(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 787 493 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.10.2014 Bulletin 2014/41

(21) Application number: **14154853.7**

(22) Date of filing: **12.02.2014**

(51) Int Cl.:
G08G 1/01 *(2006.01)* ***G08G 1/042*** *(2006.01)*
G08G 1/048 *(2006.01)* ***G08G 1/133*** *(2006.01)*
B61L 3/12 *(2006.01)* *G08G 1/052* *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **26.03.2013 JP 2013063196**

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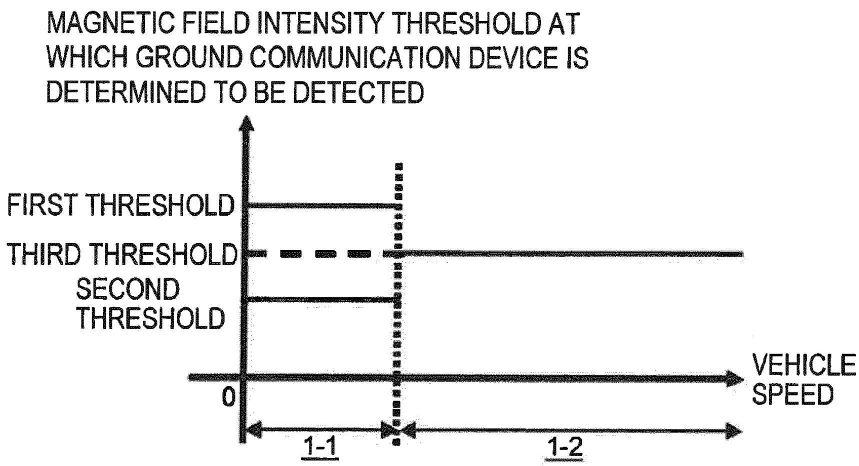
(54) **Spot communication equipment for vehicle**

(57) For example, possible shaking of a vehicle varies positional relations between an on-board communication device and a ground communication device. In such a case, a magnetic field intensity of a signal from the ground communication device received by the on-board communication device may fluctuate across a threshold beyond which the on-board communication device determines that the vehicle has entered a communication range of the ground communication device and that the vehicle has exited the communication range. When this phenomenon occurs, the on-board communication device detects one ground communication device a plurality of times, thus hindering normal vehicle control. For a threshold of the magnetic field intensity for determining detection of the ground communication device, the on-board communication device has two types of thresholds for low speed traveling, that is, a first threshold that is a ground communication device entry side threshold and a second threshold that is a ground communication device exit side threshold. The thresholds thus have a hysteresis property that resists noise, thus preventing possible misdetection of the ground communication device during low speed traveling.

FIG. 1



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Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an on-board communication device that detects a ground communication device in a system that transmits and receives, for example, position information used for moving vehicle control between the ground and the vehicle, and more particularly to prevention of possible misdetection of the ground communication device.

Description of the Related Art

[0002] According to a conventional technique, information is transmitted from the ground to a vehicle via a ground communication device installed on the ground and an on-board communication device installed on the vehicle. The ground communication device is wirelessly supplied with power by the on-board communication device using a driving power wave. After the power supply, the ground communication device transmits information to the on-board communication device by electromagnetic coupling using a frequency different from the frequency of the driving power wave.

[0003] A magnetic field intensity received from the ground communication device is utilized to determine that the on-board communication device has entered and exited the communication range of the ground communication device (hereinafter expressed as "the ground communication device has been detected"). The magnetic field intensity is maximized when an electrically central position of the on-board communication device aligns with an electrically central position of the ground communication device. The magnetic field intensity decreases with increasing distance between the electrically central position of the on-board communication device and the electrically central position of the ground communication device. This characteristic is used to set an appropriate threshold of one or more and to determine that the ground communication device has been detected when the magnetic field intensity exceeds the threshold. Refer to Japanese Patent Laid-Open No. 2005-8103 (Patent Document 1) and Japanese Patent Laid-Open No. 2010-70021 (Patent Document 2).

[0004] For example, possible shaking of a moving vehicle varies vertical and lateral positional relations between the on-board communication device and the ground communication device. In particular, when vibration occurs while the moving vehicle is stopped, the signal level of the received magnetic field intensity and the like may fluctuate across the threshold. When such a phenomenon occurs, the on-board communication device detects one ground communication device a plurality of times, thus hindering normal moving vehicle control.

SUMMARY OF THE INVENTION

[0005] With the above-described problem in view, the present invention provides an on-board communication device that has a first threshold and a second threshold for low speed traveling in connection with a threshold for determining that a ground communication device has been detected based on a magnetic field intensity received from the ground communication device, the first threshold being a ground communication device entry side threshold and the second threshold being a ground communication device exit side threshold. The thresholds have a hysteresis property that resists noise. This prevents possible misdetection of the ground communication device during low speed traveling.

[0006] Moreover, an on-board device is provided which has a third threshold for traveling and in which the on-board communication device switches among the first threshold, the second threshold, and the third threshold depending on an operating condition of a moving vehicle determined based on, for example, speed information on the moving vehicle to prevent a possible shift in the communication range between the on-board communication device and the ground communication device during traveling.

[0007] The present invention can provide an on-board device that prevents possible misdetection of the ground communication device during low speed traveling including vehicle stop.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

FIG. 1 is a diagram illustrating relations between the speed of a moving vehicle and a magnetic field intensity threshold for detection of a ground communication device;

FIG. 2 is a diagram showing Embodiment 1 according to the present invention;

FIG. 3 is a diagram showing Embodiment 2 according to the present invention;

FIG. 4 is a flowchart of an operation of detecting the ground communication device according to the present invention;

FIG. 5 is a diagram defining a third threshold;

FIG. 6 is a diagram illustrating a moving vehicle and the height of an antenna of an on-board communication device in a case where passengers are present and in a case where no passengers are present;

FIG. 7 is a diagram showing a slide distance for a communication range slide used when the value of the threshold is not changed depending on the speed of the moving vehicle;

FIG. 8 is a diagram illustrating a first threshold, a second threshold, and the third threshold;

