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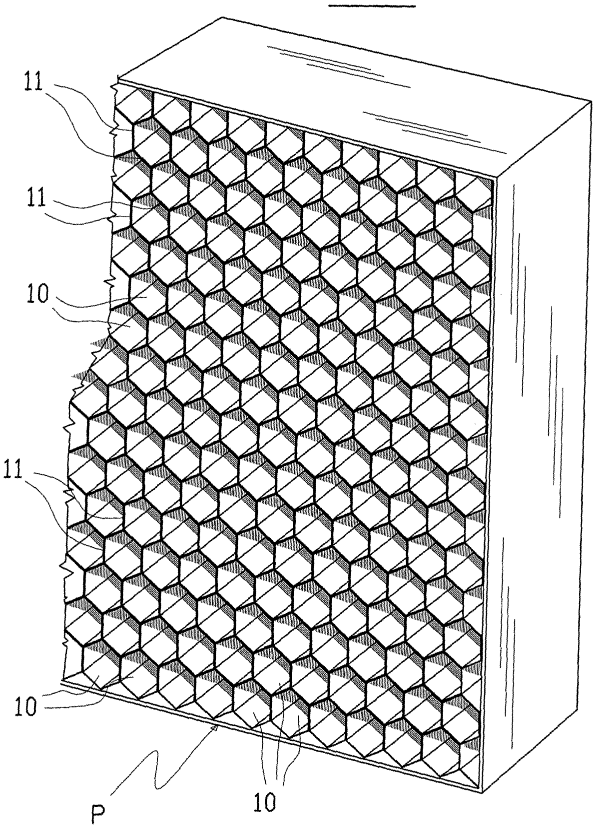
(54) **A sound-directing panel for sound conditioning**

(57) The sound-directing panel for sound conditioning comprises a cellular structure formed by a plurality of cells having frontally-open tubular chambers, in which the size of the transversal section and the length of the chambers of the cells defines corridors which can entrain and direct the sound hitting the panel in the direction of the axes of the chambers, or directions which are close thereto. In particular, the chambers of the panels are reciprocally adjacent, and have parallel axes. In a preferred embodiment, the bottom surface of the cells is closed, while in a further embodiment the surface can be open. The invention can cause a reduction and an efficient conditioning of a noise level by means of a panel which is no bigger and costs no more and possibly less than traditional panels.

FIG.1

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## Description

**[0001]** The invention relates to a sound-directing panel for sound conditioning.

**[0002]** A possible application of the invention is for the reduction of a sound level generated in closed or open environments, and/or for insulating specified zones from others in which sound is generated.

**[0003]** At present, for this purpose, the prior art includes panels, known as sound-absorbent panels, which comprise a covering with a layer of material able to absorb and therefore trap a part of the sound waves striking it.

**[0004]** The main aim of the present invention is to provide a panel which is able to considerably reduce the sound level, while at the same time offering dimensions and production costs which are the same as or less than those for traditional panels.

**[0005]** These and other aims besides are all attained by the invention as it is characterised in the appended claims.

**[0006]** The invention is now described in detail, with the aid of the accompanying figures of the drawings, which illustrate some non-exclusive embodiments of the invention.

Figure 1 is a perspective view of a portion of a panel according to a first embodiment of the invention;
figure 2 is a transversal section according to a vertical plane of the panel of figure 1;
figure 2A is a section, as in figure 2, of a second embodiment of the invention;
figure 2B is a section, as in figure 2, of a third embodiment of the invention;
figure 3 is a schematic representation of the same section of the panel as in figure 2, struck by some sound waves;
figure 4 is a schematic illustration of the same section of the panel, struck by sound waves having different modalities with respect to figure 3;
figure 5 illustrates a practical use of the panel of the invention;
figure 6 illustrates a second practical use of the panel of the invention;
figure 7 illustrates a further practical use of the panel of the invention;
figure 8 illustrates a further practical use of the panel of the invention.

**[0007]** The panel (denoted in its entirety by P in the figures) comprises a cell structure, formed by a plurality of cells 10 having tubular chambers which are frontally open, adjacent to one another, each being laterally delimited by relatively thin walls 11 and having axes which are substantially parallel to one another.

**[0008]** The dimensions of the transversal section and the length of the chambers of the cells 10 are such as to define corridors able to channel the sound hitting the panel and direct it in the direction of the axes of the cell chambers.

**[0009]** Further, preferably though not exclusively the chamber of each cell 10 has a constant transversal section and a cylindrical lateral surface 11, meaning that the surface can be curved (for example in the case of a circular section) or prismatic (for example having a polygon section), and the chambers have a constant or nearly constant transversal section.

**[0010]** The section of the cell 10 can be shaped in several different ways, rectangular, polygonal, circular, regular or not regular, and so on.

**[0011]** The axis A of the chamber of the cells 10 can be straight; alternatively it is curved or zigzagged; also, the size of the transversal sections can vary, in particular by gradually increasing or decreasing.

**[0012]** In a first embodiment, illustrated in figure 2, while the front surface is open, the bottom surface of the cells 10 is closed, for example by a bottom wall 12.

**[0013]** In the embodiment illustrated in figure 2B, the corridor defined by the cells 10 is open both frontally and posteriorly, and the axis A is curved.

**[0014]** Figures 1, 2 and 2A show a panel which develops on a vertical plane; however the panel of the invention may develop on surfaces having different geometrical forms (inclined, horizontal, curved etc.) according to needs or type of application.

**[0015]** It has been experimentally verified that when a sound wave strikes the front surface of the panel, whatever the inclination of the sound wave's trajectory with respect to the panel itself, (and within certain values, as will be better specified herein below), a same sound wave is first absorbed by the cells and then is immediately reflected and channelled in a plurality of parallel waves having a direction of the axes of the cells 10.

