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The present invention relates to a system with variable acoustic properties configured to cover boundaries (11) of a space, such as walls or ceilings of a room, the system comprising a plurality of modules or units (2) with variable acoustic properties having a front face (4) provided with openings (6) through which sound energy can enter an inner region (3) of the module or unit (2), and where one or more of the modules or units (2) comprises a sound absorbing device (12; 38, 39) in acoustic communication with the openings (6) in the front face (4), which openings (6) can be closed, such that sound energy cannot enter the inner region (3) and opened, such that sound energy can enter the inner region (3), where the front face (4), including the openings (6) herein, of a plurality of said modules or units (2) are covered by a covering sheet (8) that extends as an unbroken surface over the plurality of modules (2), and where the covering sheet (8) is configured such that it makes it possible for sound energy to enter the interior region (3) through the covering sheet (8) and the openings (6), when the openings (6) are in an open state. The invention further relates to modules for use in the above described system and to a method for altering the reverberation time of a room, especially at low frequencies.

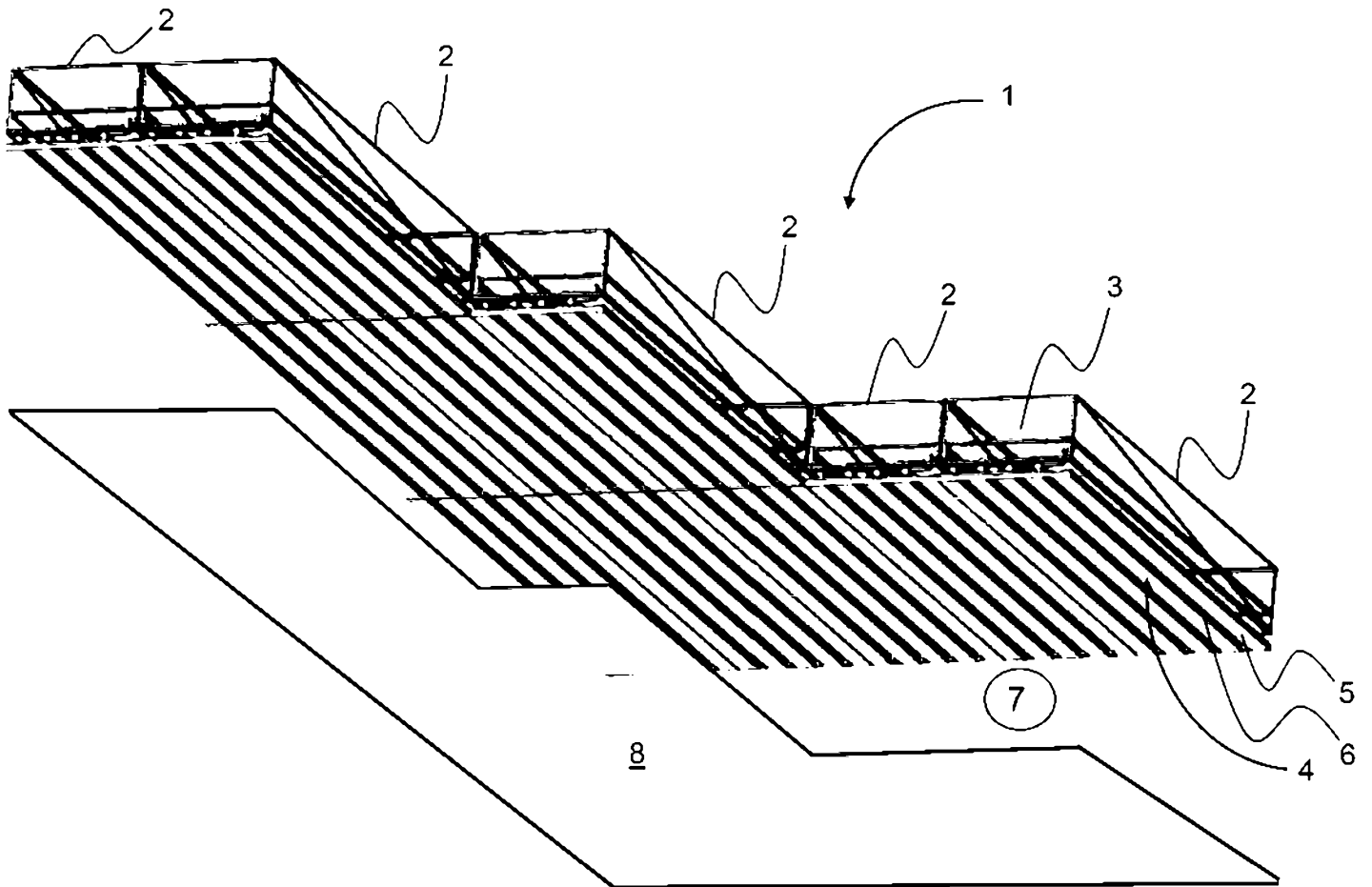


Fig. 1

VARIABLE ACOUSTIC TECHNOLOGY FOR ROOMS

TECHNICAL FIELD

The present invention relates generally to the field of room acoustics and more particularly to devices, systems and methods for altering the reverberation time of rooms or other locations, in which various kinds of live performances are to take place, such that the reverberation time can be optimized to each specific kind of live performance.

BACKGROUND OF THE INVENTION

Worldwide, multi-purpose rooms or halls are used and especially in connection with such rooms or halls it is very important that the reverberation time can be changed according to each specific need. Thus, for instance the performance of amplified music such as pop and rock may require a relatively short reverberation time especially at low frequencies, whereas performance of classical or choral music may require a longer reverberation time.

In [1] it was demonstrated that what makes a hall suitable for amplified music is first and foremost a rather low reverberation time at low frequencies (especially 125 Hz, but to some extend also the 63 and 250 Hz octave bands).

Further, in [2] it was substantiated that the reverberation time at higher frequencies above some 500 Hz can be much longer for amplified music.

Means for altering the acoustic characteristics of a room are well known in the art. This for instance US 8,573,356 B1 describes an adjustable sound panel having a sound diffusing element and a sound absorbing element. The panel can be varied by a state in which maximal sound absorption is obtained by opening passageways extending from the front of the panel to the rear of the panel where a suitable sound absorbing material is provided. The front face of the panel is configured as a sound diffuser comprising a pattern of slats with openings between adjacent slats. When mounted in a room, the visual appearance of the room is altered.

US 9,322,165 B2 describes a dynamically adjustable acoustic panel device, at the front face of which there is provided a plurality of relatively small (compared to the entire acoustic panel device) square panel elements that have a sound diffusing effect. These small panels can each be rotated about an axis whereby the panel device can obtain be brought to a sound absorbing state as the rotated small panels provide sound access to a region behind the panel device, in

which a suitable sound absorbing material is provided. As in the case of the above cited US 8,573,356 B1 the provision of the panel device alters the visual appearance of the room, when mounted herein.

US 6,431,312 B1 describes a motorized and computer operated variable acoustic treatment that comprises a plurality of acoustical treatments located in a space separated from other acoustical treatments. The acoustic treatment comprises rotating units that can be rotated about their individual axes by means of a motor, which can be controlled by a user via a user interface. As in the case of the above cited US 8,573,356 B1 and US 9,322,165 B2, the provision of the variable acoustic treatment alters the visual appearance of the room, when mounted herein.

EP 1 779 375 B1 describes devices, systems and a method for altering the reverberation time of a room or hall, especially at lower frequencies, where the reverberation time is altered by the introduction of inflatable bodies with suitable acoustic characteristics in the room. When a reduction of reverberation time is desired, the bodies are inflated. The provision of the bodies described in this document in a room will in most cases alter the visual appearance of the room significantly, unless they are provided in regions of the room that are not illuminated.

On the above background it would be desirable to have access to a variable acoustic technology to be provided in a room or hall that could alter acoustic characteristics, especially the reverberation time, of a room or hall without thereby altering the visual appearance of the room or hall when the characteristics of the acoustic treatment are altered. This technology should preferably be configured to allow easy integration into the interior design of a room or hall.

DISCLOSURE OF THE INVENTION

On the above background it is an object of the present invention to provide means for varying the reverberation time in rooms, auditoriums and the like such as – but in no way limited to – concert halls or other rooms in which music is to be performed, theatres, cinemas and multi-purpose rooms or halls. The means according to the present invention must fulfill at least two requirements:

(1) They must facilitate changing the reverberation time, especially at lower frequencies, of the room or hall in which they are used. This is according to the principles of the present invention accomplished by the provision of sound absorbing units or modules that are provided with means for absorbing sound, wherein the sound absorption can be varied between substantially

no absorption of incident sound energy and a very high absorption of incident sound energy. This large variation of sound absorption is especially desirable in the lower frequency range, for instance at frequencies below 500Hz. It is, however understood that specific values of frequencies mentioned in the context of the present invention should not be regarded as
 5 limiting the scope of protection of the invention and should only be regarded as exemplary. Thus, for instance, optimal frequency ranges of sound absorption may among many other factors depend on the specific use of a room or hall.

(2) The means according to the present invention must provide an aesthetical solution that can be widely accepted by architects or other decision makers involved in the interior design of
 10 either existing rooms or halls, or in new constructions hereof. Preferably, the means according to the present invention must be configured for integration in existing or new rooms or halls. Preferably, the means according to the present invention must, when provided in a room or hall, present one or more seemingly or physically unbroken surfaces extending over boundary portions of the room or hall. Thus, for instance, a complete wall of a multi-purpose hall will,
 15 after the provision of the wall present a seemingly or physically unbroken surface extending over the entire wall and having a unified appearance to an observer located in the hall. This appearance will according to the present invention not change when the acoustic properties of the wall provided with the means according to the invention are altered with the aim to for instance alter the reverberation time of the room or hall. Specifically it may under
 20 circumstances be advantageous by simple means (such as lightning or projection of pictures etc.) on surface portions of the means according to the invention to be able to change the visual appearance of for instance a wall on which the means according to the invention are provided.

