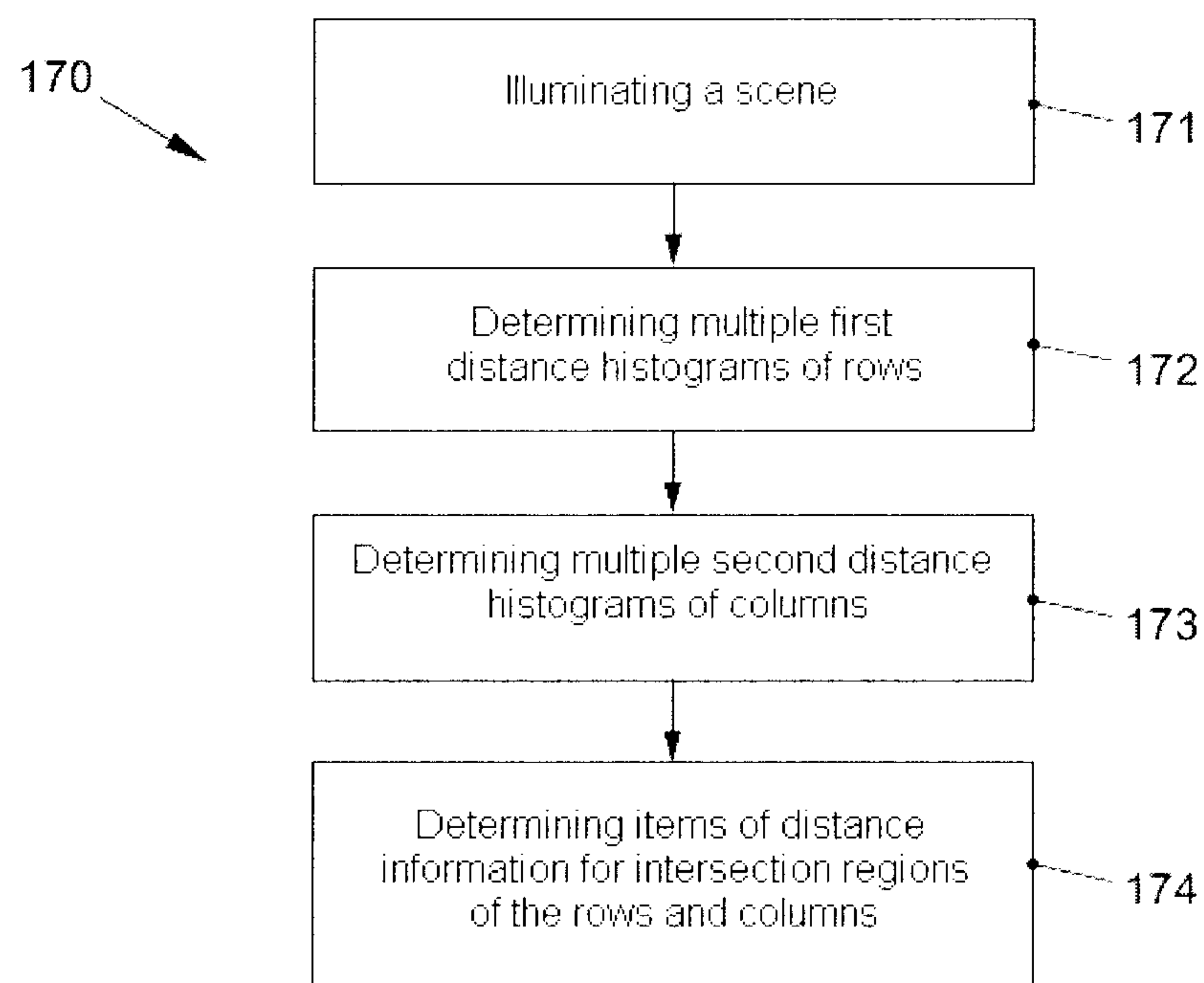


FIG. 17

