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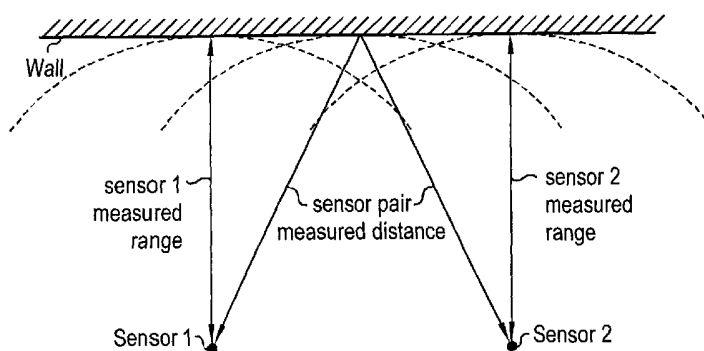
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(54) Title: OBJECT DETECTION DEVICE PERFORMING RANGE MEASUREMENTS BY AT LEAST TWO PULSE RADAR SENSORS IN MONOSTATIC AND BISTATIC OPERATION



(57) **Abstract:** An object detection device comprises at least two sensors (17), each adapted to transmit and receive signals, and a processor (3) to control operation of the sensors. Each sensor comprises a transmit pulse generator (5) operating at a first transmit pulse repetition frequency and a receive pulse generator (10) operating at a second, different, pulse repetition frequency. A timing control signal from the processor switches the sensors between transmit/receive mode and receive only mode. A first sensor (1) operates in transmit/receive mode, the first sensor transmitting at a first pulse repetition frequency and receiving reflections of the transmitted signal, reflected off an object; wherein the reflections are mixed with a reference signal to produce an intermediate frequency (IF) signal and analysed to derive a direct range measurement. The or each other sensor (2 .. n) operates in receive only mode to produce an indirect range measurement and the receiver pulse generator operates at a second pulse repetition frequency. The operation is repeated for the or each other sensor (2 .. n) operating in transmit/receive mode such that a set of direct and indirect measurements are obtained, whereby a linear distance (12) from the object is derived from the direct and indirect range measurements. The device is particularly applicable to use as a parking aid.



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OBJECT DETECTION DEVICE PERFORMING RANGE MEASUREMENTS BY AT LEAST TWO PULSE RADAR SENSORS IN MONOSTATIC AND BISTATIC OPERATION

This invention relates to an object detection device, particularly to assist a driver when parking a vehicle.

5 Many different types of parking aid have been proposed. For example, US 6,215,415 describes a system in which three sensors, capable of both transmitting and receiving, are positioned closely adjacent one another and emit signals at three different frequencies. The reflection of each emitted signal off an object is received by their respective receivers and evaluated by a processor to determine the distance of the
10 vehicle from the object. This information is then provided to the driver in the form of an audible or visual warning.

Another example is described in EP-1 043 213 in which multiple sensors are positioned around the vehicle and emit signals orthogonal to one another, reflections of which are received by the respective sensor which emitted them. The signals are
15 processed and used to control the vehicle speed as it approaches an obstacle. However, in these prior art systems, the individual sensors do not operate in a co-operative way to provide an estimate of the closest object to the rear of the vehicle.

In accordance with a first aspect of the present invention, an object detection device comprises at least two sensors, each sensor being adapted to transmit and receive
20 signals; and a processor to control operation of the sensors; wherein each sensor comprises a transmit pulse generator operating at a first transmit pulse repetition frequency and a receive pulse generator operating at a second, different, pulse repetition frequency; wherein a timing control signal from the processor switches the sensors between transmit/receive mode and receive only mode; wherein a first sensor is set to
25 operate in transmit/receive mode, the first sensor transmitting at the first pulse repetition frequency and receiving reflections of the transmitted signal, reflected off an object; wherein the reflections are mixed with a reference signal to produce an intermediate frequency (IF) signal and analysed to derive a direct range measurement; wherein the or each other sensor is set to operate in receive only mode to produce an indirect range
30 measurement; the receive pulse generator operating at the second pulse repetition frequency; and wherein the operation is repeated for the or each other sensor operating in transmit/receive mode such that a set of direct and indirect measurements are

obtained; whereby a linear distance from the object is derived from the direct and indirect range measurements.