The above and other objects and advantages are according to a first aspect of the invention
 25 provided by an acoustic module or unit with variable acoustic properties configured for covering boundaries, such as walls or ceilings or portions hereof of a room, for instance a multi-purpose room, in which it should be possible to change the acoustical properties of the room according to each specific use, where the module or unit has a front face provided with openings through which sound energy can enter an inner region of the module or unit, and where the module or
 30 unit in the inner region comprises a sound absorbing device in acoustic communication with the openings in the front face where the openings can be closed such that sound energy cannot enter the sound absorbing device and opened, such that sound energy can enter the sound absorbing device, and where the front face that is provided with the above mentioned openings is covered by a covering sheet that is configured such that it is possible for sound energy to

enter the sound absorbing device through the sheet and the openings, when the openings are in the open state.

The module or unit according to the first aspect comprises basically two entities: a frame structure that can be attached to boundaries of a room or hall or portions hereof, which frame structure defines the inner region of the module or unit in which inner region the sound absorbing device is provided, and a front face that is provided with the above mentioned openings that, when in the open state, provides sound access from the sound field in the room or hall to the inner region of the module or unit. Although it is possible to manufacture the frame and the front face as one integrated unit, it is in practice preferable to provide the frame as one entity and the front face as another entity. This allows the frame initially to be mounted on the chosen boundaries and afterwards, when the frame structure is in place to attach the front face to the frame structure. Typically, the front face will (for typical dimensions and choice of material of the modules or units) weigh about 30 kg and the corresponding frame will weigh about 12 kg. During installation, it is hence much easier to handle the frame as one separate entity and afterwards to attach the front face to the frame.

In an embodiment of the first aspect, lightning means, such as LEDs, are placed in the openings, which may emit light for instance when the openings are in the open state.

In an embodiment of the first aspect, the covering sheet is made of veneer or foil provided with perforations at least in those regions of the covering sheet that cover the openings in the front face of the module or unit. These perforations could here and anywhere throughout the description and claims be either perforations with relatively large diameter or micro-perforations or a combination of such perforations.

In an embodiment of the first aspect, a sheet or panel of medium-density fiberboard (MDF) is provided between said front face and said covering sheet.

In an embodiment of the first aspect, the sound absorbing device is configured to absorb mid and low frequency sound energy, preferably at frequencies below 1000Hz.

In an embodiment of the first aspect, the sound absorbing device is configured to absorb mid and low frequency sound energy, preferably at frequencies below 500Hz.

In an embodiment of the first aspect, the sound absorbing device is configured to absorb low frequency sound energy, preferably at frequencies in the 63Hz, 125Hz and 250Hz octave bands.

In an embodiment of the first aspect, the front face of the sound absorbing device comprises a plurality of slats with the openings provided between adjacent slats.

In an embodiment of the first aspect, the slats are made of metal, such as steel. The slats can either be solid or they can be made of hermetically closed profiles.

- 5 The slats are preferably made of a material that ensures a sufficient surface weight for instance not less than 15 kg/m² in order to obtain a low absorption value even at low frequencies in the closed mode of the openings, i.e. a high degree of sound reflection at low frequencies in the closed state. Preferably, a sound absorption coefficient of for instance max 0.1 should be obtained at 40Hz, which is the lowest frequency that is considered of interest for live
10 performances of most kinds of music.

Alternatively, or additionally, a low sound absorption coefficient may be obtained with relatively thin slats having a surface weight of for instance less than 15 kg/m², by increasing the rigidity of the slats by suitable means such as steel profiles (T or L profiles for instance) attached to the slats behind the slats, i.e. towards the inner region of the module or unit.

- 15 The surface weight required to obtain a desired sound absorption coefficient can be determined from the expression:

$$\alpha = \frac{1}{1 + \frac{2\pi f m}{2\rho c}}$$

- where α is the sound absorption coefficient, f is the frequency, m is the surface weight, ρ is the specific mass of air and c is the speed of sound in air. In an embodiment of the first aspect,
20 the thickness t of the slats (5) is less than mm, preferably less than 3mm. The thickness of the slats – and hence the depth of the openings between adjacent slats – should preferably be kept small in order to avoid an undesired Helmholtz resonator effect caused by the acoustic mass of the openings and the acoustic compliance of the interior space in the modules. The thickness of the slats should preferably be kept small in order to avoid resonator effect between
25 the sheet covering the openings in the module or unit and the opening and closing means (see below) that opens or closes sound access through the front face and into the interior region of the module or unit. This resonator effect can further be avoided or reduced by the provision of foam or rubber strips on the opening and closing means as described in the detailed description of the invention.

In an embodiment of the first aspect, the slats have a front face that is substantially planar. This feature is important in order to make it possible to mount the covering sheet firmly to the outer surface of the front face of the slats.

5 In an embodiment of the first aspect, the openings in the front face are provided with means for opening and/or closing one or more of the openings, which means comprises actuator or motor means operatively connected to the means for opening and/or closing the openings, which actuator or motor means can be remote controlled by a user from a user interface.

10 It is important that the openings in the front face can be closed hermetically if substantially no sound absorption is desired. Embodiments of mechanisms for opening and closing the openings in the front face are described in the detailed description of the invention. In the design of these mechanisms it is important to ensure that the required closing is not hindered by for instance accumulation of dust or other particles in the mechanism.

15 In an embodiment of the first aspect, the front face is provided with attachment means configured to attach said sheet or said panel of medium-density fiberboard (MDF) provided with said sheet to the front face of the module, whereby said sheet or said panel of medium-density fiberboard (MDF) provided with said sheet can be attached to the module after the module has been mounted on a boundary of a room or hall. Such attachment means comprise both mechanical attachment means and a suitable adhesive such as glue.

20 The above and further objects and advantages are according to a second aspect of the present invention provided by a system with variable acoustic properties configured to cover boundaries of a space, such as walls or ceilings of a room, such as a multi-purpose room or hall, the system comprising a plurality of modules or units with variable acoustic properties having a front face provided with openings through which sound energy can enter an inner region of the module or unit, and where one or more of the modules or units comprises a sound
25 absorbing device in acoustic communication with the openings in the front face, which openings can be closed, such that sound energy cannot enter the inner region and opened, such that sound energy can enter the inner region, and where the front face, including the openings herein, of a plurality of said modules or units are covered by a covering sheet, where the covering sheet extends as an seemingly (or physically) unbroken surface over the plurality
30 of modules, and where the covering sheet is configured such that it makes it possible for sound energy to enter the interior region through the covering sheet and the openings, when the openings are in an open state.

The above description of the modules basically comprising two entities: the frame structure and the front face applies also the second aspect of the invention. Thus for instance, when installing a system according to the second aspect, comprising a plurality of modules or units according to the first aspect, it may be advantageous to provide larger sections of the frame structure corresponding to a number of modules or units as unified entities and afterwards to attach the individual modules or units to such larger frame structures extending over larger portions of the boundaries of the room or hall.

As in the first aspect, lightning means can be provided in the openings to indicate the state of the individual modules used in the system. In an embodiment of the second aspect, the covering sheet is made of veneer provided with perforations at least in those regions of the covering sheet that cover the openings in the front face.

In an embodiment of the second aspect, a sheet or panel of medium-density fiberboard (MDF) is provided between the front face and the covering sheet with perforations at least in front of the openings in the front face.

In an embodiment of the second aspect, the sound absorbing device is configured to absorb mid and low frequency sound energy, preferably at frequencies below 1000Hz.

In an embodiment of the second aspect, the sound absorbing device is configured to absorb mid low frequency sound energy, preferably at frequencies below 500Hz.

In an embodiment of the second aspect, the sound absorbing device is configured to absorb low frequency sound energy, preferably at frequencies in the 63Hz, 125Hz and 250Hz octave bands.

In an embodiment of the second aspect, the openings in the front face are provided with means for opening and/or closing one or more of the openings, which means comprises actuator or motor means operatively connected to the means for opening and/or closing the openings, which actuator or motor means can be remote controlled by a user from a user interface.

In an embodiment of the second aspect, the system comprises user operable controlling means functionally connected to the individual actuator or motor means in one or more of the modules or units, where the controlling means are configured to open/close the openings in one or more of the sound absorbing devices under the control of a user via a suitable user interface, whereby the user via the user interface can alter the reverberation time of the space according to changing requirements.

In an embodiment of the second aspect, the system comprises a control unit that is configured to control said actuator or motor means, such that the individual modules can be changed from an open to a closed state and vice versa, which control unit is user operable from a user interface, whereby a user can alter the reverberation time of the room or hall in which the system is provided.

In an embodiment of the second aspect, the system comprises electronic storage means configured to store the settings of the individual modules in the system corresponding to each specific use of the system.

In an embodiment of the second aspect, the front faces of modules or groups of modules extend at different distances from the boundary on which they are mounted. This can for instance be obtained by varying the depth of the frame structure correspondingly. By using this embodiment of the second aspect, sound diffusion at mid and low frequencies can be obtained, if desired.

In case the modules only cover limited portions of a boundary it is important that the end and side faces of the outermost modules are covered, such that sound access via the end and side faces of the frame structure of these modules into the interior region of the modules that contain the sound absorbing means is effectively prevented.