FIG. 9 is a diagram of Example 1 of relations between time and the magnetic field intensity received by the antenna of the on-board communication device when the moving vehicle is stopped; and

FIG. 10 is a diagram of Example 2 of relations between time and the magnetic field intensity received by the antenna of the on-board communication device when the moving vehicle is stopped.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] An embodiment of the present invention will be described with reference to the drawings below. FIG. 2 shows a general configuration of the present invention. An on-board communication device including a computing section 2-2 and an antenna 2-3 is mounted on a moving vehicle 2-1. Furthermore, a speed detector 2-6 mounted to a wheel 2-5 detects a vehicle speed. The speed detected by the speed detector 2-6 is transmitted to an on-board control section 2-4 that ensures safety of a vehicle. Speed information utilized by the on-board control section 2-4 is transmitted to an on-board communication device 2-2. Each of the on-board control section 2-4 and the speed detector 2-6 are duplicated, and thus, the speed information used by the on-board control section 2-4 is very secure. Based on the speed information provided by the on-board control section 2-4, the on-board communication device 2-2 switches between a threshold beyond which the on-board communication device 2-2 determines that a ground communication device 2-7 has been detected during low speed traveling when the moving vehicle 2-1 is near a stop position such as a bus stop and a threshold beyond which the on-board communication device 2-2 determines that the ground communication device 2-7 has been detected during high speed traveling.

[0010] For the threshold used during low speed traveling, different thresholds are used for a ground communication device entry side and for a ground communication device exit side. The ground communication device entry side threshold is hereinafter referred to as a first threshold. The ground communication device exit side threshold is hereinafter referred to as a second threshold. Furthermore, a threshold used for high speed traveling is a third threshold.

[0011] The first threshold increases a determination level compared to the third threshold. The second threshold reduces the determination level compared to the third threshold. This provides the thresholds with a hysteresis property, offering resistance to noise caused by shaking and the like of the moving vehicle during low speed traveling including vehicle stop.

[0012] A flowchart in FIG. 4 shows an operation flow of detection of the ground communication device according to the present invention.

[0013] For limitation of a communication range between the ground communication device and an antenna, the third threshold is defined as a magnetic field intensity received by the on-board communication device when the distance between the ground communication device and the antenna of the on-board communication device is equal to L.

[0014] FIG. 5 shows relations between the magnetic field intensity and the distance between the antenna and the ground communication device.

[0015] Now, it is assumed that the moving vehicle is traveling from a left side to a right side in FIG. 5. The magnetic field intensity received by the antenna increases consistently as the antenna mounted on the moving vehicle approaches the ground communication device as shown at 5-1. At a point A shown at 5-2 (the distance between the ground communication device and the antenna is equal to L), the antenna receives a magnetic field intensity higher than the third threshold. This allows the on-board communication device to determine that the ground communication device has been detected (determine that the antenna has entered the communication range). That is, the on-board communication device determines that the antenna is present within the communication range of the ground communication device.

[0016] Subsequently, the moving vehicle passes over the center of the ground communication device. At a point B shown at 5-3 (the distance between the ground communication device and the antenna is equal to L), the on-board communication device receives a magnetic field intensity lower than the third threshold. Then the on-board communication device determines that the antenna has exited the communication range of the ground communication device. That is, the on-board communication device determines that the antenna is present outside the communication range of the ground communication device.

[0017] In general, a carrier frequency used for communication from the ground communication device to the on-board communication device is equal to or lower than 10 MHz, and the maximum communication range L is equal to or smaller than about 2 m. In this case, the magnetic field intensity received by the on-board communication device attenuates in proportion to the cube of the distance between the ground communication device and the on-board communication device in accordance with a neighborhood solution. Thus, the third threshold for the magnetic field intensity is expressed by:

[Equation 1]

$$\text{Third threshold} = C/(L)^3$$

[0018] In this expression, a coefficient dependent on the construction of the ground communication device and the antenna is denoted by C, which is a constant herein.

[0019] While the moving vehicle is stopped at a bus stop or the like, passengers get on and off the moving vehicle, and thus, the antenna mounted on the moving vehicle shakes in the vertical direction along with the moving vehicle. When the range of the shake is denoted by Δh, the maximum value Δh_{max} of the range of the shake can be approximated to the difference in the height of the moving vehicle between when the moving vehicle is full of passengers (full vehicle) as shown at 6-1 in FIG. 6 and when the moving vehicle has no passenger (empty vehicle) as shown at 6-2.

[0020] If the empty moving vehicle is stopped when the distance between the ground communication device and the antenna is equal to L and passengers get on the moving vehicle until the moving vehicle is full, then a magnetic field intensity H_2 received by the antenna of the on-board communication device is expressed by:

[Equation 2]

$$H_2 = C/(L-\Delta h_{max})^3$$

[0021] A change ΔH_2 from the magnetic field intensity obtained when the moving vehicle is empty is expressed by:

[Equation 3]

$$\Delta H_2 = C/(L)^3 - C/(L-\Delta h_{max})^3$$

[0022] Furthermore, if the full moving vehicle is stopped when the distance between the ground communication device and the antenna is equal to L and all the passengers get off the moving vehicle, a magnetic field intensity H_3 received by the antenna of the on-board communication device is expressed by:

[Equation 4]

$$H_3 = C/(L+\Delta h_{max})^3$$

[0023] A change ΔH_3 from the magnetic field intensity obtained when the moving vehicle is full is expressed by:

[Equation 5]

$$\Delta H_3 = C/(L)^3 - C/(L+\Delta h_{max})^3$$

[0024] The third threshold is changed to the first threshold and the second threshold when the moving vehicle is stopped so as to prevent the change in magnetic field intensity from causing the on-board communication device to detect entry into and exit from the range of communication with the ground communication device.

[0025] The on-board communication device can determine that the moving vehicle is stopped based on speed information provided by the on-board control section.

[0026] In this case, the first threshold and the second threshold are set as follows so as to prevent the Expressions (3) and (4) from being affected by the maximum range of fluctuation of the magnetic field intensity occurring when passengers get on and off the moving vehicle.

