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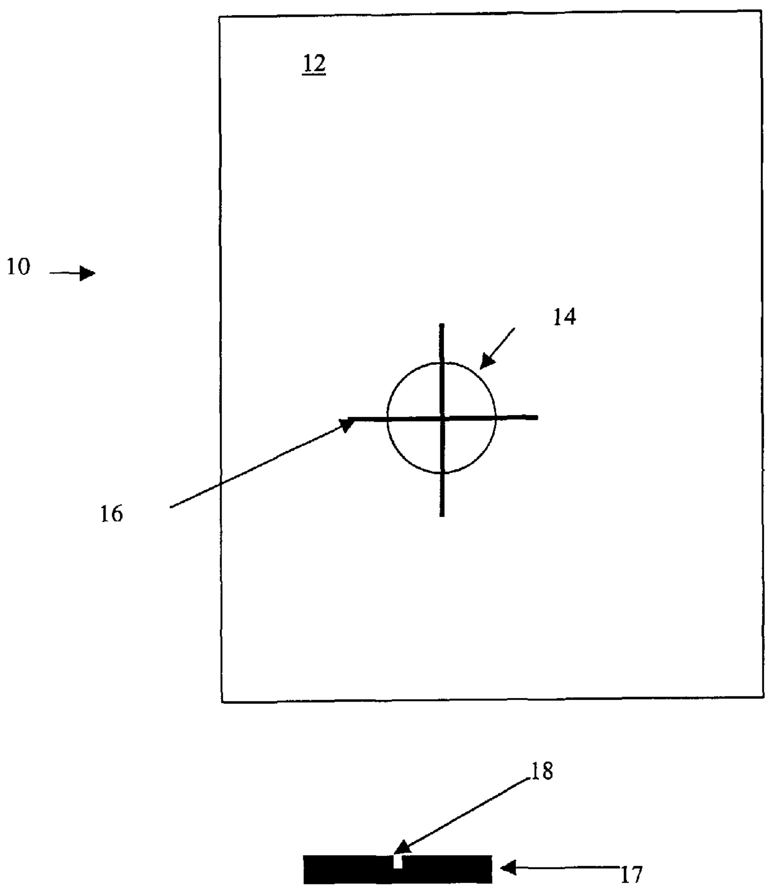
(54) Title: LOUDSPEAKERS




**(57) Abstract:** A method of making an acoustical member capable of supporting bending wave vibration comprising the steps of providing a panel (12) to form an acoustic radiator; identifying a position (14) on the panel (12) for mounting a vibration transducer (20) to excite bending waves in the panel and securing stiffening means (16) to the panel at the position (14) for mounting the transducer to stiffen the panel locally. A loudspeaker (10) comprising a bending wave panel-form acoustic radiator (12) and a vibration transducer (20) mounted to the panel (14) to excite bending-wave vibration in the panel, characterised by a stiffening member (16) which is secured to the panel locally of the transducer.

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# LOUDSPEAKERS

## DESCRIPTION

### TECHNICAL FIELD

The invention relates to loudspeakers and more particularly to bending wave panel-form loudspeakers e.g. of the general kind described in International patent application WO97/09842.

### BACKGROUND ART

The technology described in International application WO97/09842 has come to be known as distributed mode or DM technology. Such loudspeakers comprise a stiff lightweight resonant panel and a vibration transducer or exciter mounted to the member to excite bending-wave vibration in the member.

It is known that the high frequency performance of bending wave panel-form loudspeakers comprising a lossy or damped panel, may be limited in extension and even localised to the transducer position.

In International patent application WO00/15000, the bending stiffness and/or areal mass density in the panel varies over the area of the panel. In one embodiment, the transducer comprises a coil and the panel is stiffer at the transducer location since the aperture resonance caused by coupling of the coil mass within over a finite area is at an advantageously higher frequency for a stiffer panel. In WO00/15000 the panel is designed to have a non-uniform bending stiffness profile. Such a panel is complex to design and produce.

It is an object of the invention to provide a simplified process for improving the acoustic performance of a panel-loudspeaker, in particular the high frequency performance of a lossy or damped panel.