The above and further objects and advantages are according to a third aspect of the present invention provided by a method for altering the reverberation time of a room, at least at low frequencies, without thereby changing the visual appearance of the room, the method comprising:

- providing a system according to the second aspect of the invention;
- attaching the system to one or more boundaries of the room;
- varying the state (open/closed) of individual modules of the system and determining the corresponding reverberation time of the room;
- when a required reverberation time is obtained, maintaining the corresponding state (open/closed) of the individual modules.

In an embodiment of the third aspect, the method further comprising storing in electronic storage means the determined settings of the individual modules corresponding to each specific use of the room.

The modules, system and method according to the present invention will make it possible to alter the reverberation time of a room or hall very significantly also at low frequencies. This effect requires among others that the depth of the modules, i.e. the distance from the wall portion on which the modules are mounted to the front face of the modules, is optimized, as a larger depth will result in the effect extending to lower frequencies. If amplified music (or speech) is rendered in a room or hall, this will require a relatively short reverberation time at low frequencies, which short reverberation time can be obtained by applying the modules, system and method of the invention. At higher frequencies, for instance above 1kHz, the audience, empty chairs etc. in the hall will usually provide the sound absorption required to obtain a relatively low reverberation time at mid and high frequencies. Furthermore, loudspeaker systems used in live performances of rhythmic music will at mid and high frequencies have a directional characteristic that directs the major portion of sound energy at those frequencies towards the audience and not towards the boundaries of the hall. This also contributes to limiting the reverberation time at mid and high frequencies.

By the application of the modules, system and method according to the invention, the reverberation time of multi-purpose halls can be varied at least at low frequencies such that many different genres of performances can take place under optimal acoustic conditions, such as the presentation of movies, live performances of pop or rock music, chamber music, symphonic music, operas, choirs, theatrical performances and lectures.

By the application of a system according to the invention, it is possible to open some of the modules making up the system and closing others, thereby optimizing the reverberation time for a given purpose.

By the application of a system according to the invention, the variability of the reverberation time can be obtained without thereby changing the appearance of the room or hall.

By the application of a system according to the invention, it becomes possible for an operator, for instance an acoustic consultant, remotely to control the different modules to obtain a desired effect on reverberation time.

By the application of a system according to the invention, it becomes possible to store the settings of different modules corresponding to the optimal reverberation time for different applications of the room or hall.

By the application of the modules, system and method according to the invention, the reverberation time of the room or hall without the presence of the modules or system according

to the invention can be relatively long . Thereby it becomes possible after the initial design of the room or hall to install the modules or system according to the invention to provide the variability required in order to make the room or hall suitable for different purposes.

The fact that the system according to the invention can present large seemingly (or physically) unbroken surfaces to the public in the room or hall makes it possible to apply visual effects (colored light, pictures, video sequences, etc.) on these seemingly or physically unbroken surfaces, thereby varying the appearance of the room or hall according to different applications and/or providing information relating to the actual use of the room or hall directly on the seemingly or physically unbroken surface portions of the system according to the invention.

10 BRIEF DESCRIPTION OF THE DRAWINGS

Further benefits and advantages of the present invention will become apparent after reading the detailed description of non-limiting exemplary embodiments of the invention in conjunction with the accompanying drawings, wherein

15 figure 1 shows a schematic perspective view of a system according to an embodiment of the invention;

figure 2 shows a schematic cross sectional representation of a module according to an embodiment of the invention attached to a wall portion of a room, where the module is provided with a first kind of sound absorbing device;

20 figure 3(a) and 3(b) show an embodiment of an open/close mechanism for the modules according to the present invention;

figure 4 shows a schematic detailed view of the module according to the embodiment of the invention shown in figure 3(a) and 3(b) in the closed state;

25 figure 5 shows a schematic representation of a system according to an embodiment of the invention, which system is provided with a user-operable control unit,

figure 6 shows a schematic perspective view of a system according to an embodiment of the invention seen from the side of the system opposite to the front face, i.e. the side of the system that faces the boundary on which it will be mounted;

figure 7 shows a schematic perspective view of a system according to an embodiment of the invention seen from a direction towards the front face, i.e. the side of the system that faces away from the boundary on which it will be mounted;

figure 8 shows an example of a sound absorption coefficient obtained with an embodiment of a module according to the invention;

figure 9 shows an embodiment of a system according to the invention covering portions of two boundaries of a room; and

figure 10 shows examples of two alternative shapes of the modules according to the invention.

10 DETAILED DESCRIPTION OF THE INVENTION

The principles of the invention will be illustrated by various embodiments hereof. It is however understood that a person skilled in the art may conceive other embodiments than those actually shown and described in the detailed description of the invention and that the scope of the invention is defined by the independent claims.

15 With reference to figure 1 there is illustrated the basic concept of the invention by means of a schematic perspective view of an embodiment of a system according to the second aspect of the invention.

The system shown in figure 1, generally designated by reference numeral 1, comprises 10 modules 2 according to the first aspect of the invention. These modules are in use mounted on one or more boundaries of a room by suitable attachment means that are not shown in the figure. The modules 2 comprises a front face generally designated by reference numeral 4, which front face in the shown embodiment comprises a number of longitudinally extending slats 5, where an opening 6 is provided longitudinally between adjacent slats 5. These openings 6 provide access from the region 7 outside the modules 2 to an interior region 3 inside the modules 2. The openings 6 allow sound energy to pass from the outside region 7 to the interior region 3, when the openings are in an open state. Inside each module there is provided means configured to close the openings 6, such that sound energy cannot pass from the outside region 7 to the interior region 3. These opening/closing means will be described by way of non-limiting examples in the following.

According to the invention, a covering sheet 8 of a material and construction that makes it possible for sound energy to enter the interior region 3 from the region 7 outside the modules through the covering sheet 8 and the openings 6, when the openings 6 are in an open state can be attached to the front faces 5 of the modules 2 that form the system (in the shown example the ten modules 2). Thus, a seemingly or physically unbroken surface 8 can be brought to cover the modules 2 of the system, such that the individual modules 2 cannot be seen by persons in the room.

More than a single sheet may be used according to the invention. Thus, a sheet may consist of a number of individual sheets or portions . Thus, for instance in a practical installation, a sheet may be dimensioned to cover five single modules in a row (i.e. the sheet has one dimension corresponding to the height of a module). A sheet may also comprise elongated panels extending longitudinally over all or some of the slats of individual modules.

The sheet 8 is in an embodiment of the invention made of veneer that is provided with perforations, at least in the regions of the veneer that cover the openings 6 in the front faces 5 of the modules 2. The veneer can, if necessary, be attached to a sheet or panel of for instance medium-density fiberboard (MDF) that is provided between the front faces 5 and said veneer 6. In order for the system to function acoustically optimal, the airflow resistance of the micro-perforation must be as low as possible.

The modules 2 and the manner in which the modules and system according to the invention can alter the reverberation time of the room in which the modules or system is provided will now be described with reference to figures 2 through 6.

With reference to figure 2 there is shown a schematic cross sectional representation of a module generally designated by reference numeral 2 according to an embodiment of the invention. The module 2 is mounted on a boundary 11 of a room, such as a wall or a ceiling. The module comprises a front face 4 comprising slats 5 and openings 6 provided between adjacent slats. The openings 6 can be closed by means of plates 9 or similar closing/opening members that are attached by hinges 13 as indicated in figure 2 and 4.

As it appears from figure 1, the modules 2 are comprised of a frame structure (shown by reference numerals 10 and 14 in figure 2) that comprises side posts 10 and lateral posts 14. In figure 2, the module 2 is attached to a wall portion 11 via the lateral posts 14. The frame structure of the module creates an inner space 3. In this inner space 3 there is provided a sound absorbing device, which in the shown embodiment consists of a sound absorbing material 12. In the shown embodiment the sound absorbing material consists of a plate or slab

that extends laterally and longitudinally (i.e. in the direction perpendicular to the plane of the figure) over the entire width w of the module, but the sound absorbing material could alternatively fill the entire inner space 3 up to the lateral posts 14. The sound absorbing material can for instance consist of a combination of mineral wool, for instance a slab of a thickness of 10cm, and a region of air, with a thickness d_1 of a suitable value, such as for instance 25cm. It is also possible to include a membrane absorber in the interior space 3 in order to increase absorption at low frequencies with a smaller distance d_1 to save space. The slabs of mineral wool must be as far from the lateral post 14 (distance d_1 in figure 2) and hence from the wall as possible in order to obtain maximal low frequency absorption.

- 10 In case a mineral wool is used, it is mandatory to wrap this in a bag that prevents the mineral wool fibers to spread. The material of the hose must, like all other elements in the modules and system according to the invention, like all other parts of the modules preferably comply with the B,S1-d0 fire standard and still be porous for air flow.

- 15 The distance d_1 between the wall portion 11 and the sound absorbing material should preferably be as large as possible. It is also recommended that the sound absorbing material 12 be provided as close as possible to the opening and closing mechanism. It is further recommended that the distance from the wall portion 11 to the sound absorbing material be at least 10cm in order to obtain a large absorption coefficient at low frequencies.

- 20 When mounted on a boundary (such as a wall or a ceiling), the modules must define an outer surface towards the room in which the modules are mounted that is substantially hermetically closed. Hence, it is essential that the open/close mechanism provides as close a seal to the adjacent portions of the slats as absolutely possible. Likewise, the connection between adjacent modules must be as air tight as possible. Otherwise, sound energy will pass through small slits or openings between adjacent modules even though the openings 6 are hermetically closed.

- 25 The slats 5 are preferably made of a material that ensures a surface weight of not less than 15 kg/m² in order to obtain a low absorption value even at low frequencies in the closed mode of the openings 6, i.e. a high degree of sound reflection even at low frequencies in the closed state. Preferably, a sound absorption coefficient of less than 0.1 should be obtained at 40Hz, which is the lowest frequency that is considered of interest for live performances of most music.

