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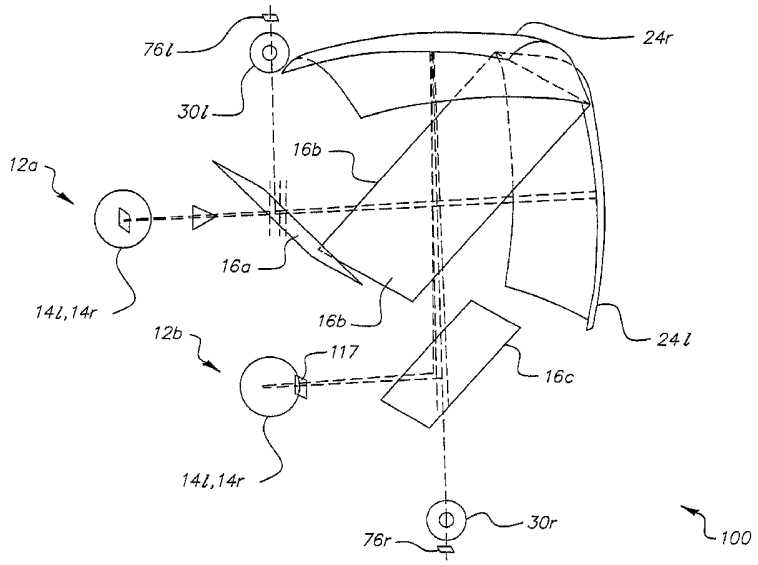
(54) Title: AUTOSTEREOSCOPIC DISPLAY FOR MULTIPLE VIEWERS



(57) Abstract: An apparatus for displaying a stereoscopic virtual image to a first viewer (12a) and to a second viewer (12b), where the stereoscopic virtual image is imaged to each viewer at a left viewing pupil (14l) and a right viewing pupil (14r). Configurations using multiple beamsplitters (16) and one or two curved mirrors (24) direct the optical path to first and second viewers (12a and 12b).

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AUTOSTEREOSCOPIC DISPLAY FOR MULTIPLE VIEWERS

FIELD OF THE INVENTION

This invention generally relates to display apparatus and more particularly relates to an apparatus and method for autostereoscopic display to multiple viewers.

BACKGROUND OF THE INVENTION

The potential value of autostereoscopic display systems is widely appreciated particularly in entertainment and simulation fields. Autostereoscopic display systems include "immersion" systems, intended to provide a realistic viewing experience for an observer by visually surrounding the observer with a three-dimensional (3-D) image having a very wide field of view. As differentiated from the larger group of stereoscopic displays that include it, the autostereoscopic display is characterized by the absence of any requirement for a wearable item of any type, such as goggles, headgear, or special glasses, for example. That is, an autostereoscopic display attempts to provide "natural" viewing conditions for an observer.

One example autostereoscopic system is disclosed in commonly-assigned U.S. Patent No. 6,416,181 (Kessler et al.), incorporated herein by reference, herein referred to as the '181 patent. In an autostereoscopic projection apparatus 10 as described in the '181 disclosure and as shown in Figure 1, a curved mirror 24 is employed, in combination with a beamsplitter 16 for providing an autostereoscopic virtual image to a viewer 12 at left and right viewing pupils 14l and 14r. For left and right viewing pupil 14l and 14r, a corresponding image generation system 70l and 70r provides an initial intermediate curved image that is then projected through a ball lens segment 30 in order to form a left or right intermediate curved image 80l or 80r at a focal plane of curved mirror 24.

The substantially monocentric optical apparatus of the '181 disclosure provides realistic autostereoscopic imaging with large viewing pupils, a very wide field of view, and minimal aberration. However, one salient limitation of the apparatus represented in Figure 1 is its constraint to use by only one viewer 12 at a time. While this arrangement may be suitable for some types of simulator

or entertainment applications, there can be applications where it is advantageous, and more cost-effective, to provide autostereoscopic images to a second viewer 12.

Autostereoscopic display systems for multiple viewers have been proposed, including the following:

U.S. Patent No. 6,449,090 (Omar et al.) discloses a dual-function apparatus that can be used to provide an autostereoscopic image to a single viewer and stereoscopic images to multiple viewers, each of whom, however, requires a polarizing or shuttering device; and

European Patent Specification EP 0 602 934 discloses an autostereoscopic display apparatus that provides a real image simultaneously to two observers. One shortcoming of this approach for many types of display applications relates to the separation of left- and right-eye images; in a disclosed embodiment, right- and left-eye images are reversed for the two observers.