## DISCLOSURE OF INVENTION

According to the invention, a method of making an acoustical member capable of supporting bending wave vibration comprising the steps of providing a panel to form an acoustic radiator; identifying a position on the panel for mounting a vibration transducer to excite bending waves in the panel and securing stiffening means to the panel at the position for mounting the transducer to stiffen the panel locally.

The method may comprise the steps of forming e.g. by cutting or otherwise, a cavity, e.g. a hole or slit, in the panel at the position for mounting the transducer and inserting the stiffening member in the cavity. The method may comprise the step of inserting adhesive between the stiffening means and the panel, the adhesive acting to form a bond between the panel and the stiffening means.

The method thus provides a straightforward process for stiffening a pre-formed panel, e.g. a standard panel with a uniform bending stiffness over the area of the panel, in the locality of the transducer to improve the high frequency performance. The method may be particularly suitable for panels constructed using core materials that exhibit low shear (< 30MPa) and compressive moduli, such as polyurethane and polystyrene non-structural foams. These foams are commonly used in combination with paper-based liners/faceskins for displayboard applications (e.g. panels manufactured from Kapa).

The cavity may be formed axially centrally of the transducer position. The cavity may be in the form of a slot or a hole. The cavity may be equal in depth to the thickness of the panel. Thus, for example, for a composite panel comprising a core layer sandwiched between skin layers, the method may comprise arranging the stiffening means to extend completely through the panel core and skin layers to increase the shear and/or compression moduli of the panel at the transducer position.

The method may comprise forming the stiffening means from discrete components which may be rod-like or curved. The stiffening means may be formed in the shape of a cross, a star or a circle.

The method may comprise locating the stiffening means entirely within a panel area bounded by the transducer position or alternatively may be located entirely outside the transducer position. The stiffening means may be located so that its centre is coincident with the centre of the transducer position.

The method may comprise arranging the orientation of the stiffening means to be preferential in relation to the principal axes of the panel. The size of the stiffening member may alternatively be adjusted to suit the desired acoustic performance of the loudspeaker.

The stiffening member may be made of carbon, plastics, metals or other materials with a higher bending stiffness than the panel material. The stiffening member may be fibrous and the orientation of the fibre may be preferentially determined.

According to a second aspect of the invention there is provided a loudspeaker comprising a bending wave panel-form acoustic radiator and a vibration transducer mounted to the panel to excite bending-wave vibration in the panel, characterised by a stiffening member which is secured to the panel locally of the transducer. The stiffening means is preferably designed to increase the shear and compression moduli of the panel at the transducer position.

The panel may be a resonant panel, e.g. as described in WO97/09842, and the transducer is adapted to excite resonant bending waves in the panel. The stiffening member may be mounted in a cavity in the panel. The stiffening means may extend completely through the panel to increase the shear and/or compression moduli of the panel at the transducer position. For a composite panel comprising a core layer sandwiched between skin layers, the stiffening member may extend through both core and skin layers or alternatively through only the core layer.

The stiffening member may be mounted axially centrally of the transducer position. The centre of the stiffening member may be coincident with the centre of the transducer position.

The stiffening member may be cruciform, or star-shaped or circular and may be formed from discrete components which may be rod-like or curved. The stiffening member may be made of carbon, plastics, metals or other material with a higher bending stiffness than the panel material. Alternatively, the stiffening member may be of fibre reinforced plastics with the orientation of the fibre preferentially determined.

## BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way of example, in the accompanying drawings in which

Figure 1 is a schematic of a loudspeaker embodying the present invention;

Figure 1a is an exploded cross-section of a stiffener of Figure 1;

Figure 2 is a cross sectional schematic of Figure 1;

Figure 3 is a graph of the frequency response for two loudspeakers one of which embodies the present invention, and

Figures 4a to 4l are schematics of various stiffener shapes.

## BEST MODES FOR CARRYING OUT THE INVENTION

Figure 1 shows a loudspeaker (10) comprising a resonant panel (12). A vibration transducer (not shown) is mounted to the panel at position (14). The panel is a 5mm thick Kapa-Mount™ panel (comprised of 0.33mm thick aluminium reinforced boxboard liners bonded to a non-structural rigid polyurethane foam) with dimensions 250mm by 185mm. This is typical of a lossy panel constructed using a core with a low shear modulus.