With reference to figure 3(a) and 3(b) there is shown an embodiment of an open/close mechanism for the front face of the modules according to the present invention.

Thus, figure 3(a) shows a schematic view of the front face 4 of the module. In the front face 4 there are provided the openings 6 as described above. The plates 9 are pivotally connected to the frame 3 such that the plates 9 can pivot between an open state (as shown in figure 3(a)) and a closed state (as shown in figure 3(b)). To each of the plates 9 there is attached a connecting member 15 that connects the rear surface of the plates 9 with a bar 16 that is pivotally connected to each respective of the connecting members 15. The actuator arm 18 of a linear actuator 19 is pivotally connected to the bar 16. When the actuator arm 18 is in the extended state as shown in figure 3(a), the plates 9 are in the open state, whereas, when the actuator arm 18 retracts into the position shown in figure 3(b) the plates 9 are pivoted about their respective hinge means and brought to the closed state, in which the plates 9 close the respective openings 6 in the front face 4. A hermetically sealed closing can be obtained for instance by providing a magnetic tape on the rear portions of the slats in the contact regions between the closing plates 9 and the rear portion of the slats. The actuator could for instance be an electric actuator or solenoid that can be controlled by providing it with electric current from a control unit under the control of for instance an operator.

On the surface of the plates 9 there can be provided rubber (or a similar material) insulating strips 20 to insure that the plates 9 closes the openings 6 entirely in the closed state. The size of these strips 20 may correspond to the size of the corresponding openings and have a thickness such that they extend at least entirely through the openings 6 in the closed state of the mechanism. By these means absorption from the micro-perforated sheet 8 in front of the openings can be significantly reduced when the mechanism is in the closed state.

With reference to figure 4 there is shown a schematic detailed view of the module according to the embodiment of the invention shown in figure 3 in the closed state. Figure 4 shows the wall portion 11 to which the module is attached and a slab 12 of sound absorbing material provided in the interior space 3 of the module. Three of the slats 5 in the front face of the module are shown and the openings 6 between adjacent slats 5 are closed by the plates 9 as shown. On the outer surface (facing towards the outer region 7) there is provided rubber (or similar) strips 20 that substantially fill the opening 6 between the respective slats 5. On the front face of the module, the micro-perforated sheet 8 is provided (or a sheet with perforations at least in the regions corresponding to the openings 6 in the front face. In the shown embodiment the strips 20 extend from the outer surface of the plates 9 to the inner surface of the micro-perforated strip, thus avoiding absorption from the micro-perforated sheet in the regions hereof overlying the openings 6.

As an alternative to the open/close mechanism shown in figures 3(a) and 3(b) a number of alternative mechanisms may be used. In one such alternative embodiment, the opening/closing plates 9 is mounted such that they can undergo a sliding movement on the inner surface of the front face between an open and a closed state. This open/close mechanism can also be operated by means of an actuator arrangement substantially similar to the one shown in figures 3(a) and 3(b).

With reference to figure 5 there is shown a schematic representation of a system according to an embodiment of the invention, which system is provided with a user-operable control unit.

The system 1 shown in figure 5 comprises modules M1 through M10 according to the first aspect of the invention in a setup similar to the one shown in figure 1. Each individual module M1 through M10 is connected to a central control unit 31 via lines 21 through 30, such that the control unit can control the opening/closing of the openings 6 in each individual module as explained above. A user can communicate with the control unit 31 via a suitable user interface 32 that is functionally connected to the control unit 31 via a line 34, and thereby control the reverberation time of the room in which the modules M1 through M10 are provided. When a suitable reverberation time has been obtained, the corresponding settings (open/close state) of each individual module can be stored in an electronic memory 37 together with a description of the kind of performance for which the obtained reverberation is regarded as optimal. The electronic memory 37 can cooperate with the control unit 31 and user interface 32 via lines 35 and 36, respectively.

With reference to figure 6 there is shown a schematic perspective view of a system generally indicated by reference numeral 38 according to an embodiment of the invention as seen from the side of the system opposite to the front face 4 of the modules or units in the system, i.e. the side of the system 38 that faces the boundary of the room or hall on which it will be mounted. Each module or unit is indicated by reference numeral 2. The system shown in figure 6 comprises 10 modules and corresponds to that shown in figure 1, except for the omission of the sheet 8 shown in figure 1. For clarity of the description, the terms "longitudinal" and "transversal" are defined by their corresponding axes in the figure. The depth or thickness of the system/modules are their extension in the direction of the z-axis.

With reference to figure 7 there is shown a schematic perspective view of a system according to an embodiment of the invention seen from a direction towards the front face, i.e. the side of the system that faces away from the boundary on which it will be mounted. The system comprises in this example embodiment (as in figure 1 and 6) 10 modules with the front faces

comprising elongated slats 5 provided with elongated openings 6 between adjacent slats 5 of each individual module. For each module, the frame structure comprises opposite end portion 39 and opposite side portion 40 that together with the front face and the boundary upon which the modules are mounted defines an inner region of the module in which a sound absorbing device, such as a slab of sound absorbing material, is provided.

With the embodiment of modules shown in figure 7, the adjacent lateral slats of two adjacent modules appears visually as a single slat of the double width as indicated at 41 in figure 7. When the system is not covered by a covering sheet 8 (as shown in figure 1), the total surface formed by the front faces of the individual slats 5 is hence not visually uniform. A visually uniform surface of the system can be obtained by means of the covering sheet 8, but it is also possible as an alternative to provide a visually uniform outer surface by providing each module with a pattern of slats and openings in which a slat extends along one longitudinal edge portion of a module and an opening extends along the opposite longitudinal edge portion of the module.

With reference to figure 8 there is shown an example of a sound absorption coefficient as a function of frequency obtained with an embodiment of a module according to the invention. The broken line 42 indicates the sound coefficient obtained with slats 5 of the dimensions shown in the figures, whereas the solid line 43 indicates the sound absorption coefficient obtainable with broader slats, i.e. with slats of larger extension in the transversal direction. It clearly appears that a very high sound absorption coefficient can be obtained with the modules/system according to the invention in the mid and low frequency range.

With reference to figure 9 there is shown an embodiment of a system according to the invention covering portions of two boundaries 44 and 45 of a room wherein a third boundary 46 is not provided with modules. The system of modules present unbroken surfaces 47 and 48 to a viewer located in the room.

With reference to figure 10(a) and 10(b) there are shown examples of two alternative shapes of the modules according to the invention.

Figure 10(a) shows six modules 2 where a first 50 and a second 51 edge portion of a side portion 49 of a module have different length, such that the front sheet 8 of a module is inclined relative to a boundary on which the module is mounted. By using such modules, the design shown in figure 10(a) can be obtained in which the front sheets 8 of different modules incline in different directions. By using this design, a sound diffusion effect of a system of modules can be obtained, if desired, when the modules are in their closed state, in which they do not

absorb sound energy. An alternative to the design shown in figure 10(a) is shown in figure 10(b) in which the modules have different depths such that the front sheets 8 of different modules are located at different distances from the boundary on which the modules are mounted. This design will also have a sound diffusing effect when the modules are in their closed states.

Although the invention has been explained in relation to the embodiments described above, it is to be understood that many other possible modifications and variations can be made without departing from the scope of the present invention. Thus, for instance, different kinds of materials can be used for the covering sheet 8 according to specific requirements of a given room or hall and/or different sizes and densities of perforations of the perforations used in the covering sheet can also be used. It is also possible to provide wooden profiles on the slats and the and the panels can appear as a visually continuous unit. A gap may be provided on adjacent slats of two neighboring modules, which will make the modules appear as one visually continuous unit. It would also be possible to replace one or more of the modules according to the first aspect of the invention with modules of the same physical dimensions but instead of the described sound absorbing means comprising for instance sound generating means, such as loudspeakers or sound signal providing means (alarms etc.). Thus, for instance, each individual module can be provided with sound emitting means that emits a notification signal in case the module becomes defective.

REFERENCES

[1] Niels Werner Aldeman-Larsen: Suitable reverberation times for halls for rock and pop music, JASA, 2010, Vol ? and No.?

[2] Niels Werner Adelman-Larsen et al.: On a variable broadband absorption product and acceptable tolerances of reverberation times in halls for amplified music". 162nd meeting of ASA, San Diego, 2011.

CLAIMS

1. A module or unit with variable acoustic properties configured for covering boundaries (11), such as walls or ceilings of a room, for instance a multi-purpose room, in which it should be possible to change the acoustical properties of the room according to each specific use, where
 - 5 the module or unit (2) has a front face (4) provided with openings (6) through which sound energy can enter an inner region (3) of the module or unit (2), and where the module or unit (2) in the inner region (3) comprises a sound absorbing device (12; 38, 39) in acoustic communication with the openings (6) in the front face (4), where the openings (6) can be closed, such that sound energy cannot enter the sound absorbing device (12; 38, 39) and
 - 10 opened, such that sound energy can enter the sound absorbing device (12; 38, 39), **characterized in** that the front face (4) that is provided with said openings (6) is covered by a covering sheet (8) that is configured such that it is possible for sound energy to enter the sound absorbing device (12; 38, 39) through the sheet (8) and the openings (6), when the openings (6) are in the open state.
 - 15 2. A module or unit according to claim 1, wherein said covering sheet (8) is made of veneer or foil provided with perforations at least in those regions of the covering sheet (8) that cover said openings (6) in the front face (4).
 3. A module or unit according to claim 1 or 2, wherein a sheet or panel of medium-density fiberboard (MDF) is provided between said front face (4) and said covering sheet (8).
 - 20 4. A module or unit according to any of the preceding claims, wherein said sound absorbing device (12; 38, 39) is configured to absorb mid and low frequency sound energy, preferably at frequencies at least below 1000Hz.
 5. A module according to any of the preceinng claims, wherein said front face (4) comprises a plurality of slats (5) with said openings (6) provided between adjacent slats (5).
 - 25 6. A module according to claim 5, wherein said slats (5) are made of metal, such as steel.
 7. A module according to claim 5 or 6, wherein the thickness t of the slats (5) is less than 4mm, preferably less than 3mm.
 8. A module according to claim 5, 6 or 7, wherein the slats (5) have a front face (5') that is substantially plane.