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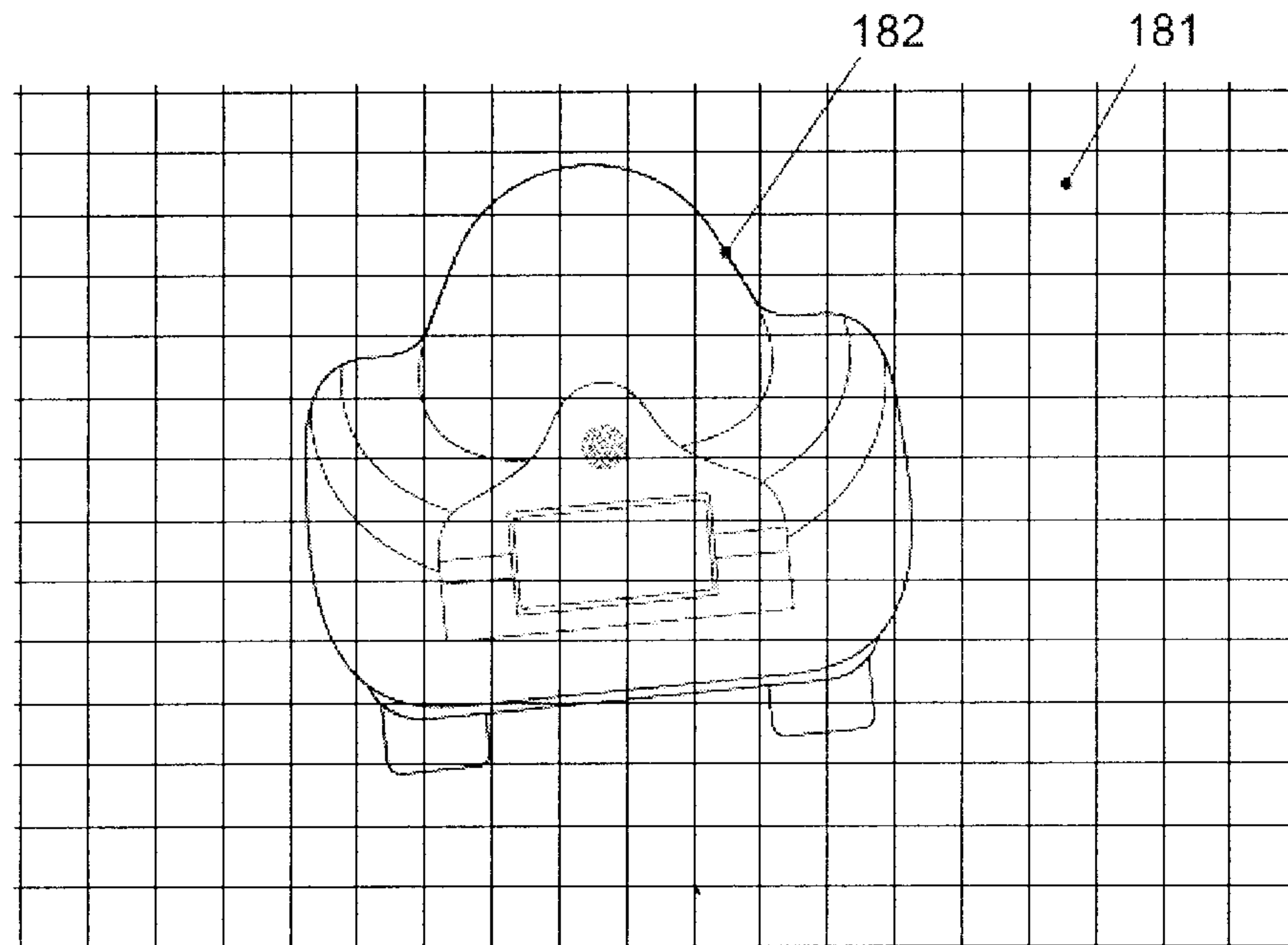