**[0016]** Figure 3 schematically illustrates the above-described phenomenon. A first wave exits from a sound source S and strikes the open front surface of a cell 10a of the panel P, in a straight trajectory R1; the wave enters the cell 10a and is channelled along the corridor up to the bottom 12 thereof, where it is reflected by the bottom 12 and exits in a trajectory R1' which coincides with the axis A of the cell 10a. The same thing happens to all the sound waves (R2, R3) issuing from source S, which strikes other cells (10b and 10c); in these cases too, the wave enters the cells (10b, 10c), is reflected by the bottom surface 12 thereof and exits according to a trajectory (R2', R3') which coincides with the axis A of the cell.

**[0017]** The result is that all of the sound waves hitting the panel P are reflected and channelled in the same direction which coincides with the axes of the cells 10, whatever the inclination with which the waves issuing from the source S strike the front surface of the panel.

**[0018]** The most probable interpretation of the phenomenon is that the sound wave, once having entered the cell 10 chamber, is channelled, probably with several reflections along the lateral walls, up until it strikes the bottom wall 12 and is reflected therefrom and sent out of the cell 10 with a "megaphone" effect, i.e. directed and issued according to the direction of the axis A of the cell 10; during this phenomenon, the surfaces of the walls 11 condition the sound wave like a megaphone and confer on it a more or less constant direction, being the direction of the axis A of the cell 10.

**[0019]** Naturally in order for this "megaphone" type effect to take place, the dimensions of the chamber of the cell 10, i.e. the size of the transversal section and the depth of the chamber, must respect certain conditions.

**[0020]** A first condition is that the transversal section must have a diameter which is preferably in the same order as the wave to be treated; thus, as we are dealing with sound waves, whose minimum values are of a few centimetres, excellent results are obtained with a section whose diameter does not exceed five centimetres. Satisfactory results have been obtained, however, with values above this, up to nine centimetres.

**[0021]** The lower this value, the more effective the conditioning the sound wave receives and the better the "megaphone" effect.

**[0022]** It must be taken into account that the smaller the section of the cells 10 the greater the front surface occupied by the front edge of the mouths of the cells 10, caused by the thickness of the walls 11, while the area occupied by the empty parts of the mouths of the cells 10 will be smaller; consequently, since the sound waves striking the front edge are not treated according to the mentioned megaphone effect, but are simply reflected, the functional performance of the panel will be greater the higher the percentage of front surface left empty. The weight and the cost of the material used to manufacture the panel will also be smaller the higher the "empty" front surface percentage.

**[0023]** A further condition to be respected is that the depth (axial dimension) of the cell 10 must have a value which is possibly not smaller than the diameter of the transversal section, as the bigger the relationship between the depth and the diameter, the more effective the conditioning which the sound wave receives and therefore the better the megaphone effect.

**[0024]** It is necessary to take account of the fact that the greater the depth of the cells 10, the greater the thickness and weight of the panel, and more generally the production costs therefor.

**[0025]** The panel, in practice, will be dimensioned according to applicational needs, as the best compromise between the conditions and the above-described factors.

**[0026]** The front faces of the cells 10 can be aligned on a same geometrical surface to give rise to a flat front surface, as illustrated in figures 1 and 2. Alternatively, the front mouths of the cells 10 can be cut to 90° with respect to the axis A of the cell 10, as illustrated in figure 2A.

**[0027]** A practical preferred shape is that the cell 10 section is polygonal (for example, square, or hexagonal as in the case illustrated in figure 1), and the cells 10 should be reciprocally adjacent, in order to entirely occupy the front panel surface, offering the greatest possible area of empty surface.

**[0028]** With the above conditions, the above-described channelling phenomenon occurs in the direction of the axis A of the cell 10.

**[0029]** However, in order for the phenomenon to occur a further geometrical condition must be observed, i.e. the trajectory of the wave issued from the source must strike the cell at such an angle as not to be immediately reflected in an external direction, from the lateral wall of the cell. Figure 4 schematically represents this scenario; the sound wave issued from the source S hits the cell 10d with a trajectory R4 that forms, with the front plane of the panel, an angle B which is relatively small, such that when the wave strikes the lateral wall of the cell, instead of being reflected into the cell and being "captured" thereby, it is reflected in an external direction; in this case the "megaphone effect" does not occur and the panel behaves like a usual reflecting surface.

**[0030]** This happens when the angle B is less than a limit value $B_0$, which depends on the inclination of the axis A of the cell; in the theoretical example illustrated in figure 4, in which the wall 11 of the cell 10d struck by the trajectory R4 behaves like a flat reflecting mirror, the limit angle $B_0$ is equal to ½ (90-k) where K is the angle the axis A of the cell forms with the frontal plane of the panel.

**[0031]** If the megaphone effect is desired, the inclination of the sound wave with respect to the frontal surface of the panel has to be taken into effect.

**[0032]** A further phenomenon encountered in the panel of the invention is that the sound reflected by the panel P, though composed of elements whose surfaces are not intrinsically sound absorbent, is subject to an energy-damping effect with respect to a sound that is simply reflected off another type of non-sound-absorbent material surface. The explanation of this phenomenon is that in the cell 10 chamber, the part of the sound wave that is reflected by the bottom 12 interferes with the part of sound wave that follows, which enters in the chamber in the opposite direction, and the portions of sound under compression combine with the portions of sound under depression, with a cancelling-out effect. In the majority of cases there is not a total reduction of sound, but there is most certainly a very considerable reduction.

**[0033]** Obviously, this sound-reducing effect can be increased by placing a known-type sound-absorbent material in the posterior zone of the cell 10 chambers.

**[0034]** The presence of the bottom 12 and the walls 11 of the cells, especially where made in a single piece, means that the structure of the panel is very strongly connected and is therefore particularly suitable for sound damping.