9. A module or unit according to any of the preceding claims, wherein said openings (6) in the front face (4) are provided with means (9, 15, 16, 17) for opening and/or closing one or more of the openings (6), said means comprising actuator or motor means (18, 19) operatively connected to the means (9, 15, 16, 17) for opening and/or closing the openings (6), which
5 actuator or motor means (18, 19) can be remote controlled by a user from a user interface (32).

10. A module or unit according to any of the preceding claims, wherein the front face (4) is provided with attachment means configured to attach said sheet (8) or said panel of medium-density fiberboard (MDF) provided with said sheet (8) to the front face (4) of the module (2),
10 whereby said sheet (8) or said panel of medium-density fiberboard (MDF) provided with said sheet (8) can be attached to the module (2) after the module (2) has been mounted on a boundary of a room or hall.

11. A system with variable acoustic properties configured to cover boundaries (11) of a space, such as walls or ceilings of a room, the system comprising a plurality of modules or units (2)
15 with variable acoustic properties having a front face (4) provided with openings (6) through which sound energy can enter an inner region (3) of the module or unit (2), and where one or more of the modules or units (2) comprises a sound absorbing device (12; 38, 39) in acoustic communication with the openings (6) in the front face (4), which openings (6) can be closed, such that sound energy cannot enter the inner region (3) and opened, such that sound energy
20 can enter the inner region (3), **characterized in** that the front face (4), including the openings (6) herein, of a plurality of said modules or units (2) are covered by a covering sheet (8) that extends as a seemingly or physically unbroken surface over the plurality of modules (2), and where the covering sheet (8) is configured such that it makes it possible for sound energy to enter the interior region (3) through the covering sheet (8) and the openings (6), when the
25 openings (6) are in an open state.

12. A system according to claim 11, wherein said covering sheet is made of veneer provided with perforations at least in those regions of the covering sheet that cover said openings in the front face.

13. A system according to claim 11 or 12, wherein a sheet or panel of medium-density
30 fiberboard (MDF) is provided between said front face and said covering sheet.

14. A system according to any of the preceding claims 11 to 13, wherein said sound absorbing device is configured to absorb low frequency sound energy, preferably at frequencies below 1000Hz.

15. A system according to any of the preceding claims 11 to 14, wherein said openings (6) in the front face (4) are provided with means for opening and/or closing one or more of the openings (6), said means comprising actuator or motor means (18, 19) operatively connected to the means for opening and/or closing the openings, which actuator or motor means can be remote controlled by a user from a user interface.

16. A module according to any of the preceding claims, wherein the slats (5) have a front face (5') that is substantially plane.

17. A system according to claim 15, wherein the system comprises a control unit (31) that is configured to control said actuator or motor means (18, 19), such that the individual modules (2) can be changed from an open to a closed state and vice versa, which control unit (31) is user operable from a user interface (32), whereby a user can alter the reverberation time of the room or hall in which the system is provided.

18. A system according to any of the preceding claims 17, wherein the system comprises user operable controlling means functionally connected to said actuator or motor means in said modules or units, where the controlling means are configured to open/close said openings in one or more of said sound absorbing devices under the control of a user via a suitable user interface, whereby the user via the user interface can alter the reverberation time of said space according to changing requirements.

19. A system according to any of the preceding claims 11 to 18, wherein the system comprises electronic storage means (37) configured to store the settings of the individual modules (2) in the system corresponding to each specific use of the system.

20. A system according to any of the preceding claims 11 to 19, wherein lightning means are provided in the openings to indicate the state of the individual modules used in the system.

20. A method for altering the reverberation time of a room, at least at low frequencies, without thereby changing the visual appearance of the room when the reverberation time is altered, the method comprising:

- providing a system according to any of the preceding claims 11 to 20;
- attaching said system to one or more boundaries of said room;
- varying the state (open/closed) of individual modules of the system and determining the corresponding reverberation time of the room;

- when a required reverberation time is obtained, maintaining the corresponding state (open/closed) of the individual modules.

21. A method according to claim 20, the method further comprising storing in electronic storage means the determined settings of the individual modules corresponding to each specific use
5 of the room.