FIG. 18

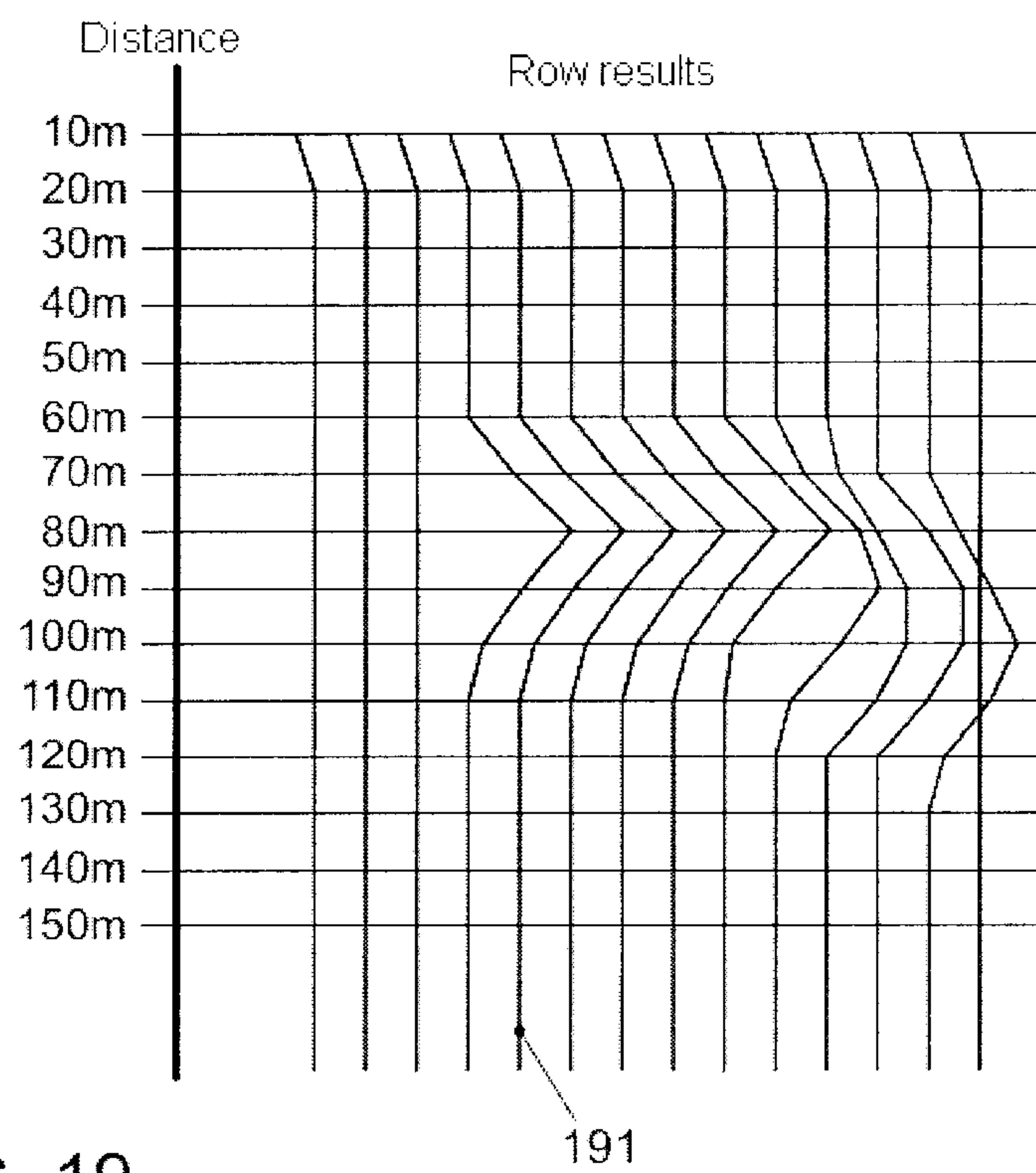


FIG. 19