[Equation 6]

$$\text{For entry determination: First threshold} = H_2 = C/(L - \Delta h_{max})^3$$

[Equation 7]

$$\text{For exit determination: Second threshold} = H_3 = C/(L + \Delta h_{max})^3$$

[0027] The on-board communication device determines that the moving vehicle has left and that loading and unloading of passengers has ended, based on the speed information provided by the on-board control section. Subsequently, the on-board communication device returns the threshold for the magnetic field intensity to the third threshold in order to limit the communication range between the antenna and the ground communication device to L. If the on-board communication device uses the first threshold and the second threshold for all the speed regions of the moving vehicle instead of switching the threshold depending on the speed, the communication range shifts by Δh_{max} in a direction in which the moving vehicle travels as shown in FIG. 7.

[0028] FIG. 1 shows relations between the vehicle speed of the antenna with respect to the ground communication device and each of the first threshold, the second threshold, and the third threshold. FIG. 8 shows relations among the distance, the magnetic field intensity, the first threshold, the second threshold, and the third threshold.

[0029] Furthermore, a case will be described in which the moving vehicle is stopped near the boundary of the communication range between the antenna and the ground communication device and in which passengers get on and off the moving vehicle.

[0030] FIG. 9 is a diagram showing relations between the time and the magnetic field intensity received at the antenna which are observed when the moving vehicle full of passengers is stopped inside the boundary of the communication range (and closer to the ground communication device) between the antenna of the on-board communication device and the ground communication device and when passengers then get off the moving vehicle. The magnetic field intensity received by the antenna of the on-board communication device while the moving vehicle is stopped as shown at 9-2 slightly exceeds the third threshold. Thus, the on-board communication device determines that the ground communication device has been detected (determines that the antenna has entered the communication range). Upon determining that the moving vehicle is stopped based on the speed information, the on-board communication device changes the third threshold to the first threshold beyond which the on-board communication device determines that the ground communication device has been detected (determines that the antenna has entered the communication range) and the second threshold beyond which the on-board communication device determines that the antenna has exited the communication range. At 9-3, a door of the moving vehicle is opened, and the passengers get off the moving vehicle. At this time, the moving vehicle vibrates up and down and moves away from the ground communication device. Thus, the received magnetic field intensity behaves as shown at 9-4. However, since the threshold beyond which the on-board communication device determines that the antenna has exited the communication range has been changed to the second threshold, the on-board communication device does not determine that the antenna has exited the communication range. At this time, if the present invention is not used and only one type of threshold is provided, then the on-board communication device repeatedly determines, at a point 9-4, that the antenna has exited the communication range and that the ground communication device has been detected (that the antenna has entered the communication range).

[0031] FIG. 10 is a diagram showing a case where an empty moving vehicle is stopped slightly outside the boundary of the communication range of the antenna of the on-board communication device and where passengers get on the moving vehicle until the moving vehicle is full. The magnetic field intensity received by the antenna of the on-board communication device while the moving vehicle is stopped as shown at 10-2 is slightly lower than the third threshold. Thus, the on-board communication device does not determine that the ground communication device has been detected (not determine that the antenna has entered the communication range). When the on-board communication device determines that the moving vehicle is stopped based on the speed information, the third threshold changes to the first threshold beyond which the on-board communication device determines that the ground communication device has been detected (determines that the antenna has entered the communication range) and the second threshold beyond which the on-board communication device determines that the antenna has exited the communication range. At 10-3, the door of the moving vehicle is opened, and passengers get on the moving vehicle. At this time, the moving vehicle vibrates up and down and approaches the ground communication device. Thus, the received magnetic field intensity behaves as shown at 10-4. However, since the threshold beyond which the on-board communication device determines that the ground communication device has been detected (determines that the antenna has entered the communication range) has been changed to the first threshold, the on-board communication device does not determine that the ground communication device has been detected. At this time, if the present invention is not used and only one type of threshold is provided, then the on-board communication device repeatedly determines, at a point 10-4, that the ground communication device has been detected (that the antenna has exited the communication range) and that the antenna has entered the communication range. Thus, one ground communication device is detected a plurality of times.

[0032] Other embodiments will be described below. Furthermore, the speed information is transmitted to the on-board communication device via the on-board control section in order to allow the use of reliable speed information. However, as shown in FIG. 3, the speed information may be transmitted from the speed detectors directly to the on-board communication device. In this case, since the speed information relates to safety, speed detection needs a high safety arrangement such as duplication. The speed information may be reliable information resulting from a duplication process carried out by an automatic vehicle control device mounted in the vehicle.

[0033] Furthermore, in the above-described embodiment, the on-board communication device determines whether the moving vehicle is traveling at high speed (the moving vehicle is traveling) or at low speed (the moving vehicle is stopped). However, another device such as the on-board control section may make this determination and report to the on-board communication device by communication.

[0034] A speed beyond which the moving vehicle is determined to be traveling at high speed (the moving vehicle is traveling) or at low speed (the moving vehicle is stopped), that is, a vehicle speed at which the threshold is switched, may be equal to or lower than a speed limit for the vicinity of a stop position (for example, 45 km/h). Alternatively, the speed may be a speed close to zero.

[0035] Additionally, the above-described embodiment determines whether the moving vehicle is traveling or stopped based on the speed information. However, a device that can detect whether the door is open or closed may be provided to allow determination of whether the moving vehicle is traveling or stopped based on door open and close information from the device, in turn allowing a change of the threshold for the magnetic field intensity. That is, when the door is closed, the on-board communication device determines that the moving vehicle is traveling and then determines the positional relation between the on-board communication device and the ground communication device using the third threshold as described above. When the door is open, the on-board communication device determines that the moving vehicle is stopped and then determines the positional relation between the on-board communication device and the ground communication device using the first and second thresholds as described above.

Claims

1. An on-board device comprising an on-board communication device that communicates with a ground communication device and a speed detection device that detects a vehicle speed,
wherein, when the vehicle speed detected by the speed detection device is equal to or lower than a predetermined value, the on-board communication device determines that the on-board communication device is present within a communication range of the ground communication device when a signal magnetic field intensity of a signal from the ground communication device received by the on-board communication device is higher than a first threshold, and
when the vehicle speed detected by the speed detection device is higher than the predetermined value, the on-board communication device determines that the on-board communication device is present within the communication range of the ground communication device when the signal magnetic field intensity of the signal from the ground communication device received by the on-board communication device is higher than a third threshold smaller than the first threshold.