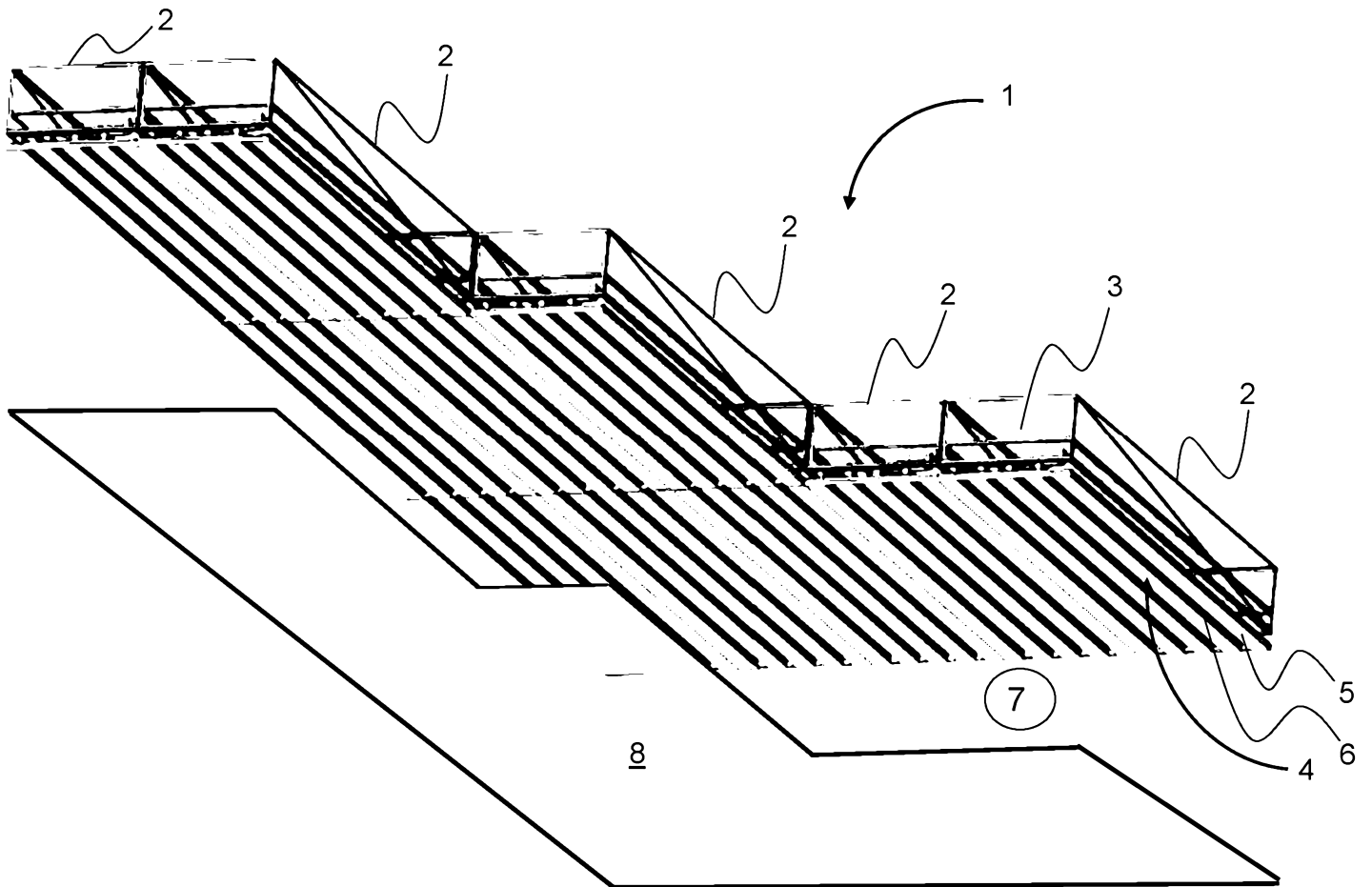


Fig. 1

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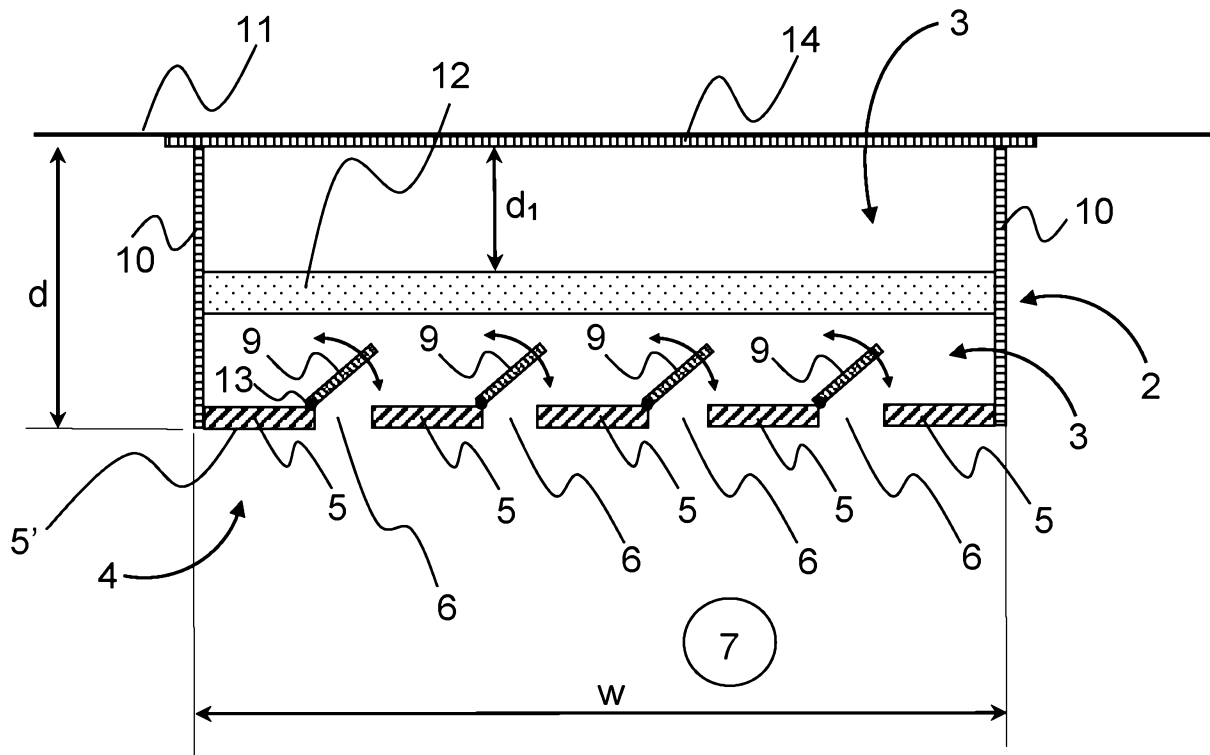


Fig. 2

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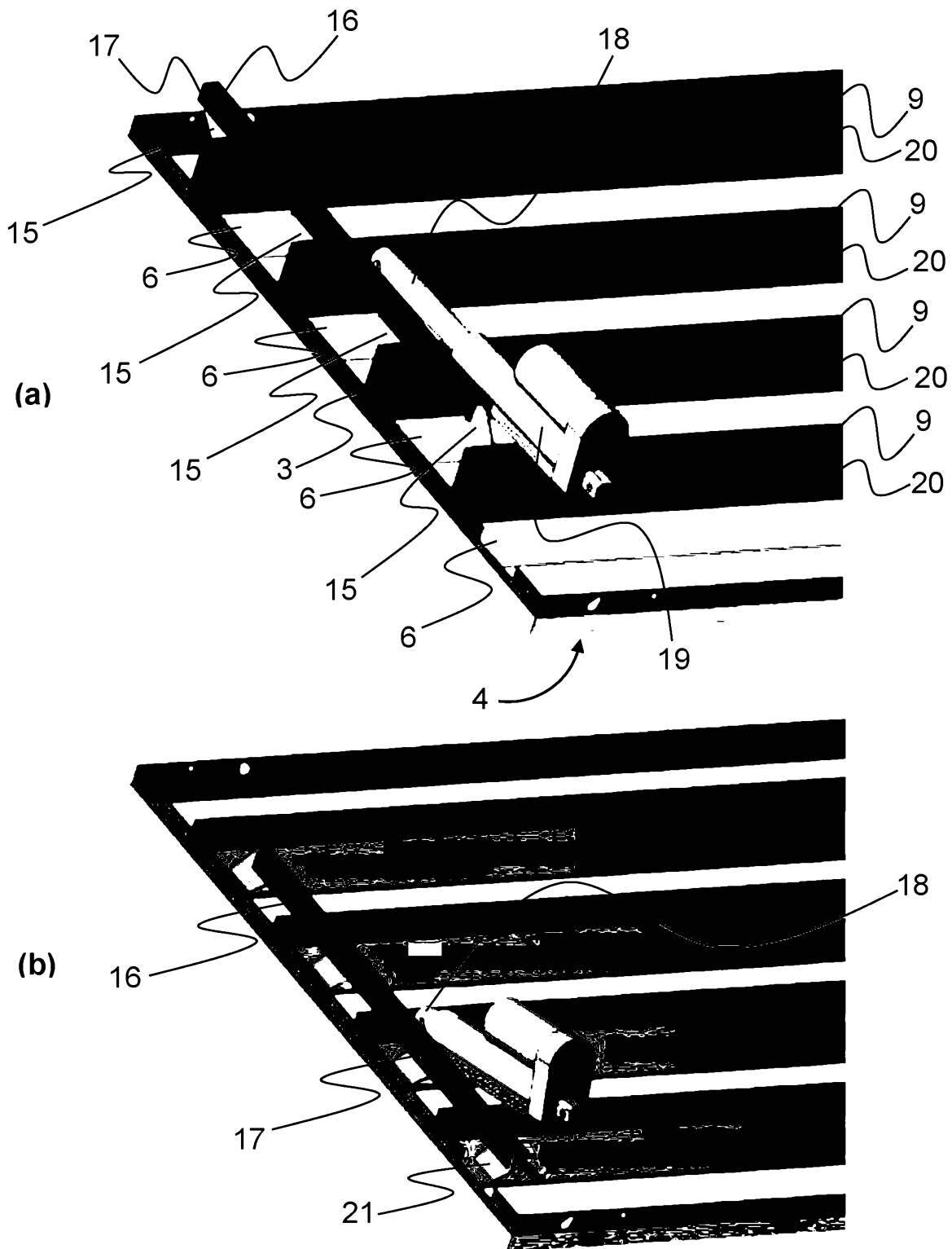
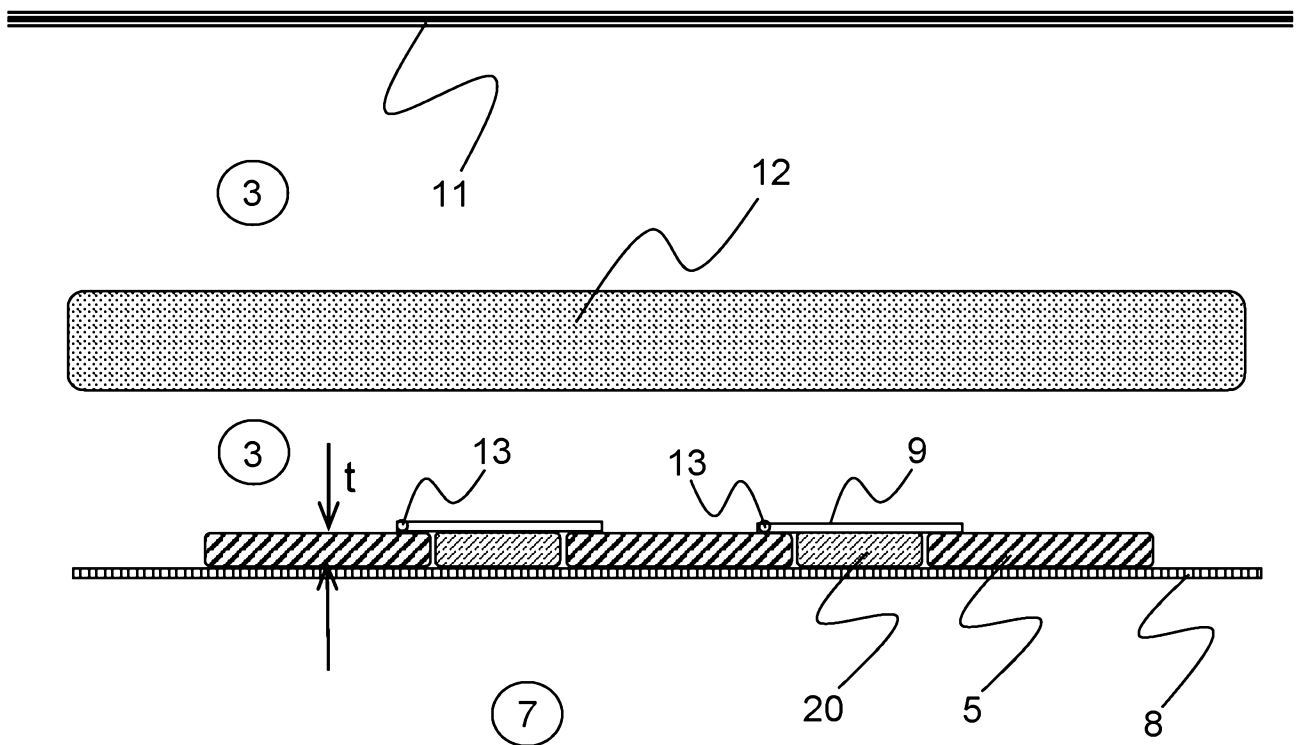