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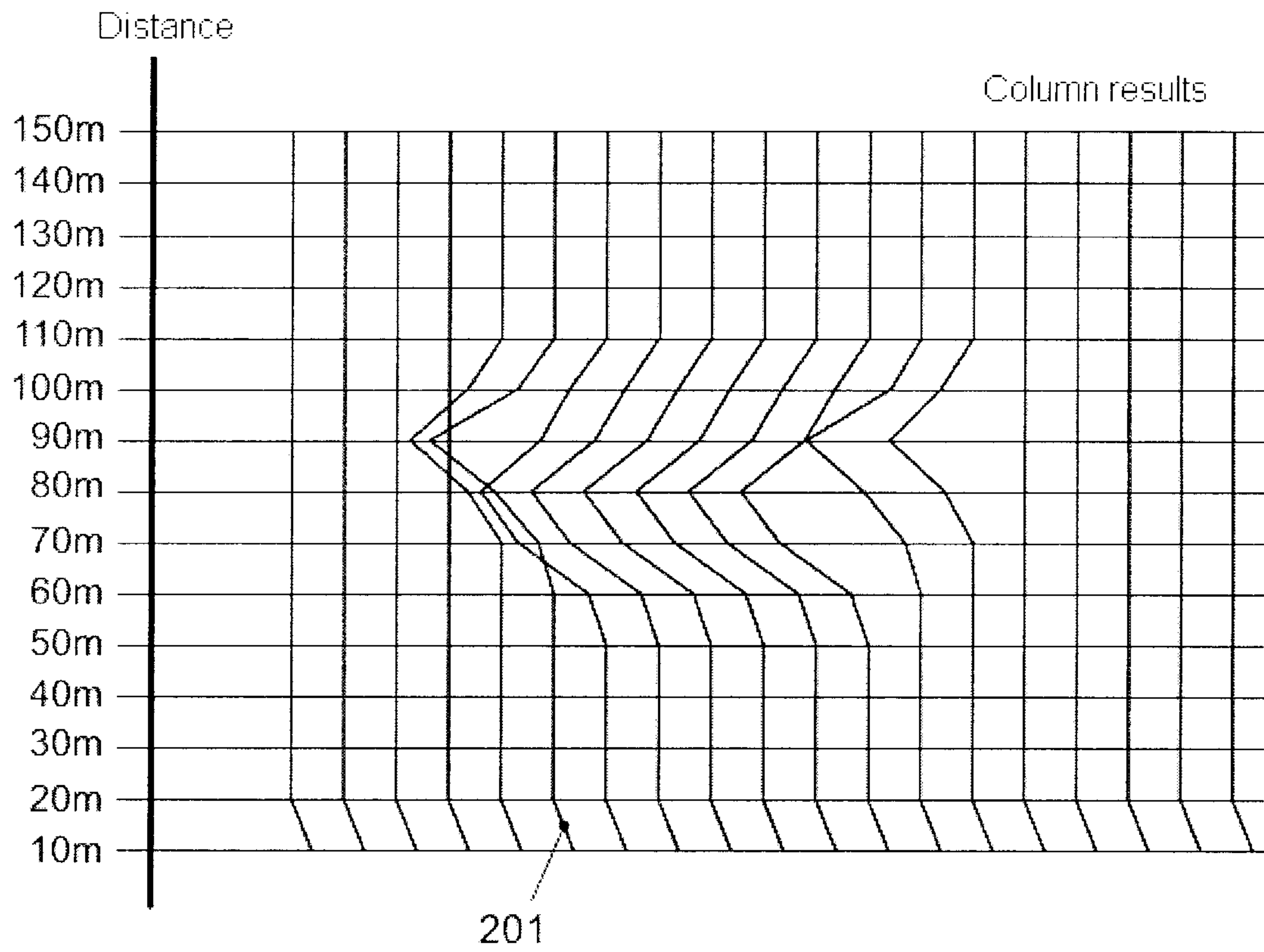