2. The on-board device according to claim 1, wherein, when the vehicle speed detected by the speed detection device is equal to or lower than the predetermined value, the on-board communication device determines that the on-board communication device is present outside the communication range of the ground communication device when the signal magnetic field intensity of the signal from the ground communication device received by the on-board communication device is lower than a second threshold smaller than the third threshold, and
when the vehicle speed detected by the speed detection device is higher than the predetermined value, the on-board communication device determines that the on-board communication device is present outside the communication range of the ground communication device when the signal magnetic field intensity of the signal from the ground communication device received by the on-board communication device is lower than the third threshold.

3. The on-board device according to claim 2, wherein the magnetic field intensity received by the on-board communi-

cation device from the ground communication device is used as the third threshold when a distance between the on-board communication device and the ground communication device is equal to a prescribed value.

4. The on-board device according to claim 2 or claim 3, wherein the magnetic field intensity received by the on-board communication device from the ground communication device is used as the second threshold when the distance between the on-board communication device and the ground communication device is equal to the prescribed value plus a difference between a height of the vehicle measured when the vehicle is empty and a height of the vehicle measured when the vehicle is full.

5. The on-board device according to any one of claims 2 to 4, wherein the magnetic field intensity received by the on-board communication device from the ground communication device is used as the first threshold when the distance between the on-board communication device and the ground communication device is equal to the difference between the height of the vehicle measured when the vehicle is empty and the height of the vehicle measured when the vehicle is full, minus the prescribed value.

6. The on-board device according to claim 1, wherein information on the vehicle speed detected by the speed detection device is reliable information duplicated by an automatic vehicle control device.

7. The on-board device according to claims 1 to 6, wherein the predetermined value is equal to or lower than 45 km/h.

8. The on-board device according to claims 1 to 6, wherein the predetermined value is a speed close to zero.

9. An on-board device comprising an on-board communication device that communicates with a ground communication device and a door open and close detection device for a vehicle,
wherein, when door open and close information detected by the door open and close detection device is indicative of door close, the on-board communication device determines that the on-board communication device is present within a communication range of the ground communication device when a signal magnetic field intensity of a signal from the ground communication device received by the on-board communication device is higher than a first threshold, and
when the door open and close information detected by the door open and close detection device is indicative of door open, the on-board communication device determines that the on-board communication device is present within the communication range of the ground communication device when the signal magnetic field intensity of the signal from the ground communication device received by the on-board communication device is higher than a third threshold smaller than the first threshold.

10. The on-board device according to claim 9, wherein, when the door open and close information detected by the door open and close detection device is indicative of door close, the on-board communication device determines that the on-board communication device is present outside a communication range of the ground communication device when the signal magnetic field intensity of the signal from the ground communication device received by the on-board communication device is lower than a second threshold smaller than the third threshold, and
when the door open and close information detected by the door open and close detection device is indicative of door open, the on-board communication device determines that the on-board communication device is present outside the communication range of the ground communication device when the signal magnetic field intensity of the signal from the ground communication device received by the on-board communication device is lower than the third threshold.

FIG. 1

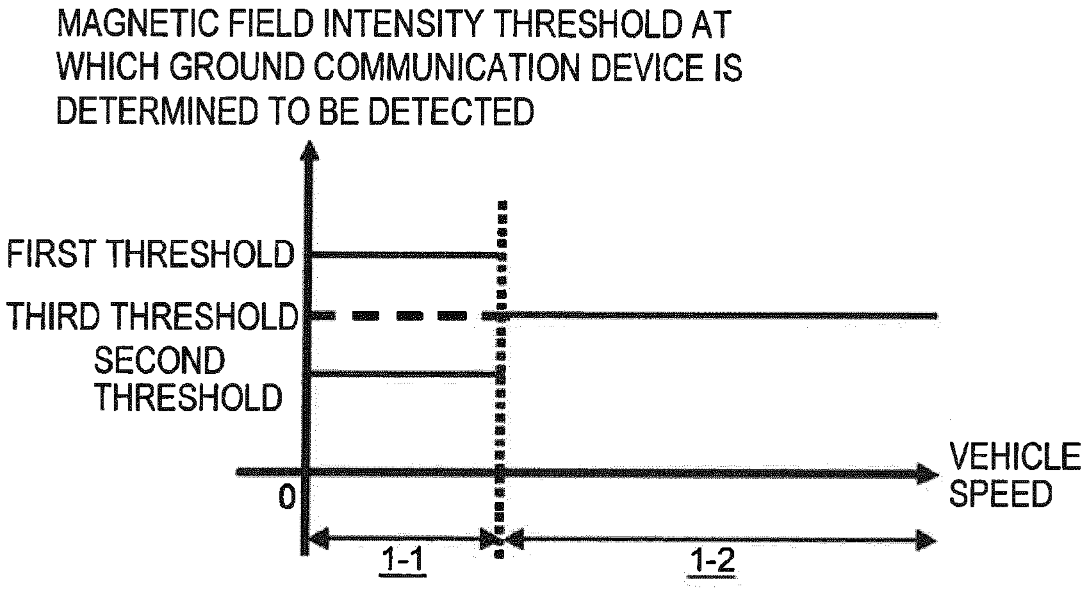

MAGNETIC FIELD INTENSITY THRESHOLD AT WHICH GROUND COMMUNICATION DEVICE IS DETERMINED TO BE DETECTED
FIRST THRESHOLD
THIRD THRESHOLD
SECOND THRESHOLD
0
VEHICLE SPEED
1-1
1-2