**[0035]** If no bottom surface 12 is included (see figure 2B), and the cells 10 are therefore open throughout, the sound wave striking the front surface of the panel P, whatever the inclination of the trajectory thereof with respect to the panel, is channelled by the cells 10 and issued in a plurality of waves, parallel to one another and having a direction coinciding with the axes of the cells 10; during this phenomenon, the surfaces of the walls 11 condition the sound wave like a megaphone and confer thereon a direction which is practically constant in the direction of the axis A of the cell 10.

**[0036]** Obviously in this case the sound wave enters the panel from one side and exits from the other side. It may be worthwhile using cells 10 having a curved axis A, so that the axis A of the cell is inclined differently at the exit in comparison to at the entrance thereof; the angle can be determined according to the application. It must be noted, however, that this application does not result in a reduction of the sound level, because the sound exiting from the cells 10 has not been reflected.

**[0037]** The possible practical applications of the panel of the invention are many and various.

**[0038]** One possible application of the invention, illustrated in figure 5, is to reduce the quantity of sound present in a predetermined zone Z1, for example a worksite producing considerable amounts of noise, which is also located close to a sound-reflecting surface 21, such as a nearby building 23. In this case, a panel P according to the invention (especially the type of embodiment thereof illustrated in figures 2 or 2A) is placed between the worksite and the building, which panel P has the axes of the tubular cells 10 oriented so that the cells 10 are able to collect at least a majority of the sound waves R5 produced by the source 22 (for example, a pneumatic drill) and to send them (trajectory R5') in an upwards direction, above the zone Z1 so that the people working in the work-site are spared being struck full blast by the noise. There are two major benefits: the sound produced by the source 22, reflected by the surface 21, is not sent back into the zone Z1, and the building 23 is also not struck by the issuing sound.

**[0039]** A further possible application, illustrated in figure 6, is for acoustically isolating a first zone Z3, in which for example there are dwellings 31, from a second zone Z4, where a sound is generated, for example a busy street. In this case, between the two zones Z3 and Z4, a panel P according to the invention is placed (in particular a panel of the type illustrated in figure 2B), in which the axes of the tubular cells 10 are oriented such that the cells are able to gather at least the majority of the sound waves R6 coming from the second zone Z4 and send them (trajectory R6') upwards and above the first zone Z3. It may be advisable in this case to use cells 10 having a curved corridor axis A, having an inclination and being almost horizontal at the entrance thereof, so as to capture all or nearly all of the sound waves coming from the street (as the waves will strike the panel at an angle B which is greater than the described limit angle $B_0$) and direct them , as they exit, upwards at an inclination which overshoots the zone comprising the dwellings 31.

**[0040]** A further possible application, illustrated in figure 7, is for reducing the noise in a large closed space, such as inside a workshop 40 tending to be noisy. For example, the lateral walls of the workshop 40 are covered floor-to-ceiling with vertical panels P1 according to the invention (in particular of the type illustrated in figure 2 or 2A), while different panels P2 are used at ceiling height (which might also basically be of the type illustrated in figure 2 or 2A) which are shorter in height, parallel to one another and vertically projecting downwards starting from the roof covering 41, and defining a series of adjacent chambers 42. These chambers 42 extend over the whole length of the roof covering 41 and are inferiorly closed by other panels P3 which are horizontal or inclined parallel to the roof covering 41 (of the type illustrated in figure 2B). Further, in each chamber 42, the axes of the cells 10 of the panels P2 set side-by-side are parallel to each other as well as to the roof covering 41.

**[0041]** The axes of the cells 10 of the panels P1 are directed upwards so that when they are struck by the waves (trajectories R7) coming from a sound source S in the internal environment, the waves (trajectories R7') are reflected towards the panels P3. Other waves (trajectories R8), issuing from the source S, directly strike the panels P3, and others besides (not illustrated in the figure) strike the panels P3 after various reflections against other surfaces (for example, the floor) or objects. Thus almost all of the sound waves produced by the source S which are not absorbed by the surfaces struck are sent on, thanks to the lateral panels P1, towards the upper panels P3. The panels P3 then direct the sound waves (trajectories R7") internally of the chambers 42 towards the panels P2; the panels P2 are directed one towards another and produce trajectories R7" which bounce from one panel P2 to another, are therefore damped and never exit from the chamber 42. The result of this is that a notable quantity of the sound produced in the closed environment is absorbed by the chambers 42.

**[0042]** A further possible application, illustrated in figure 8, is for acoustically isolating a first zone Z5, containing for example swellings, from a second zone Z6 in which a sound is generated, for example a busy street. In this case, a panel P according to the invention is placed between the two zones Z5 and

**[0043]** Z6; in particular the type of panel used is as in figure 2. The axes of the tubular cells 10 are oriented downwards so that the cells 10 can gather up the majority of the sound waves R9 coming from the second zone Z6. In this case, and differently to the case illustrated in figure 6, the waves exiting from the panel P are directed (trajectory R9') downwards (where the part which is not absorbed is reflected upwards - trajectories R9") and in any case away from the zone Z6, so that they do not strike the dwellings 51.

**[0044]** The last embodiment, which is conceived mostly with open spaces in mind, is particularly advantageous from the point of view of realisation.

**[0045]** Obviously numerous modifications of a practical-applicational nature can be brought to the invention with its forsaking the ambit of the inventive idea as claimed herein below.

## Claims

1. A sound-directing panel for sound conditioning, **characterised in that** it comprises a cell structure formed by a plurality of cells having tubular chambers which are frontally open, dimensions of a transversal section and a length of the chambers being such as to define corridors able to channel and direct a sound striking the panel in a direction of axes of the chambers or in directions nearby thereto.

2. The panel of claim 1, **characterised in that** the chambers of the panels are reciprocally adjacent, and have axes which are parallel to one another.