Stiffening means or member in the form of a cross-shaped stiffener (16) has been inserted into the panel (12) at the transducer position (14). The stiffener (16) is located centrally within the transducer position (14).

The stiffener (16) is made of 0.13mm thick undirectional carbon fibre reinforced polyamide(known in the trade as a CF/PA12 thermoplastic prepreg tape stiffener). The stiffener is constructed from two identical parts (17). Figure 1a shows each part of the stiffener to be generally rectangular with a small notch (18) at the crossover point.

Figure 2 shows the location of the stiffener (16) in relation to the transducer (20) and the panel (12). The stiffener (16) is mounted in a slit in the panel (12) and is comparable in thickness to the total thickness of the panel, namely the thickness including both the skins (24) and core (22). The transducer (20) is mounted on a surface (21) of the panel via mounts (23).

The stiffener (16) is inserted using a three-step process:

- Slitting of panel including both the skins (24) and core (22) with scalpel (ultrasonic knife or alternative technique may be used in production)
- Insertion of epoxy adhesive into slit
- Insertion of stiffener

In this way, a stiffener may be inserted in a finished panel.

The effect of the stiffener on the frequency performance can clearly be seen in Figure 3 which shows the frequency response (26) for the panel (12) described above without a stiffener and the frequency response (28) for the same panel with stiffener (16) inserted. The frequency responses were measured on-axis at a distance of 50cm with a 25mm 4ohm NEC transducer with 2.83V.

Figure 3 shows that the carbon fibre reinforced polyamide stiffener (16) increases the aperture resonance by 3.2kHz up to 10kHz with no loss in sensitivity.

Figures 4a to 4l show various embodiments of stiffeners (16) which may be used according to the invention to stiffen a pre-formed panel to improve high frequency performance. The stiffeners (16) have a variety of shapes, for example generally cruciform in Figures 4a, 4b and 4g, generally star-shaped in Figures 4d, 4e and 4h or circular in Figures 4c, 4f and 4i.

The stiffeners (16) are formed from one piece as in Figure 4c, 4f and 4i or alternatively the stiffeners (16) are formed from several discrete components. For example, the stiffeners of Figures 4b and 4c are formed from 4 and 8 rod-like pieces (30) respectively. The stiffener (16) in 4j is formed from two generally hyperbolic pieces (32) which are spaced apart. In Figure 4k the stiffener is formed from two parabolic pieces (34) joined at the bases of the parabolas to a rod-like piece (30). The stiffener in 4l is formed from two parallel rod-like pieces (30).

The position of the stiffener relative to the transducer position (14) is also indicated in Figures 4a to 4l. In Figures 4c, 4g and 4h the stiffeners (16) are located entirely within the perimeter of the transducer position (14). In contrast in Figure 4i the stiffener (16) is located outside the transducer position (14) and is concentric therewith. In Figure 4f, the shape of the stiffener (16) matches the perimeter of the transducer position (14). In the remaining Figures 4a, 4b, 4d, 4e, 4j, 4k and 4l, the stiffener (16) crosses the perimeter of the transducer position (14). Furthermore, the centre of the stiffener (16) in Figures 4a to 4i and 4k coincides with the centre of the transducer position (14).

INDUSTRIAL APPLICABILITY

The invention thus provides a simplified process for improving the acoustic performance of a panel-loudspeaker by adding a stiffener at the transducer position.

The advantages of adding a stiffener are as follows:

- Structural integrity of the panel is maintained
- Insertion of stiffener is straightforward
- The stiffener can be inserted into a finished panel
- The high frequency range of a low specification panel (e.g. Kapa™) can be extended with no loss in sensitivity.

It will be appreciated that this local stiffening approach could also apply to higher performance panels such as those containing structural core materials (e.g. polymethacrylimide foam).

CLAIMS

1. A method of making an acoustical member capable of supporting bending wave vibration comprising the steps of providing a panel (12) to form an acoustic radiator; identifying a position (14) on the panel (12) for mounting a vibration transducer (20) to excite bending waves in the panel and securing stiffening means (16) to the panel at the position (14) for mounting the transducer to stiffen the panel locally.

2. A method according to claim 1, comprising the steps of forming a cavity in the panel (12) at the position (14) for mounting the transducer and inserting the stiffening means (16) in the cavity.