FIG. 2

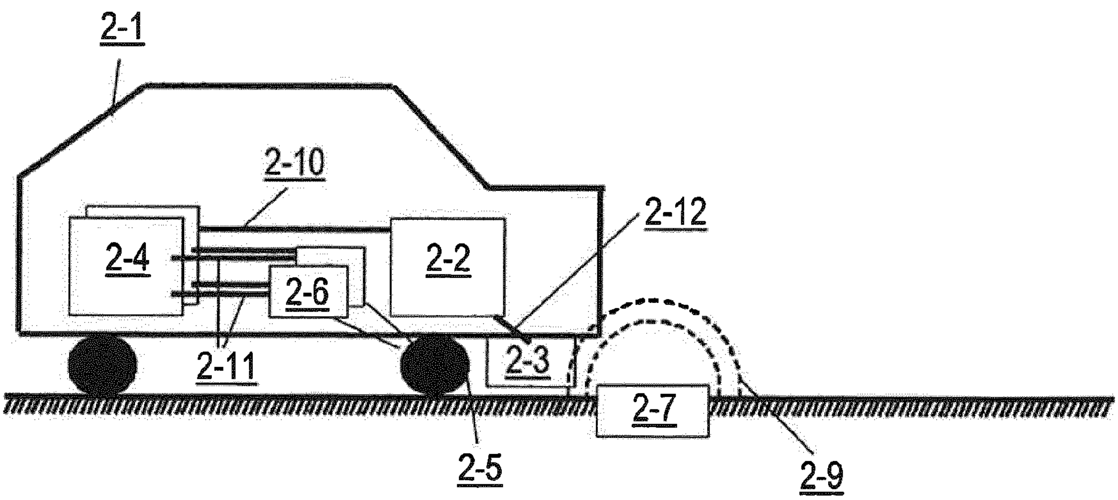

2-1
2-10
2-12
2-4
2-2
2-6
2-3
2-11
2-7
2-5
2-9

FIG. 3

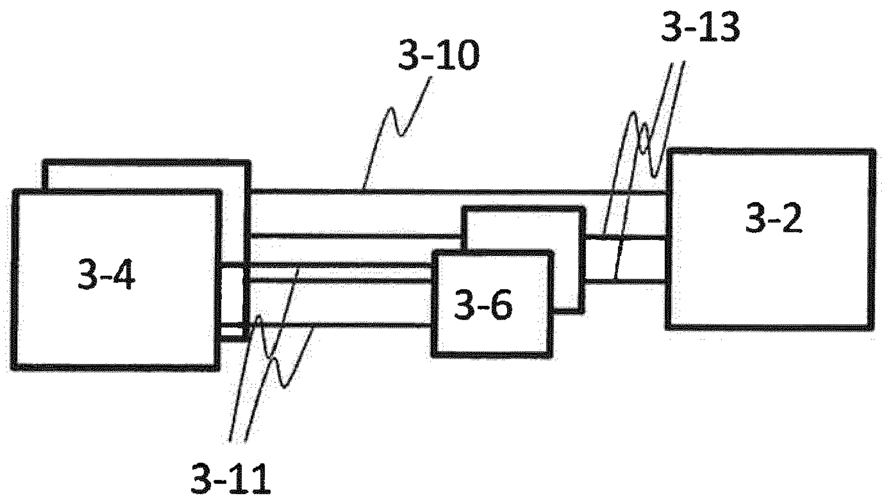


FIG. 4

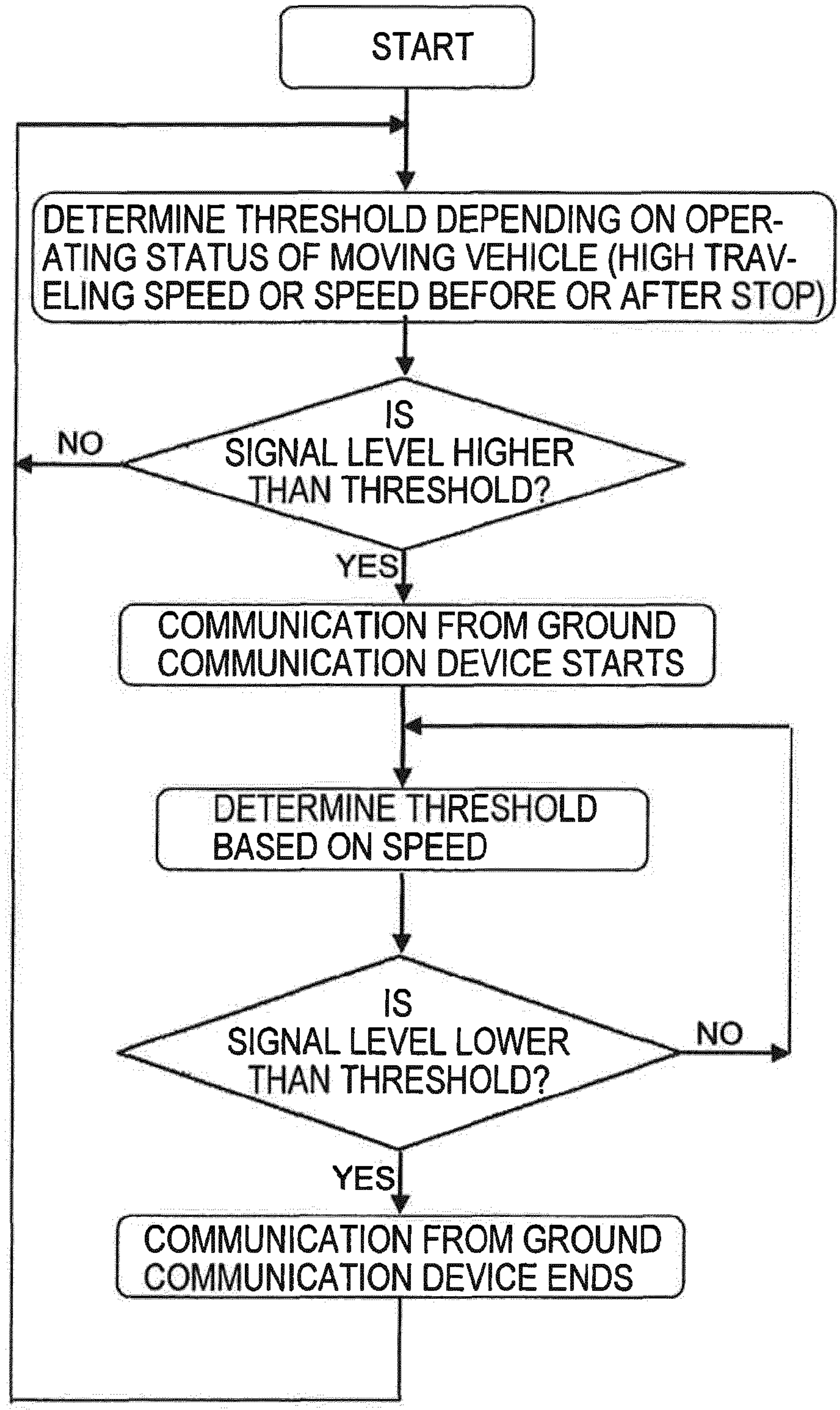

START
DETERMINE THRESHOLD DEPENDING ON OPERATING STATUS OF MOVING VEHICLE (HIGH TRAVELING SPEED OR SPEED BEFORE OR AFTER STOP)
IS SIGNAL LEVEL HIGHER THAN THRESHOLD?
NO
YES
COMMUNICATION FROM GROUND COMMUNICATION DEVICE STARTS