3. The panel of claim 2, **characterised in that** the chambers of the cells are delimited by thin walls.

4. The panel of claim 1, **characterised in that** a bottom surface of the cells is closed.

5. The panel of claim 1, **characterised in that** the bottom surface of the cells is open.

6. The panel of claim 1, **characterised in that** the cells are substantially identical to one another.

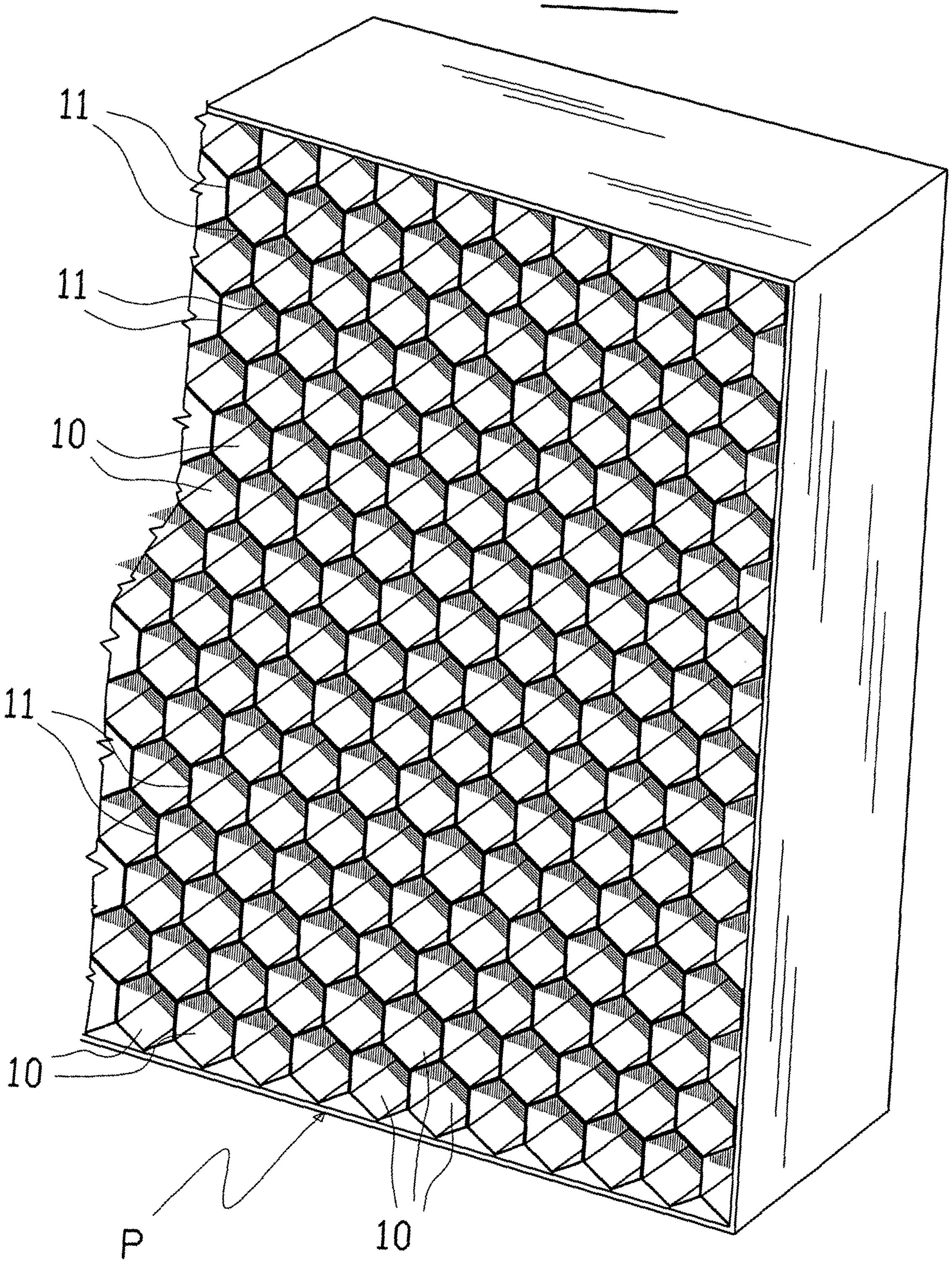
7. The panel of claim 1, **characterised in that** each cell has a constant transversal section and a cylindrical lateral surface.

8. The panel of claim 5, **characterised in that** the cell has a polygonal section, and the cells are reciprocally adjacent, and occupy a whole front surface of the panel.

9. The panel of claim 1, wherein the panel reduces a quantity of sound present in a specific zone, **characterised in that** axes of the tubular cells are oriented in a direction in which the cells are able to gather at least a majority of sound waves and direct the sound waves to positions which are external of the zone.

10. The panel of claim 1, for acoustically isolating a first zone from a second zone in which second zone a sound is generated, **characterised in that** the axes of the tubular cells are oriented so that the tubular cells are able to gather at least a majority of the sound waves coming from the second zone and direct them externally of the first zone.