3. A method according to claim 1 or claim 2, comprising the step of inserting adhesive between the stiffening means and the panel, the adhesive acting to form a bond between the panel and the stiffening means.

4. A method according to claim 2 or claim 3, comprising forming the cavity co-axially centrally of the transducer position.

5. A method according to any preceding claim, wherein the panel is a composite comprising a core layer (22) sandwiched between skin layers (24), comprising arranging the stiffening means to extend completely through the panel to increase the shear and/or compression moduli of the panel at the transducer position.

6. A method according to any preceding claim, comprising forming the stiffening means from discrete components (17, 30,32,34).

7. A method according to any preceding claim, comprising locating the stiffening means (16) entirely within a panel area bounded by the transducer position.

8. A method according to any preceding claim, comprising arranging the orientation of the stiffening means to be preferential in relation to the principal axes of the panel.

9. A loudspeaker (10) comprising a bending wave panel-form acoustic radiator (12) and a vibration transducer (20) mounted to the panel (14) to excite bending-wave vibration in the panel, characterised by a stiffening member (16) which is secured to the panel locally of the transducer.

10. A loudspeaker according to claim 9, wherein the panel is a resonant panel and the transducer is adapted to excite resonant bending waves in the panel.

11. A loudspeaker according to claim 9 or claim 10, wherein the stiffening member is mounted in a cavity in the panel.

12. A loudspeaker according to any one of claims 9 to 11, wherein the panel is a composite comprising a core layer (22) sandwiched between skin layers (24), and wherein the stiffening member (16) extends completely through the

panel to increase the shear and/or compression moduli of the panel at the transducer position.

13 A loudspeaker according to any one of claims 9 to 12, wherein the stiffening member (16) is mounted centrally of the transducer position (14).

14. A loudspeaker according to any one of claims 9 to 13, wherein the centre of the stiffening member is coincident with the centre of the transducer position (14).

15. A loudspeaker according to any one of claims 9 to 14, wherein the stiffening member (16) is cruciform, or star-shaped or circular.

16. A loudspeaker according to any one of claims 9 to 15, wherein the stiffening member is made of carbon, plastics, metals or other material with a higher bending stiffness than the panel material.

17. A loudspeaker according to any one of claims 9 to 15, wherein the stiffening member is of fibre reinforced plastics with the orientation of the fibre preferentially determined.