For fully satisfactory 3-D viewing, an autostereoscopic display system should provide separate, high-resolution images to right and left eyes. It can also be readily appreciated that such a system is most favorably designed for compactness, creating an illusion of depth and width of field, while occupying as little actual floor space and volume as is possible. For the most realistic viewing experience, the observer should be presented with a virtual image, disposed to appear a large distance away. Thus, it can be seen that there is a need for an autostereoscopic imaging subsystem using pupil imaging that provides virtual images for multiple viewers.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an autostereoscopic display apparatus that can be viewed by multiple viewers. With this object in mind, the present invention provides an autostereoscopic optical apparatus for displaying a stereoscopic virtual image to a first viewer and to a

second viewer, wherein the stereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the apparatus comprising:

(a) a left image generation system for forming a curved left intermediate image;

(b) a left projection system comprising a left ball lens segment, wherein the pupil of the left ball lens segment is substantially concentric with the curved left intermediate image, the left ball lens segment forming a real image of the curved left intermediate image;

(c) a first beamsplitter disposed to direct the curved left intermediate image toward a focal surface of a first curved mirror, the first curved mirror forming a virtual image of the curved left intermediate image thereby, and the first curved mirror disposed to form:

(i) through the first beamsplitter, a real image of the pupil of the left ball lens segment at the left viewing pupil of the first viewer; and

(ii) through a second beamsplitter, a real image of the pupil of the left ball lens segment at the left viewing pupil of the second viewer;

(d) a right image generation system for forming a curved right intermediate image;

(e) a right projection system comprising a right ball lens segment, wherein the pupil of the right ball lens segment is substantially concentric with the curved right intermediate image, the right ball lens segment forming a real image of the curved right intermediate image;

(f) a third beamsplitter disposed to direct the curved right intermediate image toward a focal surface of a second curved mirror, the second curved mirror forming a virtual image of the curved right intermediate image thereby, and the second curved mirror disposed to form:

(i) through the third beamsplitter, a real image of the pupil of the right ball lens segment at the right viewing pupil of the second viewer; and

(ii) through the second beamsplitter, a real image of the pupil of the right ball lens segment at the right viewing pupil of the first viewer.

It is a feature of the present invention that it utilizes light that is otherwise unused for a single-viewer autostereoscopic immersion system. The system is essentially monocentric, inherently minimizing image aberrations.

It is an advantage of the present invention that it provides, from a single display apparatus full autostereoscopic viewing for at least two viewers.

These and other objects, features, and advantages of the present invention will become apparent to those skilled in the art upon a reading of the following detailed description when taken in conjunction with the drawings wherein there is shown and described an illustrative embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of the present invention, it is believed that the invention will be better understood from the following description when taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a perspective view showing a prior art autostereoscopic optical apparatus for display to a single viewer;

Figure 2a is schematic view showing the optical paths for a display apparatus serving multiple viewers simultaneously;

Figure 2b is a perspective view showing an arrangement of optical components corresponding to the schematic view of Figure 2a;

Figure 3a is schematic view showing the optical paths for another embodiment of a display apparatus serving multiple viewers simultaneously, using a single mirror;

Figure 3b is a perspective view showing an arrangement of optical components corresponding to the schematic view of Figure 3a;

Figure 4a is schematic view showing the optical paths for yet another single-curved-mirror embodiment of a display apparatus for a display apparatus serving multiple viewers simultaneously;

Figure 4b is a perspective view showing an arrangement of optical components corresponding to the schematic view of Figure 4a;

Figure 5a is schematic view showing the optical paths for yet another alternative display apparatus serving multiple viewers simultaneously;

Figure 5b is a perspective view showing an arrangement of optical components corresponding to the schematic view of Figure 5a;

Figure 6a is schematic view showing the optical paths for yet another alternative display apparatus using a single curved mirror to serve multiple viewers simultaneously; and

Figure 6b is a perspective view showing an arrangement of optical components corresponding to the schematic view of Figure 6a.

DETAILED DESCRIPTION OF THE INVENTION

The present description is directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the invention. It is to be understood that elements not specifically shown or described may take various forms well known to those skilled in the art.

The disclosure of U.S. Patent No. 6,416,181 and U.S. Patent Application Serial Nos. 10/393,236 and 10/465,503 give detailed information on how an intermediate image can be formed using a linear or an area spatial light modulator. The description of the present invention that follows concerns itself with the optical path that, given these left and right intermediate images, forms left and right virtual images in order to provide an apparatus allowing multiple viewers.