FIG.1



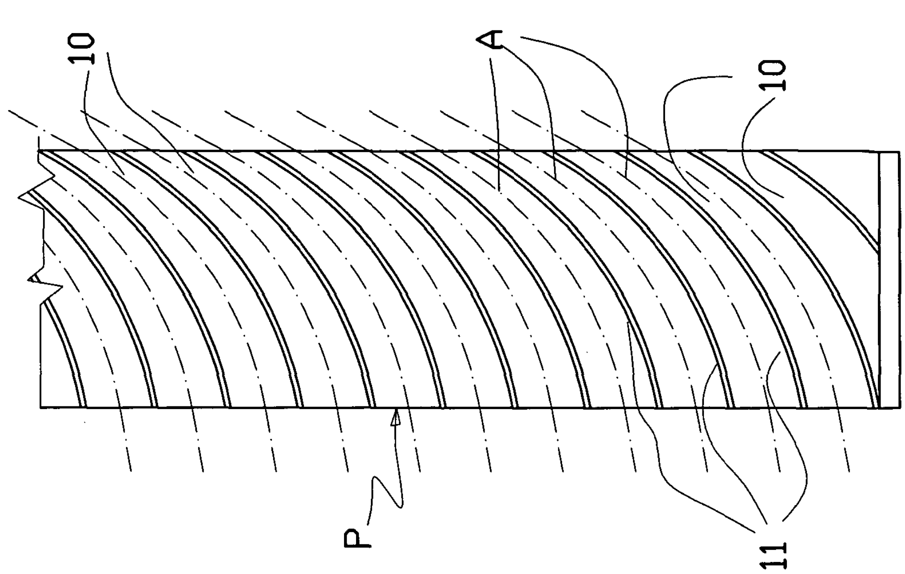



FIG.2B

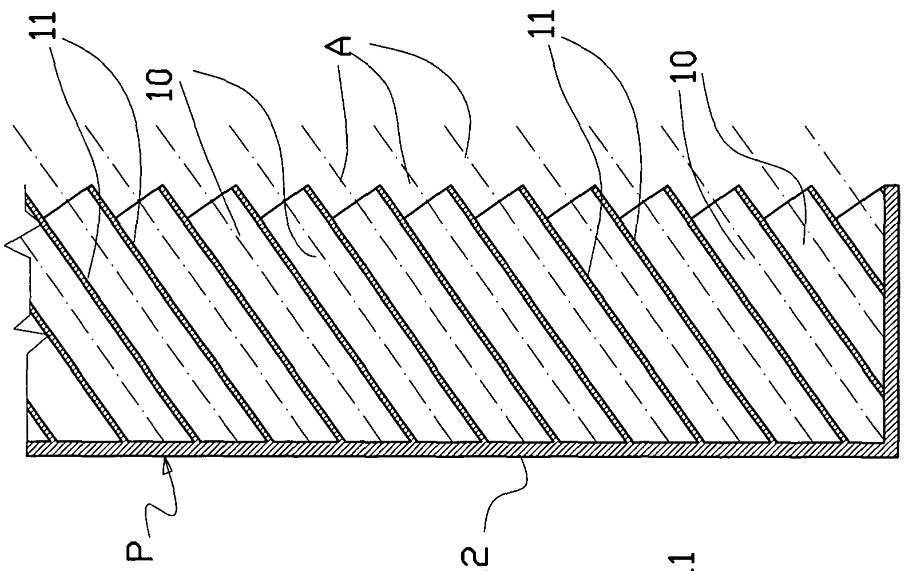



FIG.2A