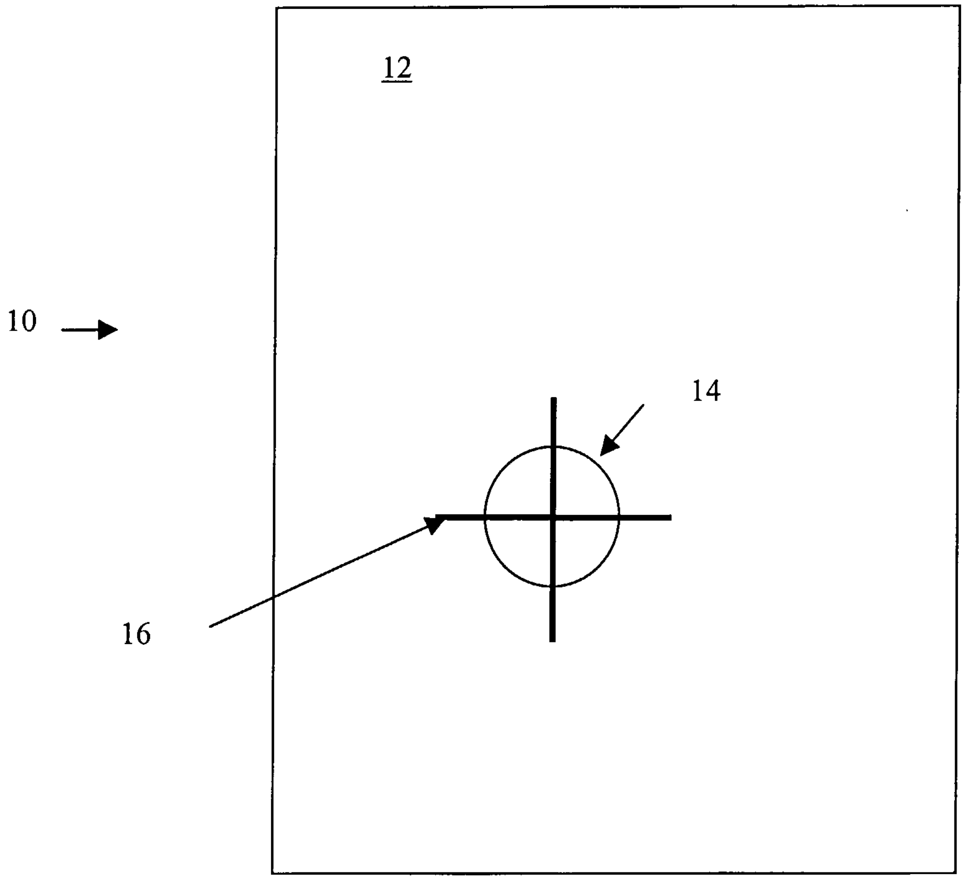



**Figure 1**

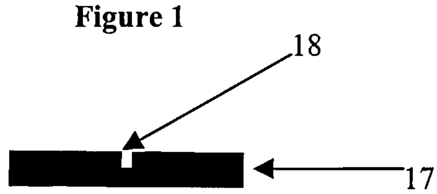



**Figure 1a**

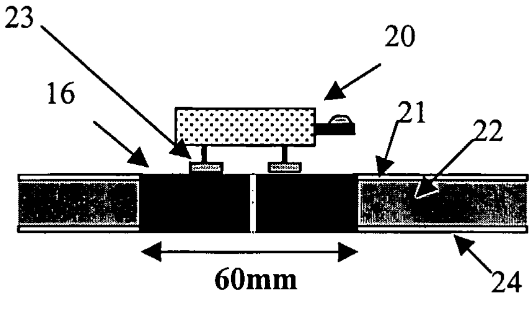
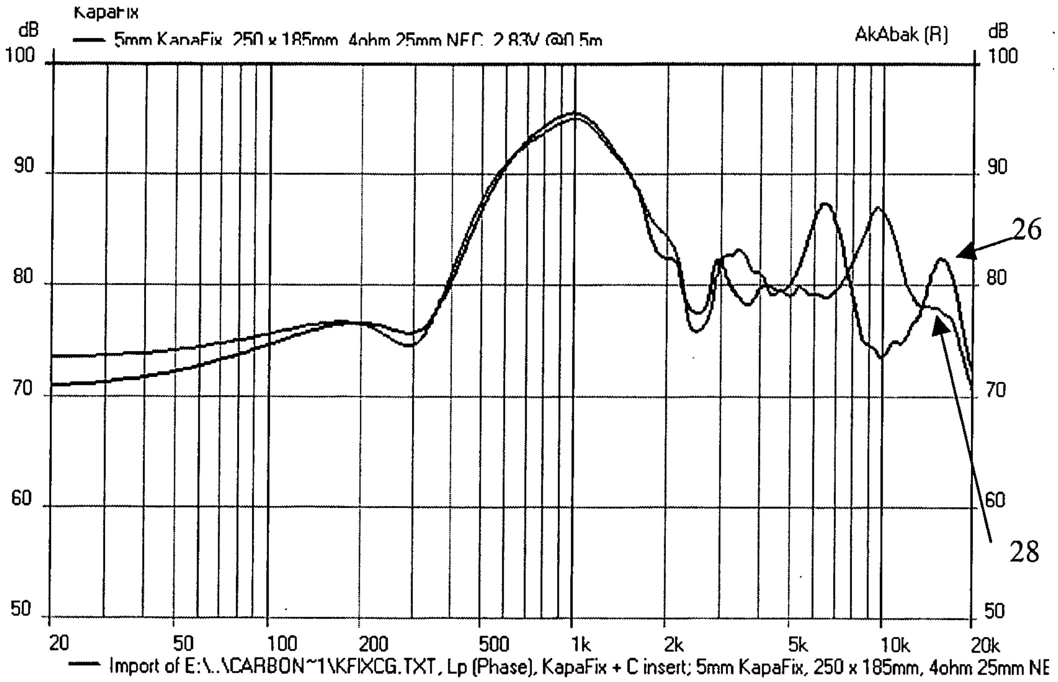