Fig. 3

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**Fig. 4**

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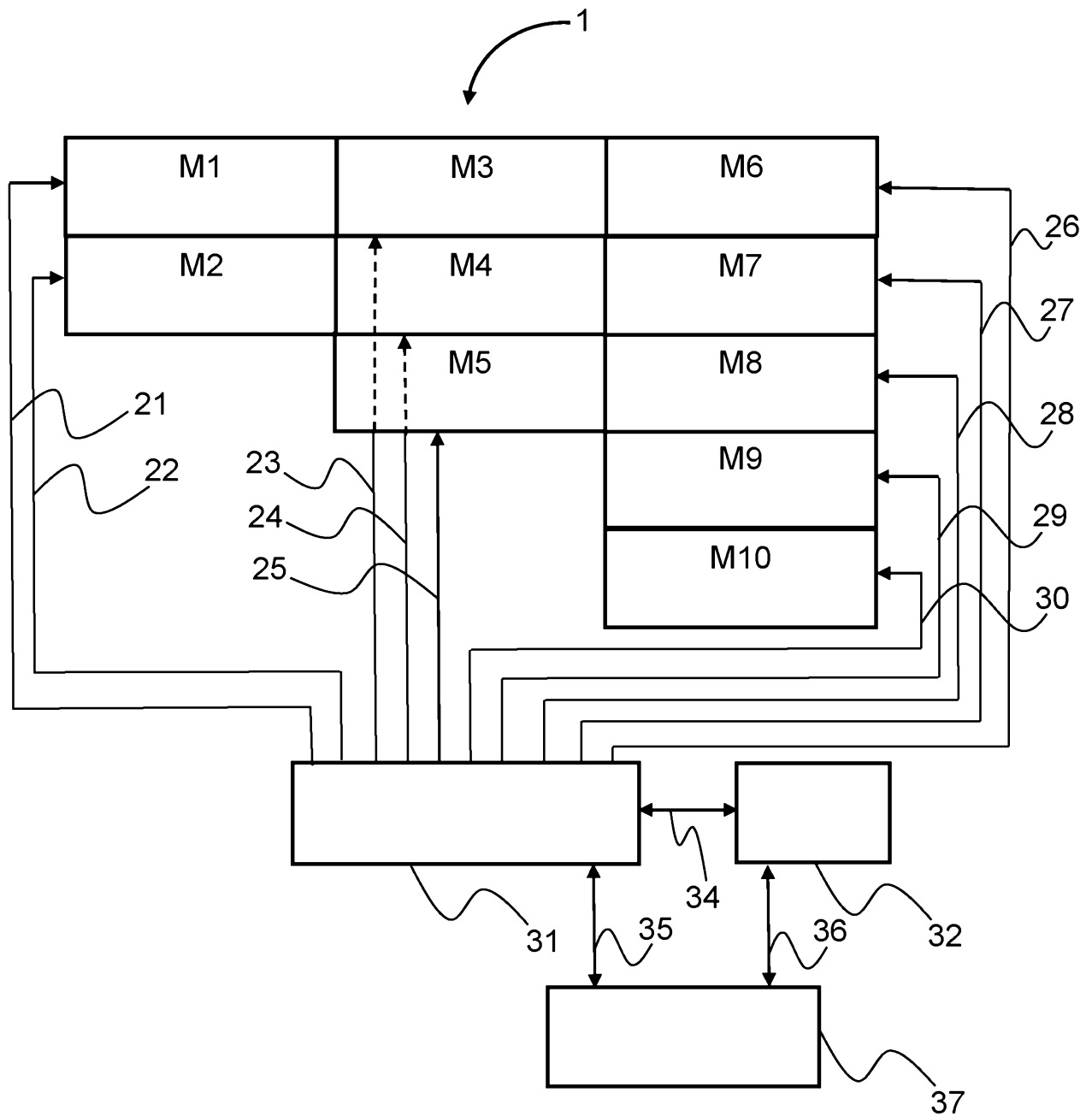


Fig. 5

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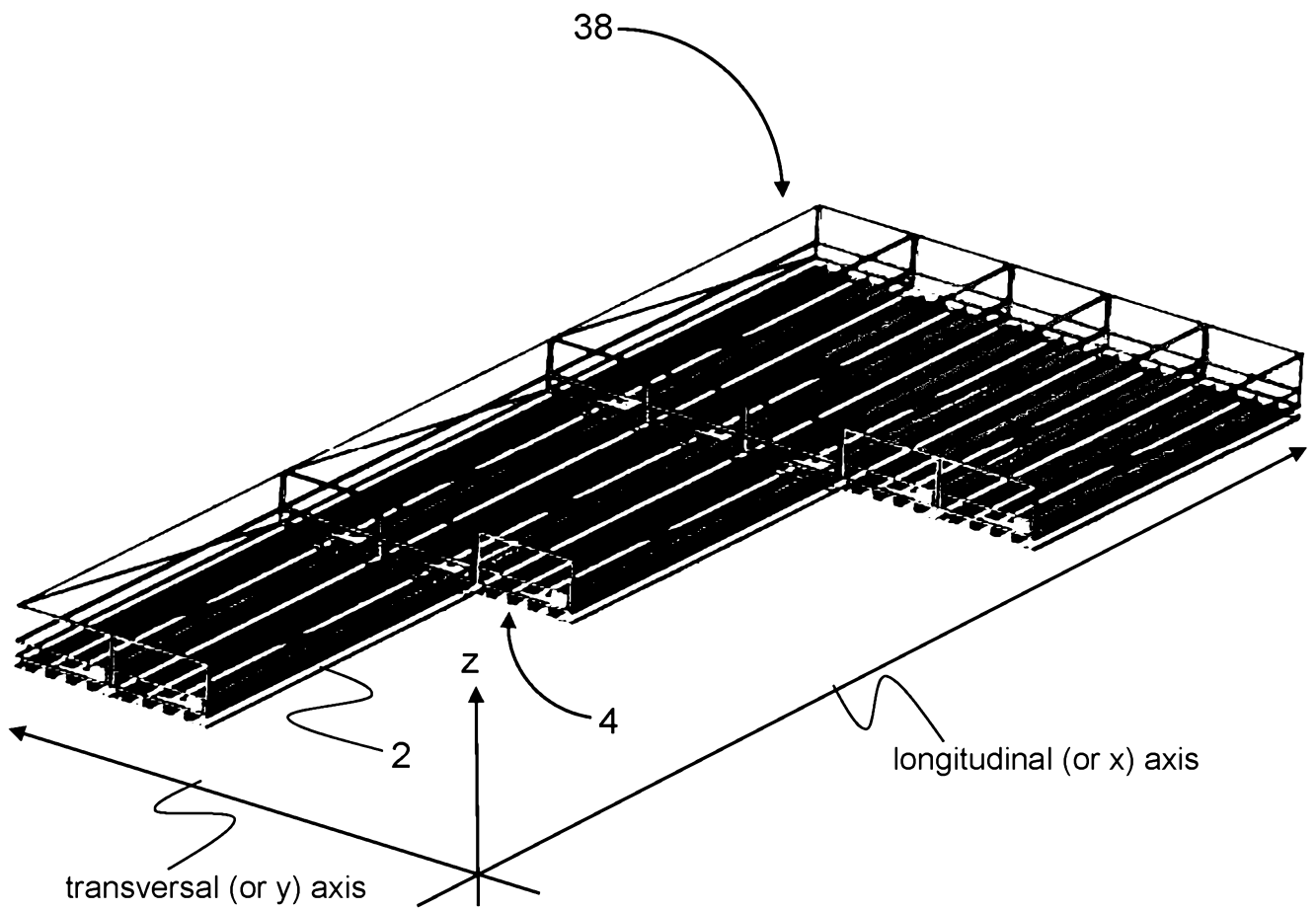


Fig. 6

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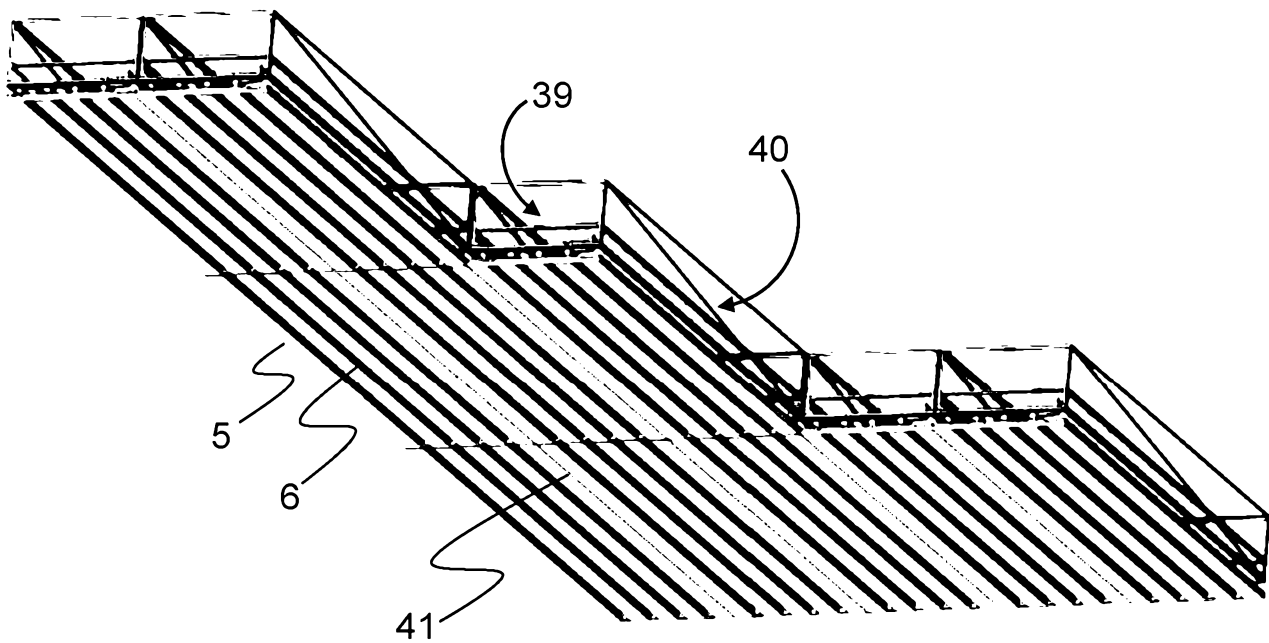