The present invention provides an object detection device which is able to use sensors in an arrangement which maintains the simplicity of processing of individual
5 sensors making direct measurements, but enables a receiver at a remote location to be used to make indirect measurements. The combined effect gives a linear distance from an object, without complex processing being required.

Preferably, the sensors are pulse radar sensors.

For use in motor vehicles, this has the benefit over ultrasonic sensors that no cut-
10 out in the bumper is required, which would 'spoil' the car's styling.

Typically, the sensors operate at frequencies in the range 2 to 100 GHz .

Preferably, the timing control signal from the processor provides phase and time synchronisation for each sensor during operation.

Preferably, the processor is incorporated into at least one sensor.

15 Preferably, the timing control signal from the processor is derived from the pulse repetition frequency of the transmit and receive pulse generators.

Preferably, the timing control signal has a frequency of the order of MHz.

In accordance with a second aspect of the present invention, a vehicle parking aid comprises an object detection device according to the first aspect, wherein a
20 reference plane is defined at either end of the vehicle where sensors are provided, the reference plane being orthogonal to a centreline of the vehicle and positioned such as to be between all parts of the respective end of the vehicle and the object being sensed; and wherein the linear distance derived is the shortest distance between the reference plane and the object being sensed.

25 An example of an object detection device according to the present invention will now be described with reference to the accompanying drawings in which:-

Figure 1 illustrates examples of general arrangements of an object detection device according to the present invention;

Figure 2 illustrates in more detail, a sensor in the device of Fig. 1;

30 Figure 3 illustrates potential errors in range estimates for prior art systems and how the present invention overcomes these; and,

Figure 4 illustrates the linear distance derived when the device of Fig. 1 is used in a vehicle parking aid.

For simplicity, in the example as shown in Fig. 1a, the system of the present invention comprises a first and second sensors 17 connected to a central unit 3. The central unit 3 provides phase and time synchronising signals to each sensor during operation and receives range data from the sensors which it then processes. However, commonly the system would comprise multiple sensors and optionally, the central unit 3 would be an integral part of one or more sensors (1 .. n) as shown in Fig. 1b. For example, the processing function of the central unit could be incorporated into one controlling sensor, or else all the sensors could be manufactured with the potential to perform a controlling function, but with this function disabled if not required. The former arrangement has the benefit of avoiding manufacturing redundant elements and so reduces overall cost. In the example of Fig. 1b, sensor 1 is connected to sensors 2 to n. Instead of a central unit, a processor within sensor 1 provides phase and time synchronising signals to these sensors and processes range data received from the sensors. An advantage of this system is that the synchronising signals have a low frequency (of the order of MHz) which is related to the pulse repetition frequency (PRF) and are easy to distribute compared to synchronising the actual transmission between sensors.

The sensor itself is shown in more detail in Fig. 2. The sensor comprises a microcontroller 4 which controls a first pulse generator 5 operating at a first pulse repetition frequency, which acts as a transmitter so that a signal for transmission is output through a directional coupler 6 via an antenna 7. The transmitted signal reflected off an object is received by the antenna 7 and input to a low noise amplifier (LNA) 8 via the directional coupler 6. The output of the LNA is mixed in a mixer 9 with a signal from a second pulse generator 10, operating at a second, different, pulse repetition frequency to produce an intermediate frequency (IF) signal which is amplified in the IF amplifier 11 and analysed by the microcontroller 4. The transmit pulse generator and receive pulse generator outputs differ only by a small amount with respect to their pulse repetition frequencies. The IF signal incorporates a time expansion factor related to the difference in pulse repetition frequencies. This simplifies the processing of the IF signal. A substantially stable frequency difference is maintained between the frequencies of the first and second pulse generators.

In one example, the pulse generators operate at 5.8GHz, with a pulse repetition frequency of 3.6MHz, an IF of 70KHz, and the frequency difference is maintained at 43Hz. A benefit of using this sampling technique is that the scaling factor on the IF is significantly less than on the RF, so standard signal processing techniques can be used for processing of the received reflected signals. For this example the synchronising signals between sensors could be the PRF signal at 3.6 MHz and the difference frequency at 43 Hz.