FIG. 20

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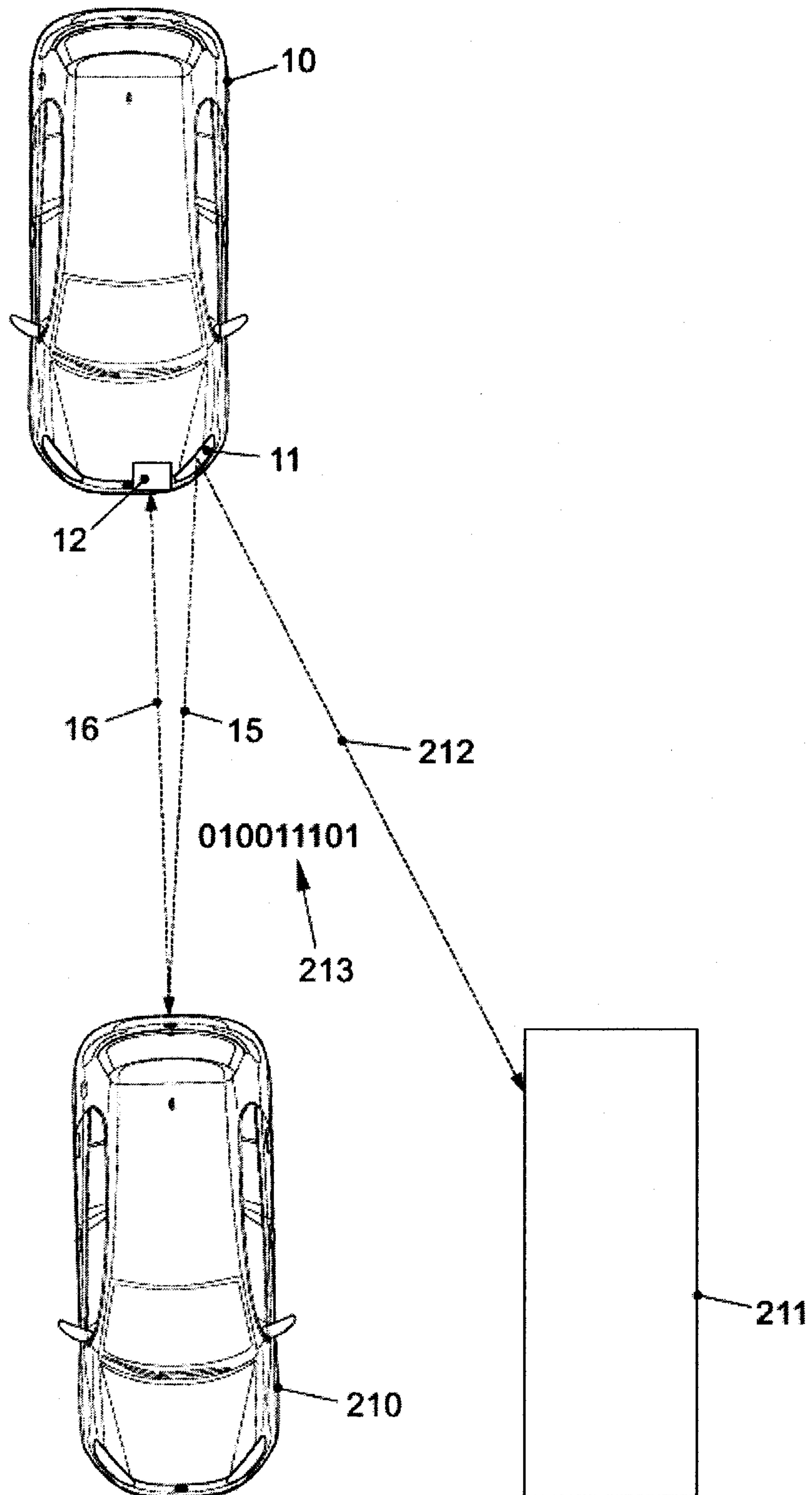