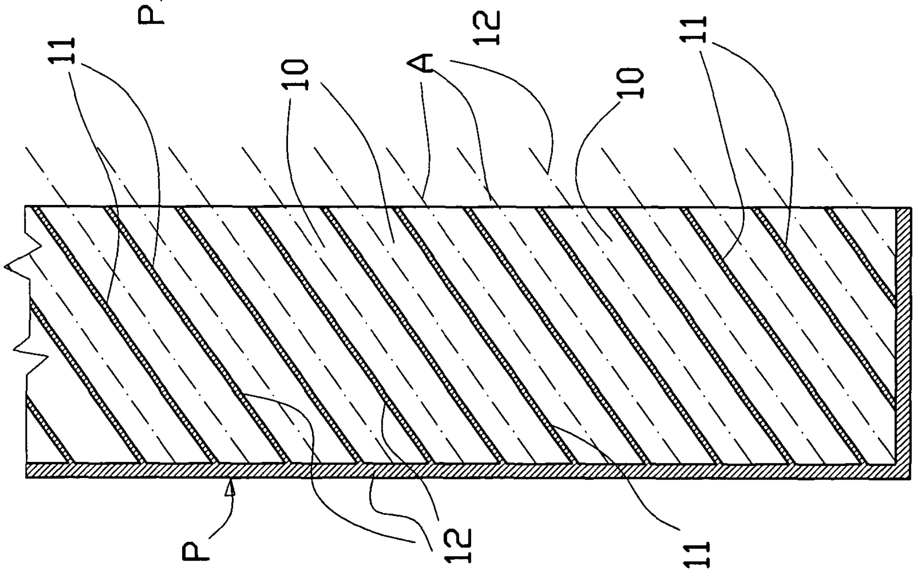



FIG.2

FIG.4

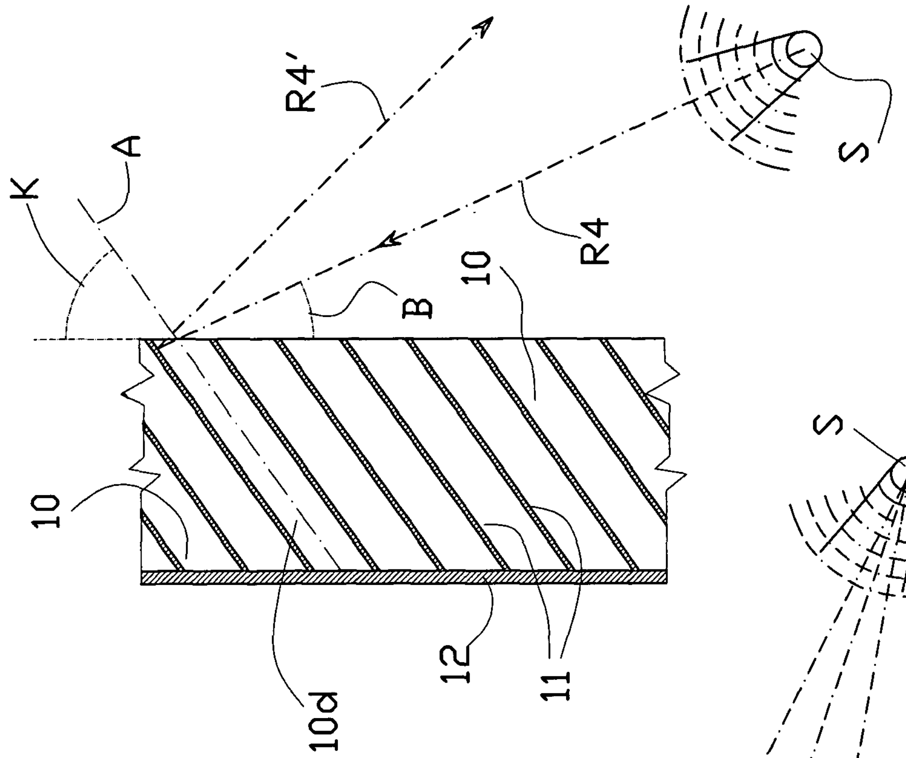
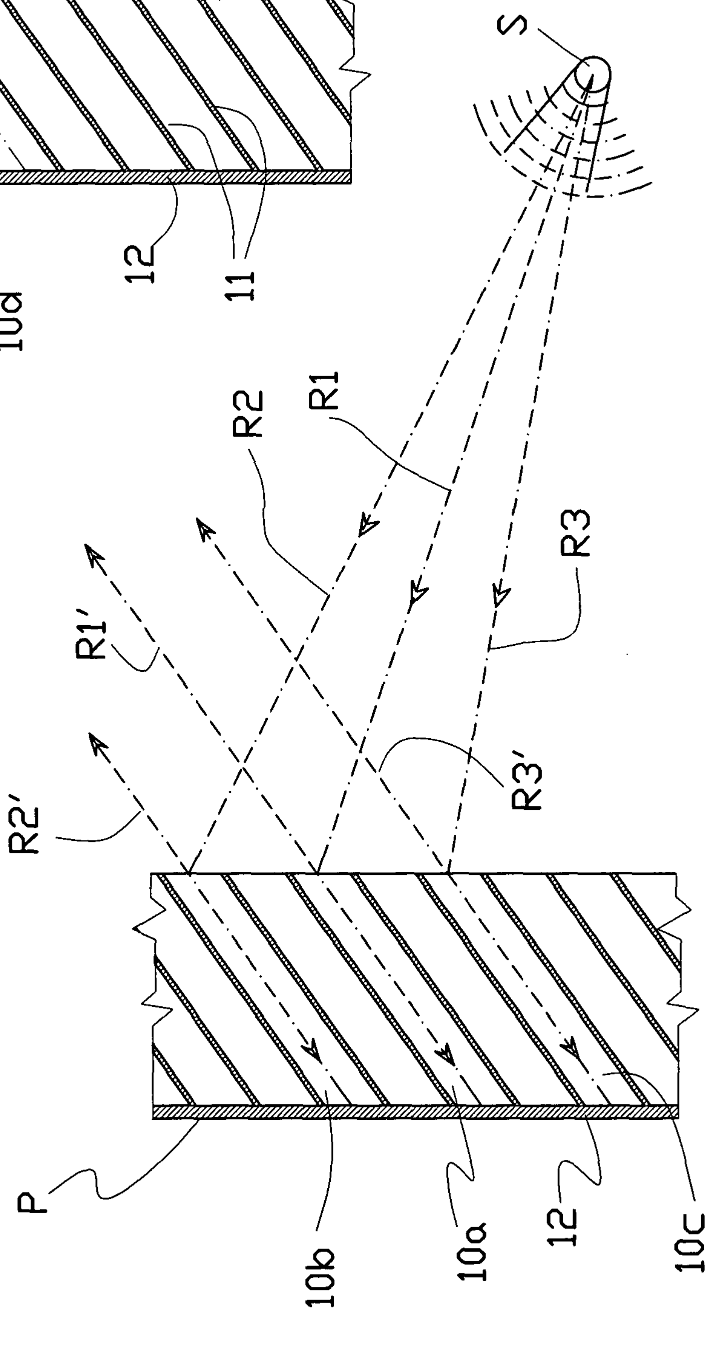