DETERMINE THRESHOLD BASED ON SPEED
IS SIGNAL LEVEL LOWER THAN THRESHOLD?
NO
YES
COMMUNICATION FROM GROUND COMMUNICATION DEVICE ENDS

FIG. 5

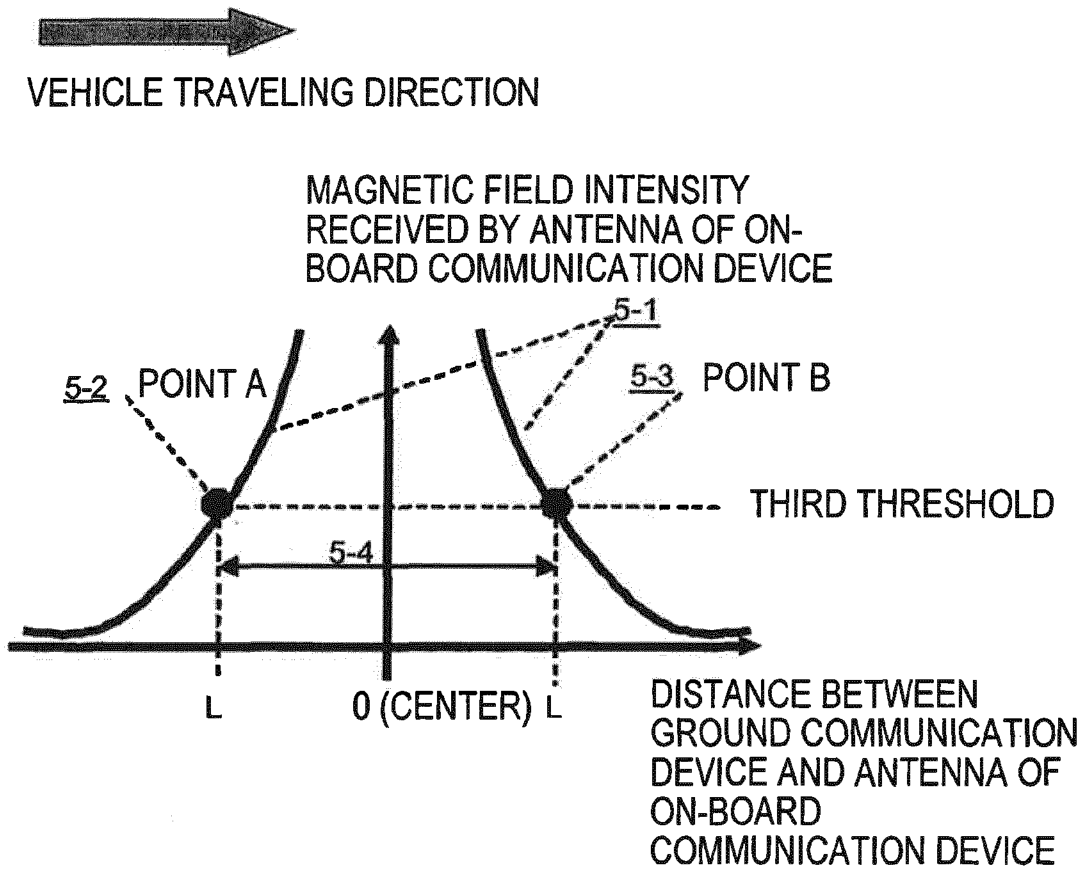

VEHICLE TRAVELING DIRECTION
MAGNETIC FIELD INTENSITY RECEIVED BY ANTENNA OF ON-BOARD COMMUNICATION DEVICE
5-1
5-2
POINT A
5-3
POINT B
THIRD THRESHOLD
5-4
L
0 (CENTER)
L
DISTANCE BETWEEN GROUND COMMUNICATION DEVICE AND ANTENNA OF ON-BOARD COMMUNICATION DEVICE