FIG. 21

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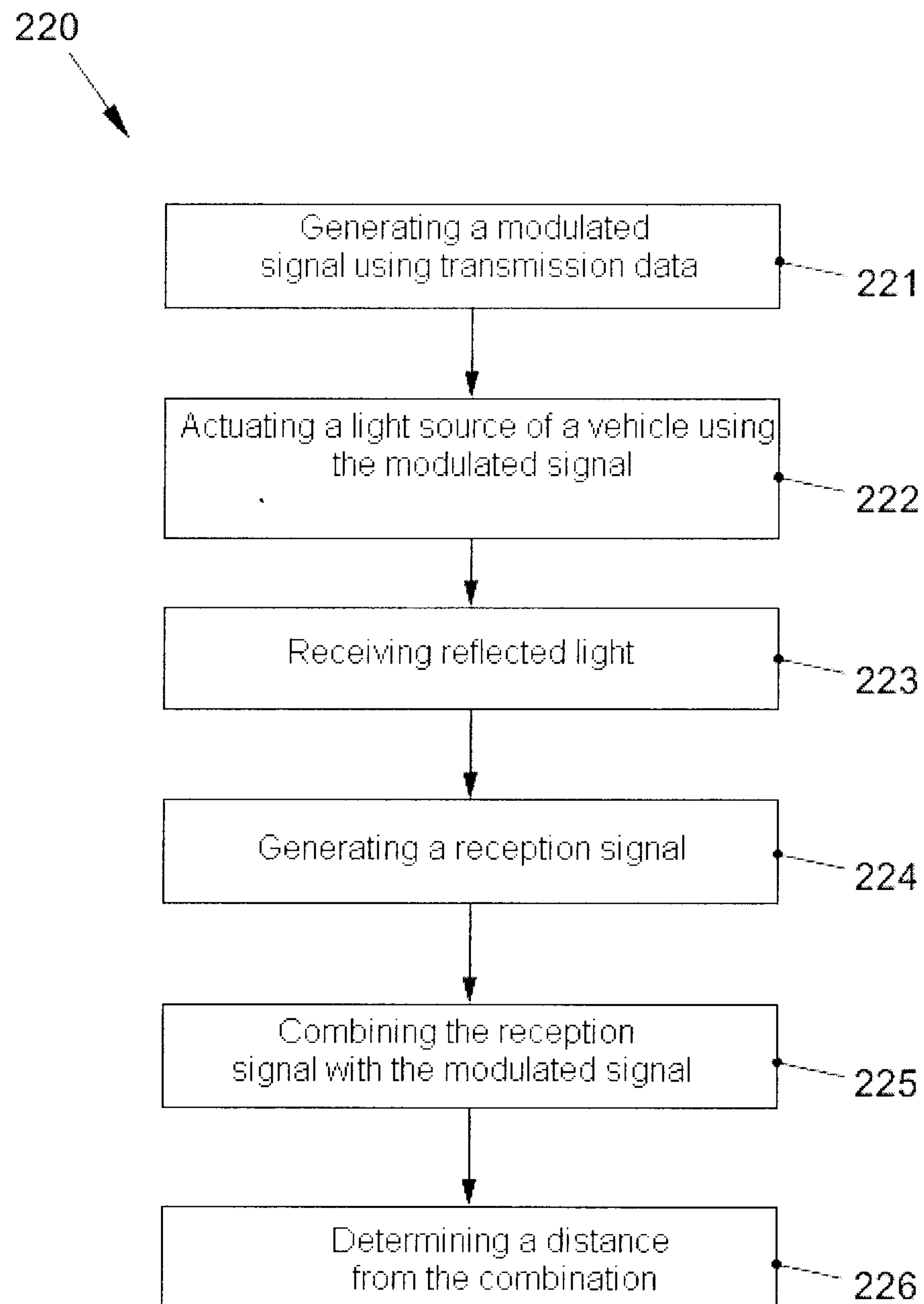


FIG. 22