**Figure 2**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5mm KapaFix 250 x 185mm 4ohm 25mm NEC 2.83V @0.5m
AkAbak (R)
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70
60
50
20
50
100
200
500
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2k
5k
10k
20k
26
28
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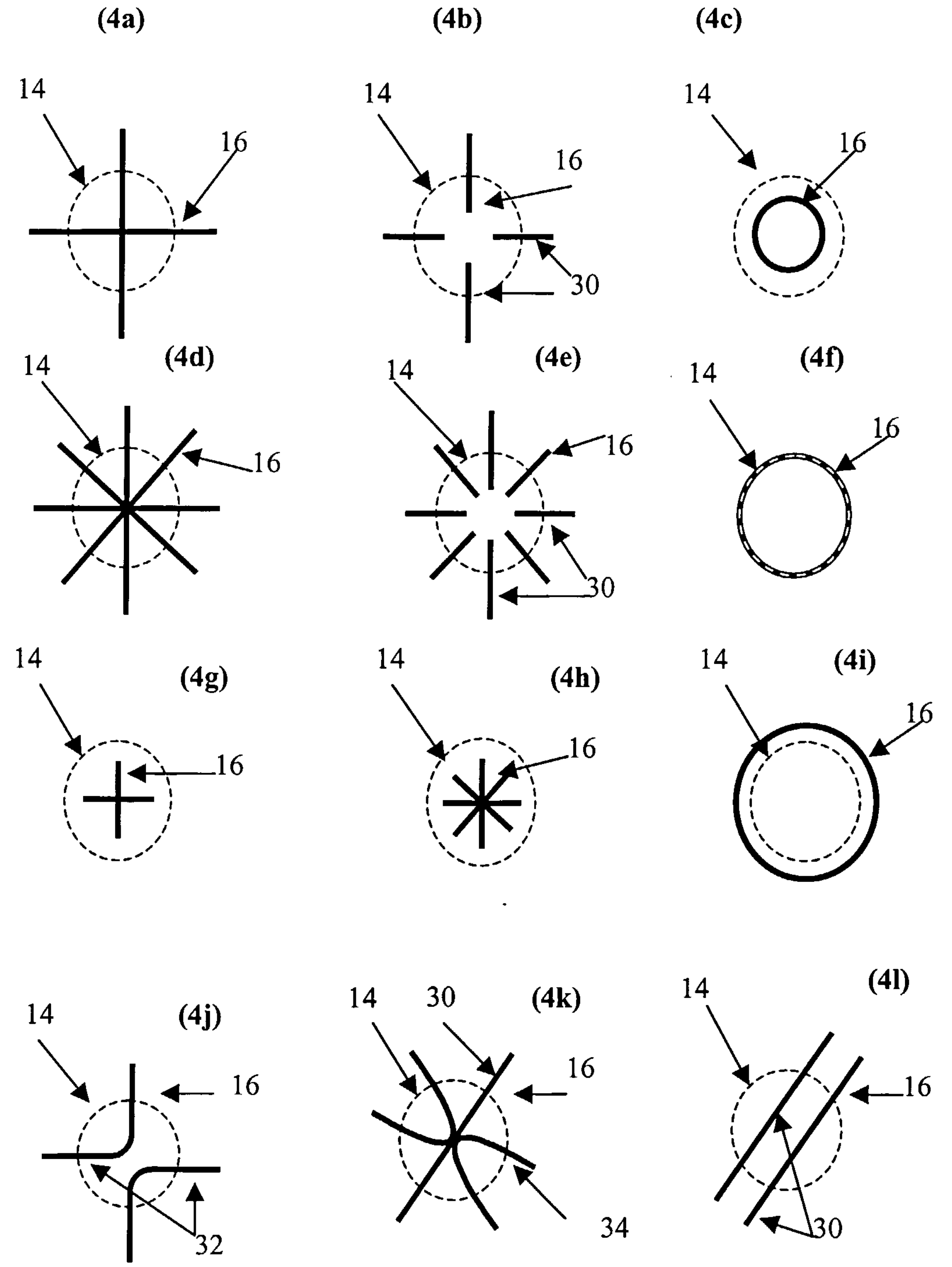
**Figure 3**

**Figure 4**


(4a)
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