FIG.3



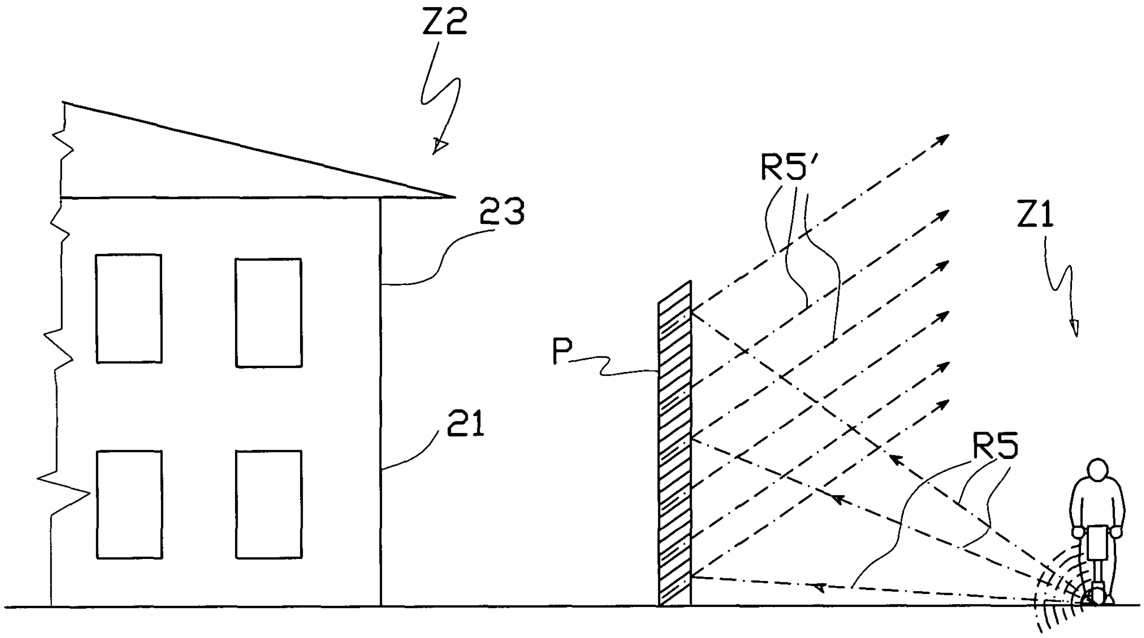



FIG.5

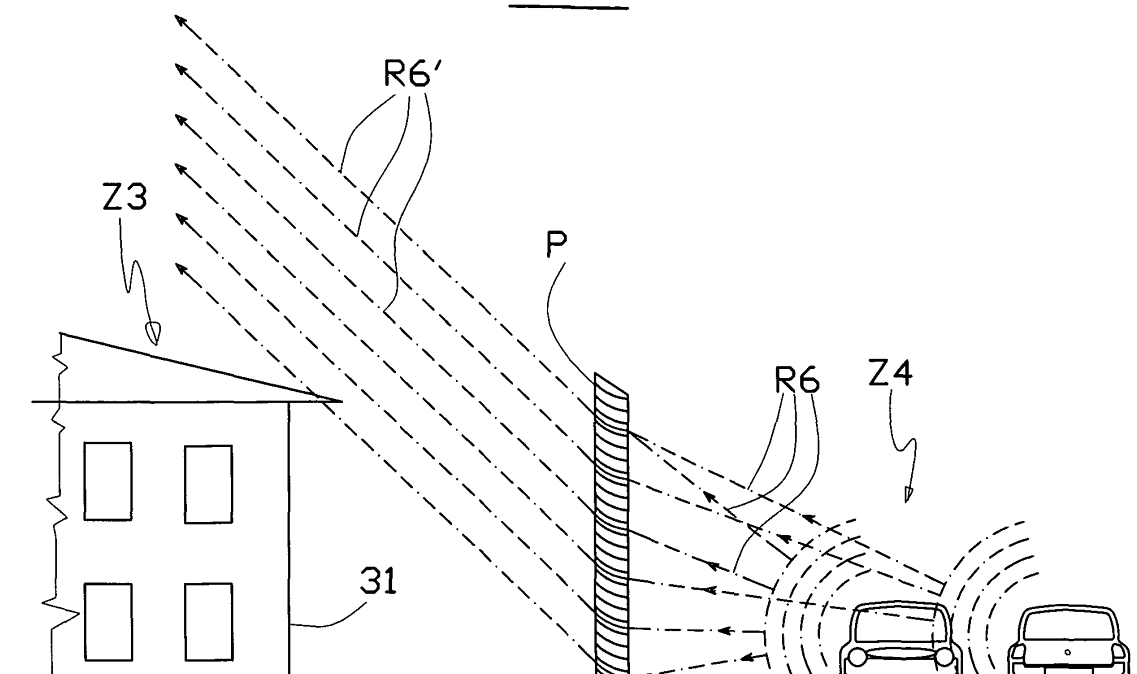



FIG.6

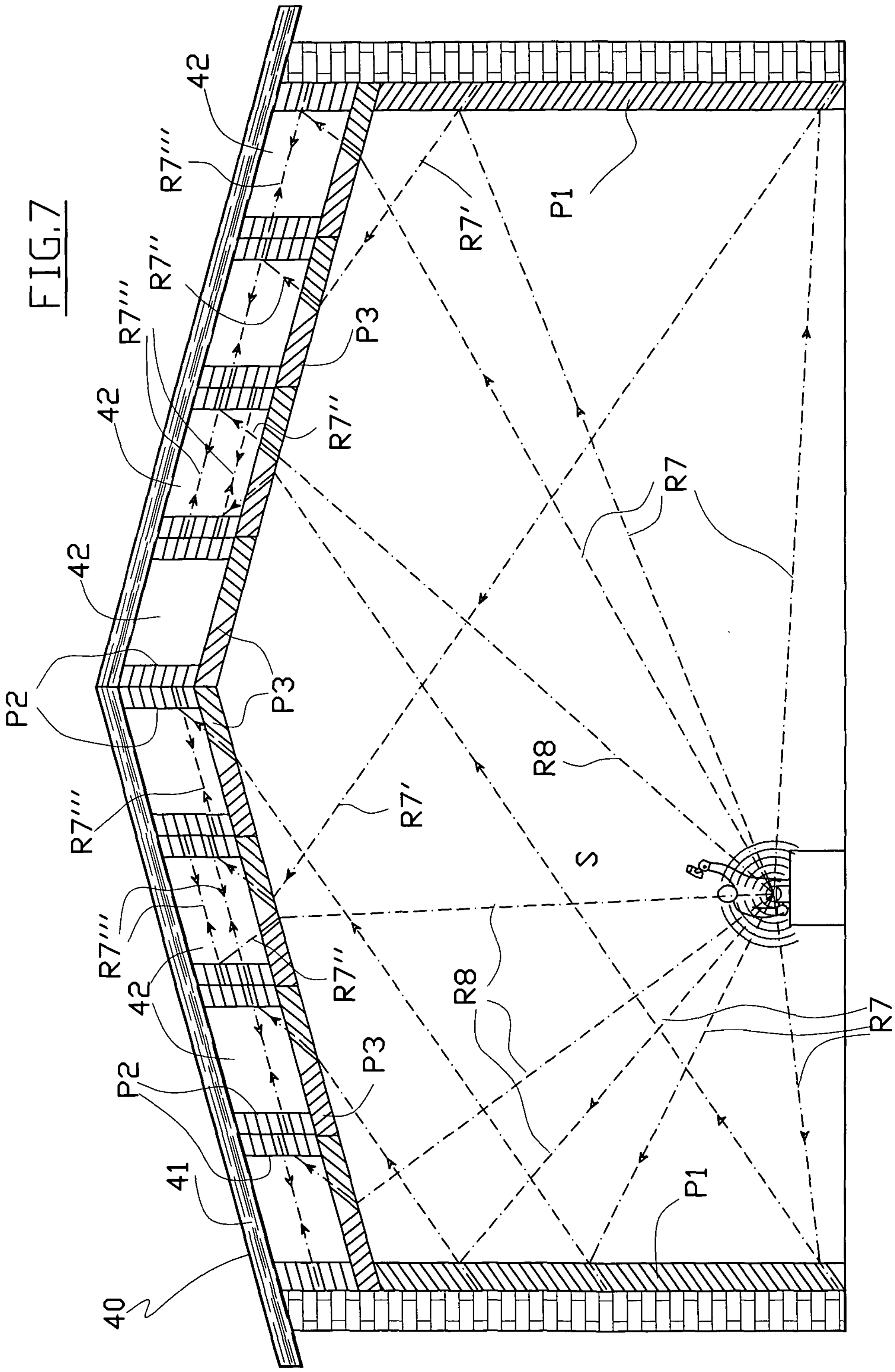
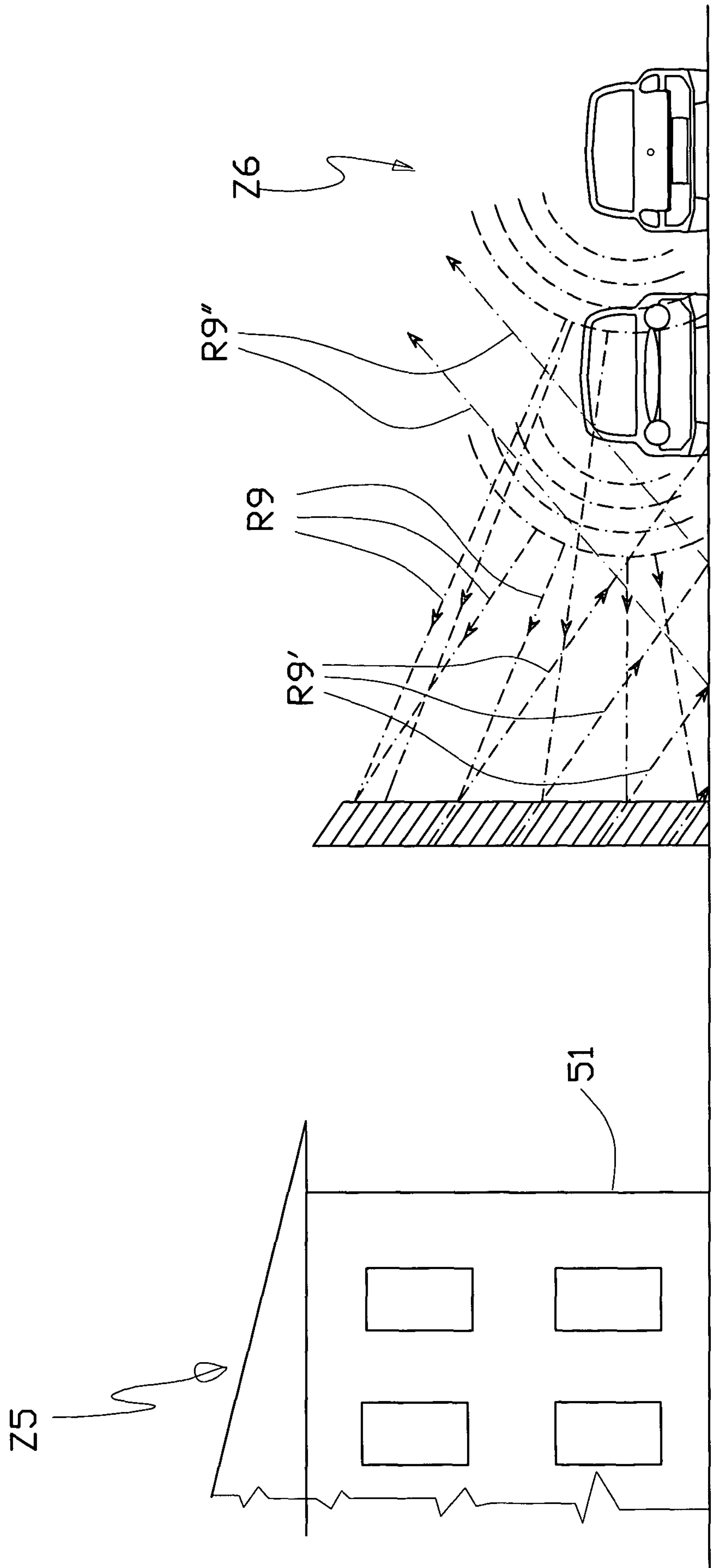

42
R7'''
R7'
P1
R7''
R7'''
P3
42
R7''
R7
R7
P2
42
P3
R8
R7'''
R7'
S
R7'''
42
R7''
R8
R7
P2
P3
41
P1
40

FIG.7

FIG. 8



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# EUROPEAN SEARCH REPORT

Application Number
EP 04 07 8315

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| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |
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E04B
E01F

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 30 March 2005 | Kriekoukis, S |

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