Fig. 7

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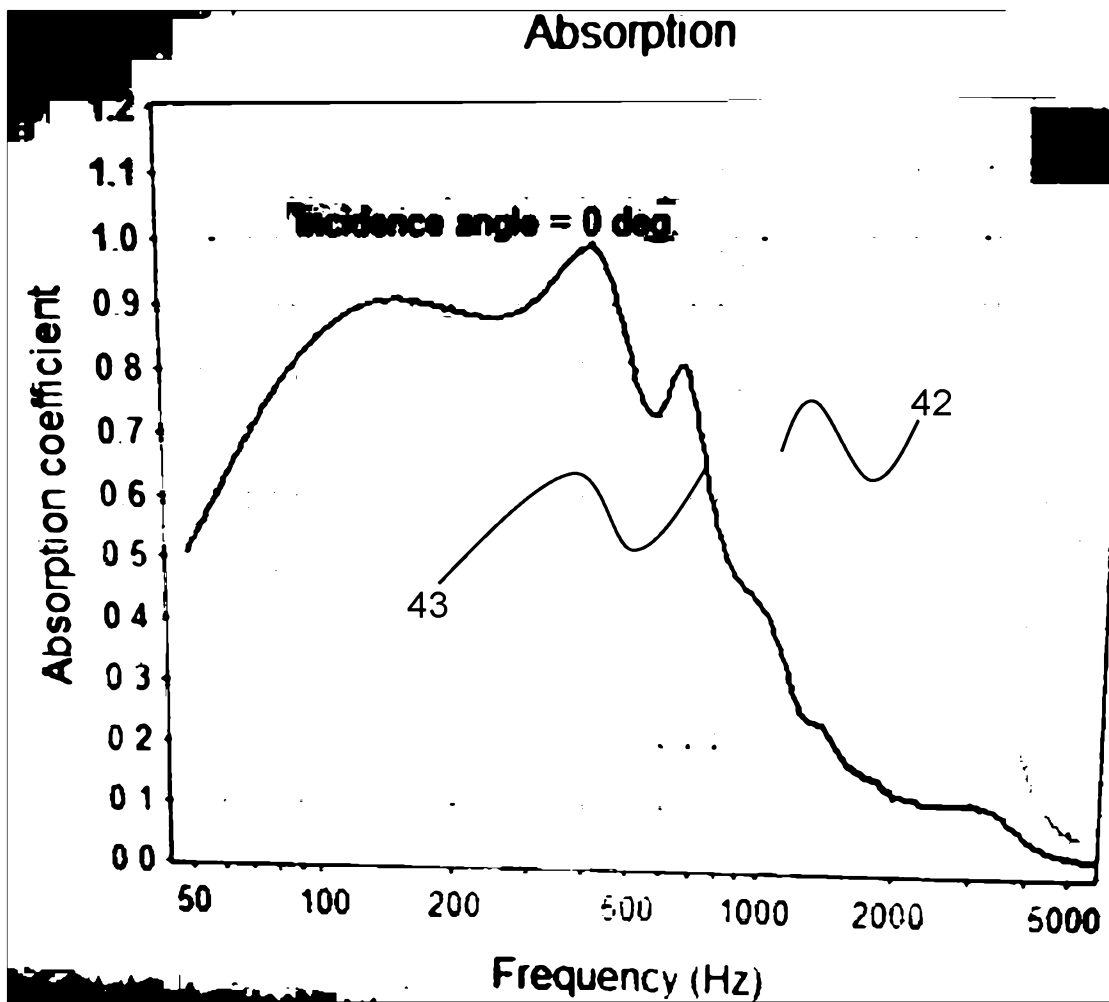
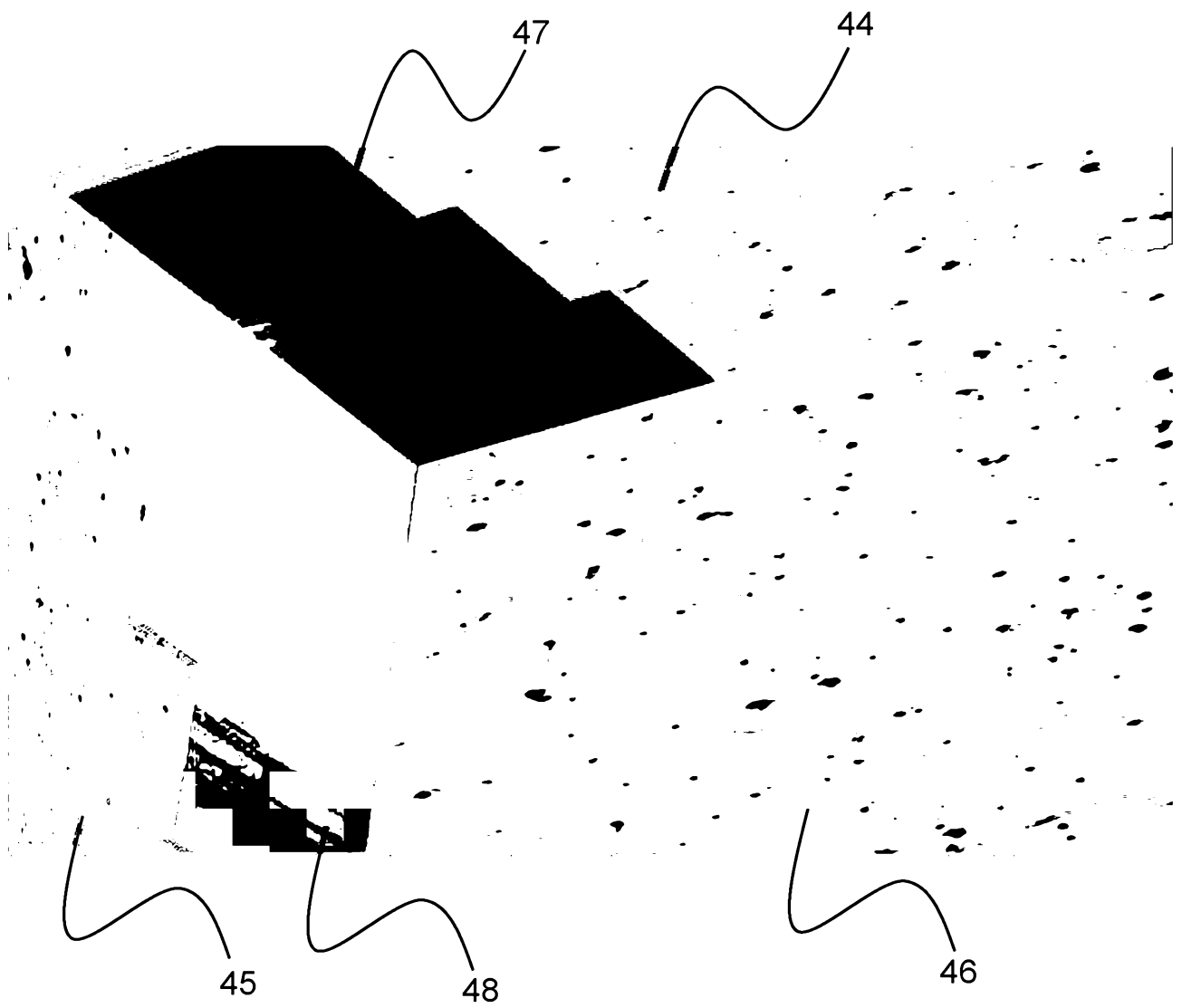


Fig. 8

**Fig. 9**

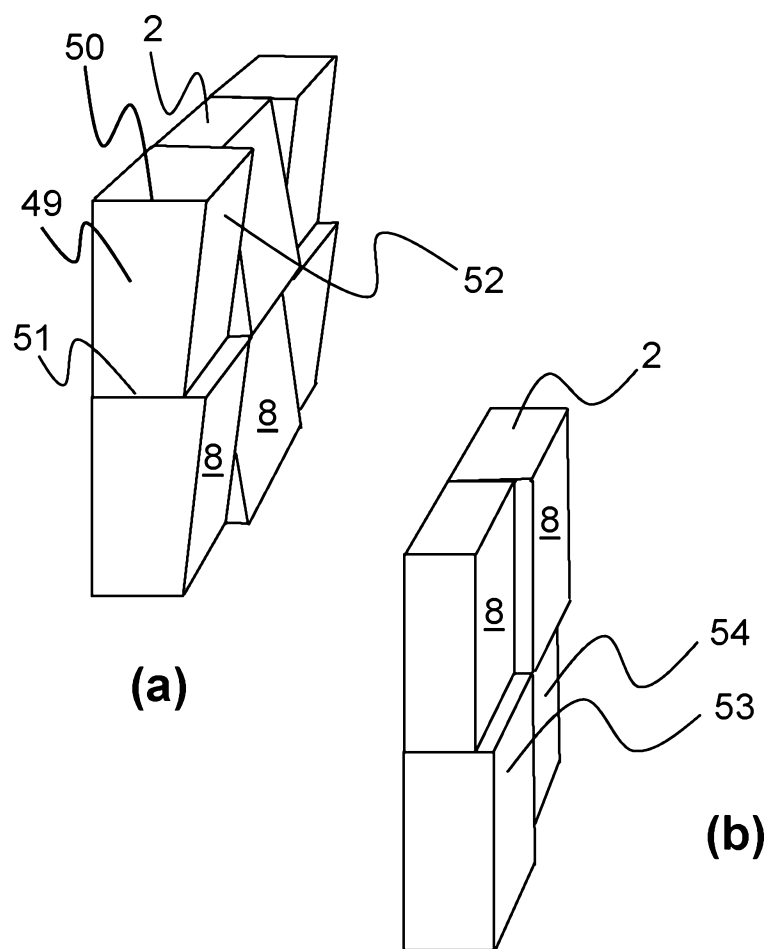


Fig. 10