Embodiments with Multiple Curved Mirrors 24

Referring to Figure 2a, there is shown, in side-view schematic form, an embodiment of a multi-viewer autostereoscopic imaging apparatus 100 employing a left curved mirror 24l for providing an image to left pupils 14l of viewers 12a and 12b. In the optical path for both left pupils 14l, a left intermediate image 76l is generated from left image generation system 70l, as

shown in Figure 1 and described in the '181 disclosure. Left ball lens segment 30l may be a ball lens component comprising a fully spherical lens or may be an hemispheric lens segment having a reflective surface, as is disclosed in commonly-assigned U.S. Patent No. 6,511,182 (Agostinelli et al.), incorporated herein by reference. Left intermediate image 76l is projected by left ball lens segment 30l and reflected from a beamsplitter 16a to the focal surface of left curved mirror 24l as a real image. The resulting collimated left virtual image is then viewed by viewer 12a at left viewing pupil 14l. A second beamsplitter 16b cooperates with a third beamsplitter 16c to direct the collimated left virtual image to left viewing pupil 14l of viewer 12b.

From the schematic view of Figure 2a, the optical path to left viewing pupil 14l for viewer 12a can be traced through the following points:

Channel I → P1→ P2→ P4→P2→P1→ Left viewing pupil 14l

The optical path to left viewing pupil 14l for viewer 12b can be traced through the following points:

Channel I → P1→ P2→ P4→P2→P5→ Left viewing pupil 14l

The optical path for both right pupils 14r of viewers 12a and 12b begins with right intermediate image 76r, employs a curved mirror 24r and beamsplitters 16a, 16b, and 16c, and can be similarly traced. From the schematic view of Figure 2a, the optical path to right viewing pupil 14r for viewer 12a can be traced through the following points:

Channel II→P5→P2→P3→P2→P1→ Right viewing pupil 14r

The optical path to right viewing pupil 14r for viewer 12b can be traced through the following points:

Channel II→P5→P2→P3→P2→P5→ Right viewing pupil 14r

Referring to Figure 2b, there is shown a perspective view of optical components corresponding to the arrangement of Figure 2a.

A second embodiment using multiple curved mirrors 24l and 24r is shown in Figures 5a and 5b. In this alternate arrangement, ball lens segments 30l and 30r are located close together, as is shown most clearly in the perspective view of Figure 5b. Only two beamsplitters 16a and 16b are required. A folding mirror 82 is used for directing the light path to viewer 12b.

From the schematic view of Figure 5a, the optical path to left viewing pupil 14l for viewer 12a can be traced through the following points:

Channel I → P1→ P2→ P3→P2→P1→ Left viewing pupil 14l

The optical path to left viewing pupil 14l for viewer 12b can be traced through the following points:

Channel I → P1→ P2→ P3→P2→P5→ Left viewing pupil 14l

From the schematic view of Figure 5a, the optical path to right viewing pupil 14r for viewer 12a can be traced through the following points:

Channel II→P1→P2→P4→P2→P1→ Right viewing pupil 14r

The optical path to right viewing pupil 14r for viewer 12b can be traced through the following points:

Channel II→P1→P2→P4→P2→P5→ Right viewing pupil 14r

Embodiments with a Single Curved Mirror 24

Referring to Figure 3a, there is shown, in side-view schematic form, an embodiment of a multi-viewer autostereoscopic imaging apparatus 100 employing a single curved mirror 24 for providing images at both left and right pupils 14l and 14r for viewers 12a and 12b. In the optical path for both left pupils 14l, a left intermediate image 76l is generated from left image generation system 70l (not shown in Figure 3a). Left intermediate image 76l is projected by left ball lens segment 30l and reflected from first beamsplitter 16a to second beamsplitter 16b near the focal surface of left curved mirror 24l, as a real image. The resulting collimated left virtual image is then reflected from second beamsplitter 16b and, through first beamsplitter 16a can be viewed by viewer 12a at left viewing pupil 14l. Second beamsplitter 16b also cooperates with third beamsplitter 16c to direct the collimated left virtual image to left viewing pupil 14l of viewer 12b.

From the schematic view of Figure 3a, the optical path to left viewing pupil 14l for viewer 12a can be traced through the following points:

Channel I → P1→ P2→ P3→P2→P1→ Left viewing pupil 14l

The optical path to left viewing pupil 14l for viewer 12b can be traced through the following points:

Channel I → P1→ P2→ P3→P2→P5→ Left viewing pupil 14l

From the schematic view of Figure 3a, the optical path to right viewing pupil 14r for viewer 12a can be traced through the following points:

Channel II→P5→P2→P3→P2→P1→ Right viewing pupil 14r

The optical path to right viewing pupil 14r for viewer 12b can be traced through the following points:

Channel II→P5→P2→P3→P2→P5→ Right viewing pupil 14r

Referring to Figure 3b, there is shown a perspective view of optical components corresponding to the arrangement of Figure 3a.