With a single sensor only the radial distance from the sensor to the object can be determined. For a parking aid the linear distance from the rear of the vehicle to the object is required, hence multiple sensors are required. Using direct measurements from one or more sensors allows an obstacle's position to be calculated by triangulation (intersection of circles). An example of a technique for obtaining direct measurements is given in US-A-4,521,778.

However, a possible error mechanism which arises in systems using only direct measurements for an extended target is illustrated in Fig. 3a. Deriving a linear distance, by using both direct and indirect measurements as proposed in the present invention, allows this situation to be detected and corrected as shown in Fig. 3b. Obtaining indirect measurements provides further information placing obstacles on ellipses and so improving the accuracy of the position estimate. For some object positions, an object will not record a direct measurement for one of the sensors but will provide an indirect measurement, hence the position can still be calculated.

For the purpose of this application the term "linear distance" refers to the shortest distance between a reference plane and the object being sensed. For example, as shown in Fig. 4, when used in a motor vehicle, the object detection device has a reference plane defined at the or each end of the vehicle where sensors are provided. The reference plane is orthogonal to a centreline of the vehicle and is positioned such as to be between all parts of the respective end of the vehicle and the object being sensed.

CLAIMS

1. An object detection device, the device comprising at least two sensors, each sensor being adapted to transmit and receive signals; and a processor to control
5 operation of the sensors; wherein each sensor comprises a transmit pulse generator operating at a first transmit pulse repetition frequency and a receive pulse generator operating at a second, different, pulse repetition frequency; wherein a timing control signal from the processor switches the sensors between transmit/receive mode and receive only mode; wherein a first sensor is set to operate in transmit/receive mode, the
10 first sensor transmitting at the first pulse repetition frequency and receiving reflections of the transmitted signal, reflected off an object; wherein the reflections are mixed with a reference signal to produce an intermediate frequency (IF) signal and analysed to derive a direct range measurement; wherein the or each other sensor is set to operate in receive only mode to produce an indirect range measurement; the receive pulse
15 generator operating at the second pulse repetition frequency; and wherein the operation is repeated for the or each other sensor operating in transmit/receive mode such that a set of direct and indirect measurements are obtained; whereby a linear distance from the object is derived from the direct and indirect range measurements.
- 20 2. A device according to claim 1, wherein the sensors are pulse radar sensors.
3. A device according to claim 1 or claim 2, wherein the sensors operate at frequencies in the range 2 to 100 GHz .
- 25 4. A device according to any preceding claim, wherein the timing control signal from the processor provides phase and time synchronisation for each sensor during operation.
5. A device according to any preceding claim, wherein the processor is
30 incorporated into at least one sensor.

6. A device according to any preceding claim, wherein the timing control signal from the processor is derived from the pulse repetition frequency of the transmit and receive pulse generators.
- 5 7. A device according to any preceding claim, wherein the timing control signal has a frequency of the order of MHz.
8. A vehicle parking aid comprising an object detection device according to any preceding claim, wherein a reference plane is defined at either end of the vehicle where
10 sensors are provided, the reference plane being orthogonal to a centreline of the vehicle and positioned such as to be between all parts of the respective end of the vehicle and the object being sensed; and wherein the linear distance derived is the shortest distance between the reference plane and the object being sensed.