FIG. 6

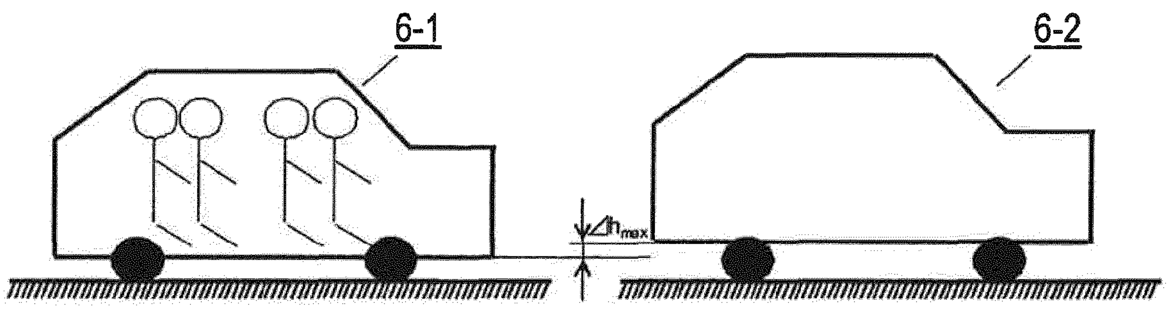

6-1
6-2
⊿hmax

FIG. 7

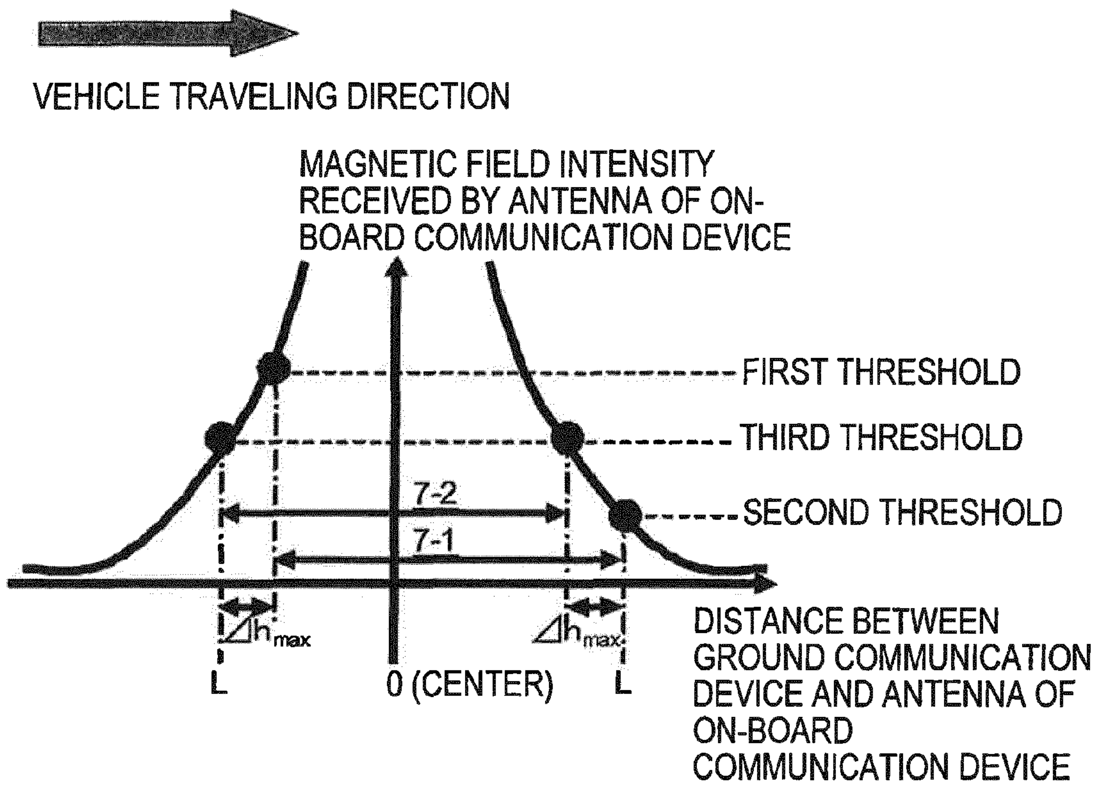

VEHICLE TRAVELING DIRECTION
MAGNETIC FIELD INTENSITY RECEIVED BY ANTENNA OF ON-BOARD COMMUNICATION DEVICE
FIRST THRESHOLD
THIRD THRESHOLD
SECOND THRESHOLD
7-2
7-1
⊿h'max
⊿hmax
L
0 (CENTER)
L
DISTANCE BETWEEN GROUND COMMUNICATION DEVICE AND ANTENNA OF ON-BOARD COMMUNICATION DEVICE

FIG. 8

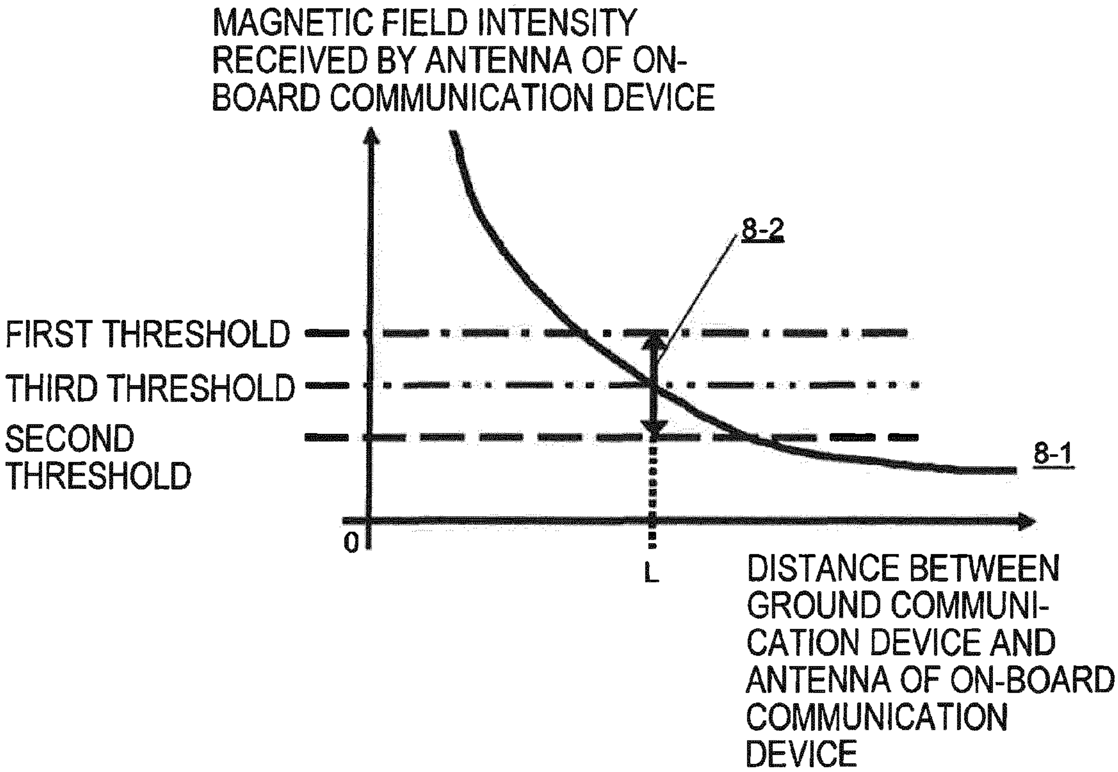

MAGNETIC FIELD INTENSITY RECEIVED BY ANTENNA OF ON-BOARD COMMUNICATION DEVICE
8-2
FIRST THRESHOLD
THIRD THRESHOLD
SECOND THRESHOLD
8-1
0
L
DISTANCE BETWEEN GROUND COMMUNICATION DEVICE AND ANTENNA OF ON-BOARD COMMUNICATION DEVICE