Referring to Figures 4a and 4b, there is shown an alternate arrangement for multi-viewer autostereoscopic imaging apparatus 100 using one curved mirror 24, with folding mirror 82 added. From the schematic view of Figure 4a, the optical path to left viewing pupil 14l for viewer 12a can be traced through the following points:

Channel I → P1→ P2→ P3→P2→P1→ Left viewing pupil 14l

The optical path to left viewing pupil 14l for viewer 12b can be traced through the following points:

Channel I → P1→ P2→ P3→P2→ P4→P5→ Left viewing pupil 14l

From the schematic view of Figure 4a, the optical path to right viewing pupil 14r for viewer 12a can be traced through the following points:

Channel II→P4→P2→P3→P2→P1→ Right viewing pupil 14r

The optical path to right viewing pupil 14r for viewer 12b can be traced through the following points:

Channel II→P4→P2→P3→P2→ P4→P5→ Right viewing pupil 14r

Yet another embodiment using one curved mirror 24 is shown in Figures 6a and 6b. In this alternate arrangement, ball lens segments 30l and 30r are located close together, as is shown most clearly in the perspective view of Figure 6b. Only two beamsplitters 16a and 16b are required. Folding mirror 82 is used for directing the imaging light path to viewer 12b.

From the schematic view of Figure 6a, the optical path to left viewing pupil 14l for viewer 12a can be traced through the following points:

Channel I → P1→ P2→ P4→P2→P1→ Left viewing pupil 14l

The optical path to left viewing pupil 14l for viewer 12b can be traced through the following points:

Channel I → P1→ P2→ P3→P2→P5→ Left viewing pupil 14l

From the schematic view of Figure 6a, the optical path to right viewing pupil 14r for viewer 12a can be traced through the following points:

Channel II→P1→P2→P4→P2→P1→ Right viewing pupil 14r

The optical path to right viewing pupil 14r for viewer 12b can be traced through the following points:

Channel II→P1→P2→P4→P2→P5→ Right viewing pupil 14r

As is noted hereinabove, embodiments shown in Figures 2b, 3b, 4b, 5b, and 6b depict ball lens segments 30l, 30r as spherical; however, with any of these configurations, one or both ball lens segments 30l, 30r could use a hemispheric lens segment having a reflective surface.

Advantages and Tradeoffs for Embodiments Shown

The embodiments shown in Figures 2b, 3b, 4b, 5b, and 6b use different arrangements of curved mirror 24 and left and right ball lens segment 30l and 30r. It is instructive to note some advantages and drawbacks presented by the various design approaches shown in these figures. As advantages, designs using a single curved mirror 24, as shown in Figures 3a, 3b, 4a, 4b, 6a, and 6b, use fewer components and allow a longer working distance. Among disadvantages where using a single curved mirror 24 are off-axis anomalies for forming left and right viewing pupils 14l and 14r. For each viewer 12, both left and right optical paths must be slightly off-axis with respect to curved mirror 24. This causes a slight keystoning aberration in each optical path, with keystoning in opposite directions between left and right images. To some extent, this effect can be corrected electronically.

Designs using left and right curved mirrors 24l and 24r, such as those shown in Figures 2a, 2b, 5a, and 5b allow on-axis imaging, minimizing or eliminating keystoning effects. However, designs using multiple mirrors are disadvantaged due to mechanical placement constraints; it is difficult to arrange both left and right curved mirrors 24l and 24r without some obstruction and consequent reduction of field width.

Another design consideration relates to the relative positioning of left and right ball lens segments 30l and 30r. In the embodiments of Figures 2b, 3b, and 4b, both left and right ball lens segments 30l and 30r can be separately positioned, with a relatively large distance between them. This arrangement eases space requirements for imaging support components and allows the size of ball lens segment 30 components to be relatively larger, providing a larger viewing pupil 14. By contrast, the embodiments of Figures 5b and 6b require that ball lens segments 30l and 30r be positioned closely together, but allow a more compact design overall.