FIG 1A

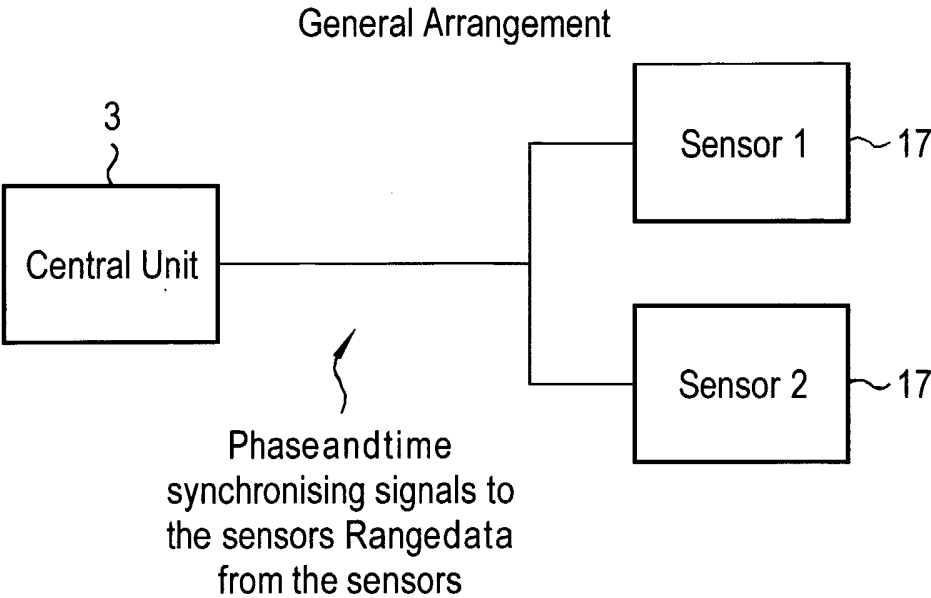


FIG 1B

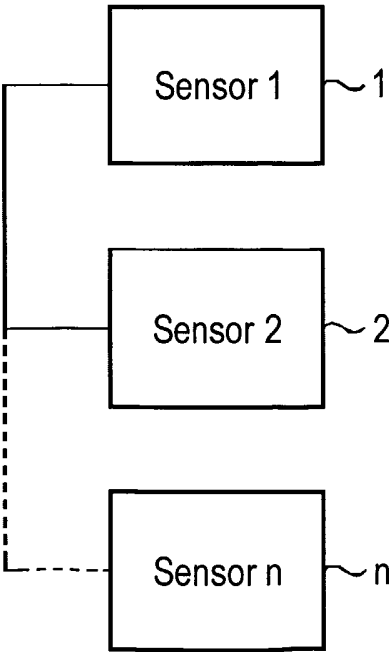


FIG 2

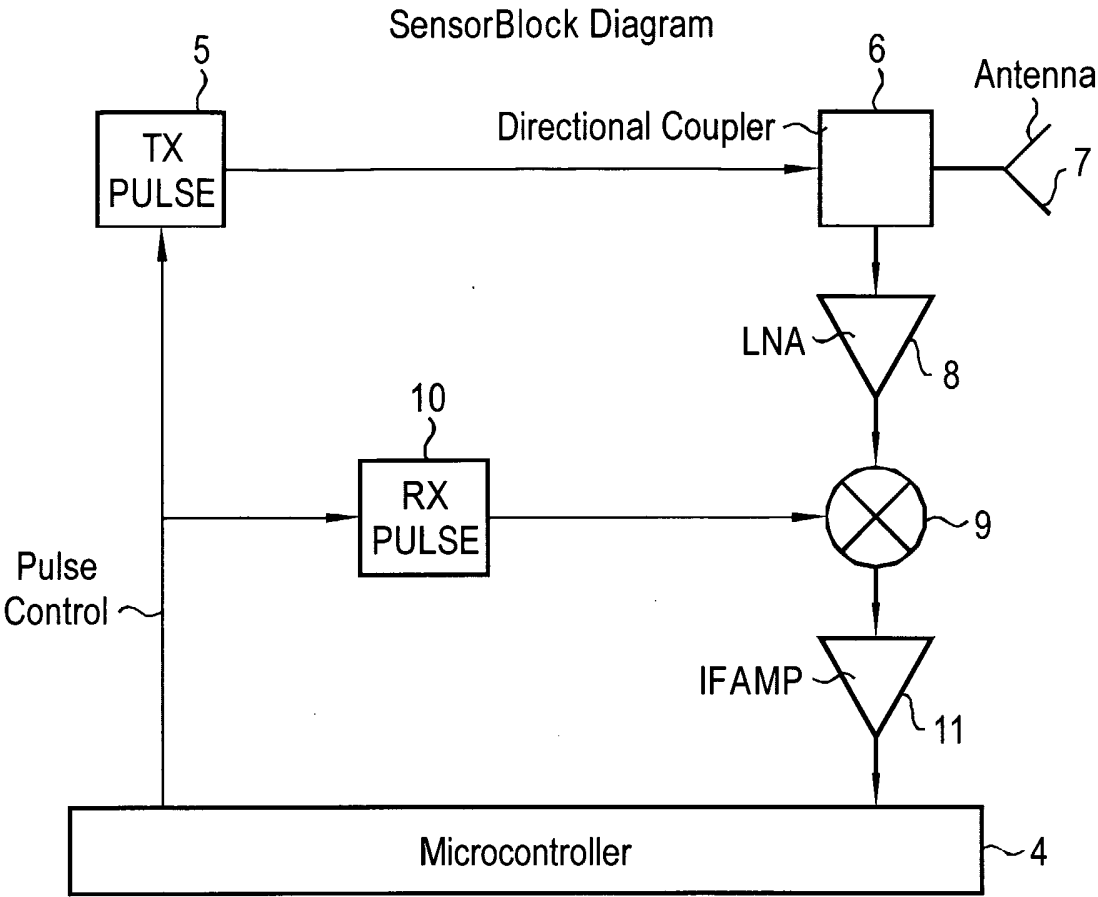
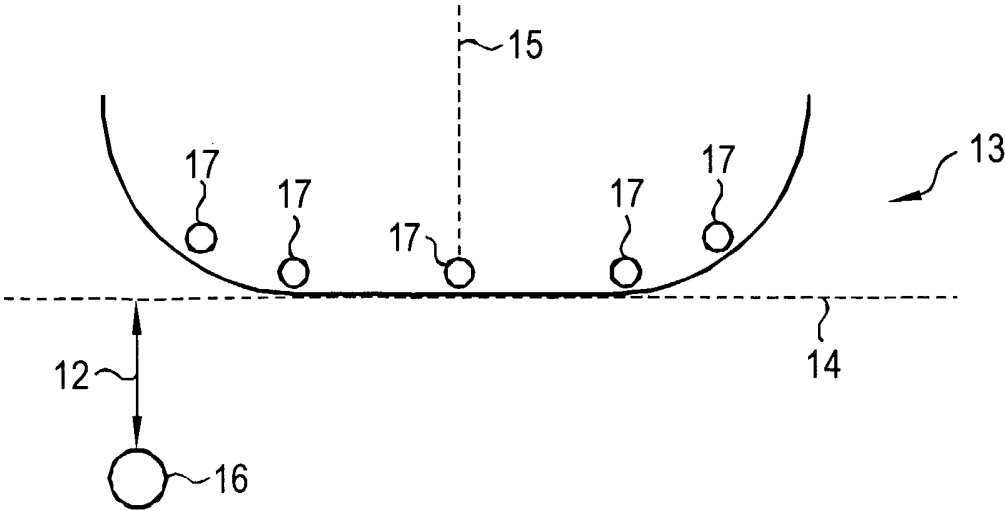
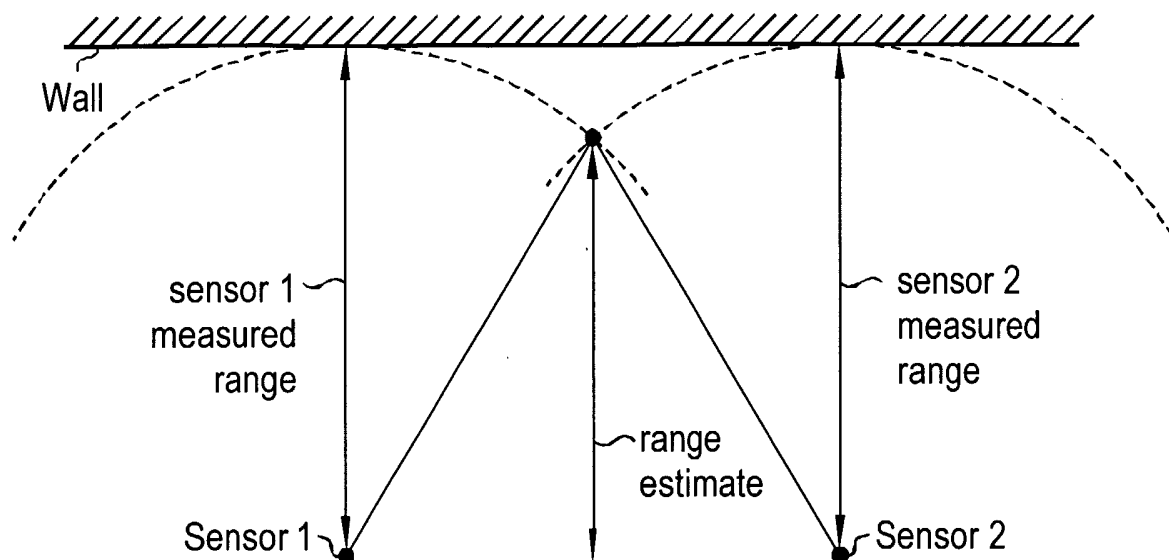
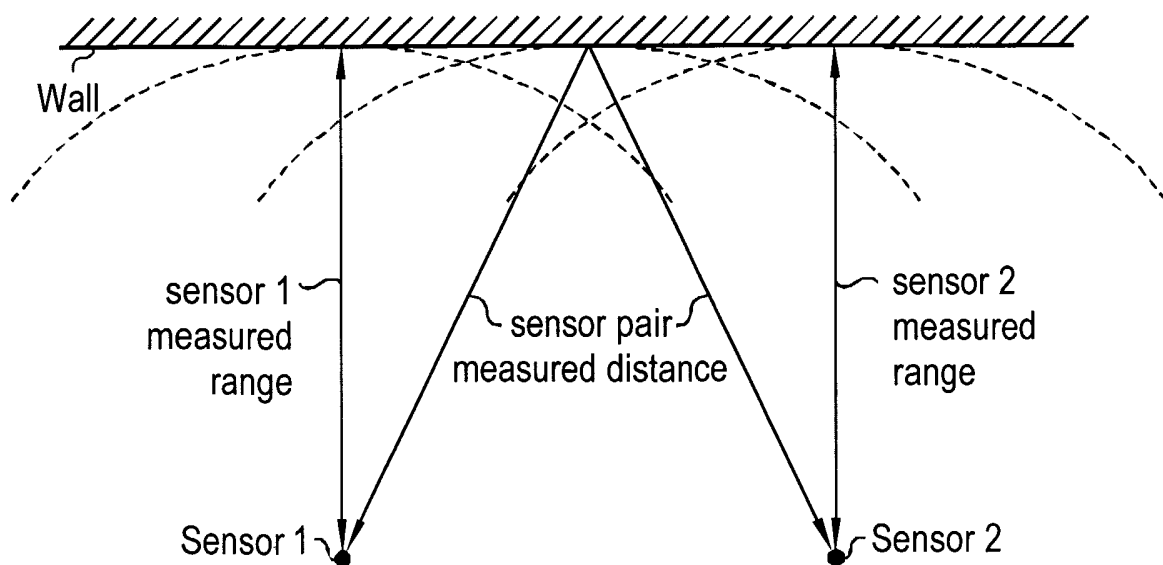


FIG 4



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FIG 3A**FIG 3B**

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/08552

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G01S13/87 G01S13/00 G01S13/93

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G01S

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 448 243 A (BETHKE KARL-HEINZ ET AL) 5 September 1995 (1995-09-05)	1-7
Y	abstract; claims 16,17; figure 9 column 3, line 16-51 column 4, line 50-56 column 6, line 16-27,48-68 column 10, line 33 ---	8
Y	DE 197 11 467 A (MANNE SMANN VDO AG) 1 October 1998 (1998-10-01) abstract; figure 1 column 1, line 34-59 column 2, line 58-68 column 3, line 5-9 column 4, line 35-49 --- -/--	1-8

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/08552

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 521 778 A (KNEPPER UDO) 4 June 1985 (1985-06-04) cited in the application abstract; figure 1 column 4, line 6-18 column 5, line 37 -----	1-8

INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/EP 02/08552

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