FIG. 9

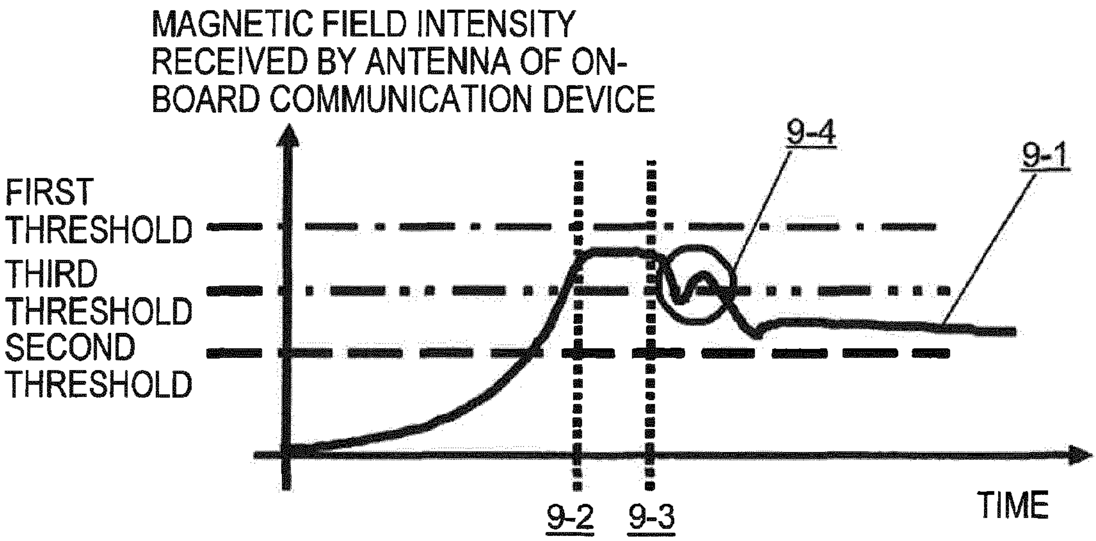
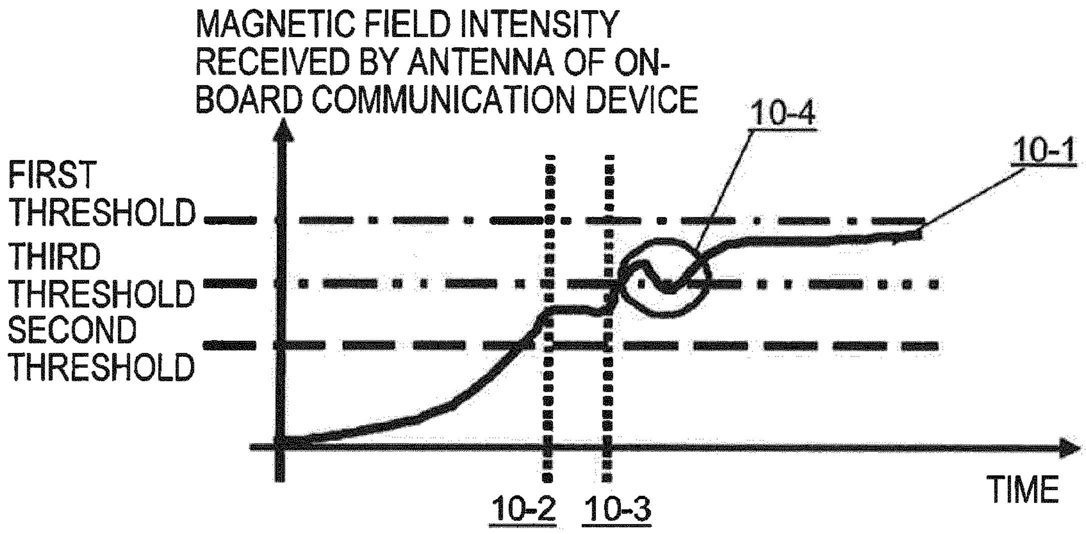

MAGNETIC FIELD INTENSITY RECEIVED BY ANTENNA OF ON-BOARD COMMUNICATION DEVICE
9-4
9-1
FIRST THRESHOLD
THIRD THRESHOLD
SECOND THRESHOLD
9-2
9-3
TIME

FIG. 10


MAGNETIC FIELD INTENSITY
RECEIVED BY ANTENNA OF ON-
BOARD COMMUNICATION DEVICE
10-4
10-1
FIRST
THRESHOLD
THIRD
THRESHOLD
SECOND
THRESHOLD
TIME
10-2
10-3

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 14 15 4853

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	JP 2010 070021 A (KYOSAN ELECTRIC MFG) 2 April 2010 (2010-04-02) * abstract * * paragraphs [0004], [0006] - [0020] * * figures 1-4 * * The interpretation of the document is based on a computer generated translation which was obtained from Thomson Scientific. A copy of the translation is annexed to this communication. * -----	1-8	INV. G08G1/01 G08G1/042 G08G1/048 G08G1/133 B61L3/12 ADD. G08G1/052
A	US 3 334 224 A (ALLEN ROBERT K ET AL) 1 August 1967 (1967-08-01) * column 3, line 48 - line 61 * * column 5, line 34 - line 63 * * column 8, line 41 - line 68 * * column 11, line 18 - line 25 * * figures 1-3 * -----	1-10	
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Place of search	Date of completion of the search	Examiner
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