A number of different image generation system 70 configurations could be employed, using either scanned linear spatial light modulators or area spatial light modulators. Examples of scanned linear spatial light modulators include grating light valve (GLV) linear arrays, as described in U.S. Patent No. 5,311,360 (Bloom et al.) and conformal grating electromechanical system (GEMS) components, as disclosed in commonly-assigned U.S. Patent No. 6,307,663 (Kowarz). Examples of area spatial light modulators include liquid crystal device (LCD) or digital micromirror device (DMD) components, both well known in the digital imaging arts.

The curved image formed as left or right intermediate image 76l, 76r could be formed on a diffusive surface, as was described in the '181 disclosure, or could be formed using techniques disclosed in copending applications noted above, U.S. Patent Application Serial Nos. 10/393,236 and 10/465,503.

Thus, what is provided is an autostereoscopic display apparatus and method for providing a virtual image display using pupil imaging to multiple viewers.

PARTS LIST

10	Autostereoscopic imaging apparatus
12	Viewer
12a	Viewer
12b	Viewer
14	Viewing pupil
14l	Viewing pupil, left
14r	Viewing pupil, right
16	Beamsplitter
16a	Beamsplitter
16b	Beamsplitter
16c	Beamsplitter
24	Curved mirror
24l	Left curved mirror
24r	Right curved mirror
30	Ball lens segment
30l	Left ball lens segment
30r	Right ball lens segment
70	Image generation system
70l	Left image generation system
70r	Right image generation system
76l	Left intermediate image
76r	Right intermediate image
80	Intermediate curved image
80l	Intermediate curved image, left
80r	Intermediate curved image, right
82	Folding mirror
100	Multi-viewer autostereoscopic imaging apparatus

CLAIMS:

1. An autostereoscopic optical apparatus for displaying a stereoscopic virtual image to a first viewer and to a second viewer, wherein the stereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the apparatus comprising:

(a) a left image generation system for forming a curved left intermediate image;

(b) a left projection system comprising a left ball lens segment, wherein the pupil of said left ball lens segment is substantially concentric with said curved left intermediate image, said left ball lens segment forming a real image of said curved left intermediate image;

(c) a first beamsplitter disposed to direct said curved left intermediate image toward a focal surface of a first curved mirror, said first curved mirror forming a virtual image of said curved left intermediate image thereby, and said first curved mirror disposed to form:

(i) through said first beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the first viewer; and

(ii) through a second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the second viewer;

(d) a right image generation system for forming a curved right intermediate image;

(e) a right projection system comprising a right ball lens segment, wherein the pupil of said right ball lens segment is substantially concentric with said curved right intermediate image, said right ball lens segment forming a real image of said curved right intermediate image;

(f) a third beamsplitter disposed to direct said curved right intermediate image toward a focal surface of a second curved mirror, said second curved mirror forming a virtual image of said curved right intermediate image thereby, and said second curved mirror disposed to form:

(i) through said third beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the second viewer; and

(ii) through said second beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the first viewer.

2. An autostereoscopic optical apparatus according to claim 1 wherein said left ball lens segment comprises an hemispheric lens and a reflective surface.

3. An autostereoscopic optical apparatus according to claim 1 wherein said left image generation system comprises a liquid crystal display component.

4. An autostereoscopic optical apparatus according to claim 1 wherein said right ball lens segment comprises an hemispheric lens and a reflective surface.

5. An autostereoscopic optical apparatus according to claim 1 wherein said right image generation system comprises a liquid crystal display component.

6. An autostereoscopic optical apparatus for displaying a stereoscopic virtual image to a first viewer and to a second viewer, wherein the stereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the apparatus comprising:

(a) a left image generation system for forming a curved left intermediate image;

(b) a left projection system comprising a left ball lens segment, wherein the pupil of said left ball lens segment is substantially

concentric with said curved left intermediate image, said left ball lens segment forming a real image of said curved left intermediate image;

(c) a first beamsplitter disposed to direct said curved left intermediate image toward a second beamsplitter said second beamsplitter then directing said curved left intermediate image toward a focal surface of a first curved mirror, said first curved mirror forming a virtual image of said curved left intermediate image, and said first curved mirror disposed to form:

(i) through said second and first beamsplitters, a real image of the pupil of said left ball lens segment at the left viewing pupil of the first viewer; and

(ii) through said second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the second viewer;

(d) a right image generation system for forming a curved right intermediate image;

(e) a right projection system comprising a right ball lens segment, wherein the pupil of said right ball lens segment is substantially concentric with said curved right intermediate image, said right ball lens segment forming a real image of said curved right intermediate image;

(f) said first beamsplitter disposed to direct said curved right intermediate image toward said second beamsplitter, said second beamsplitter then directing said curved right intermediate image toward said focal surface of said first curved mirror, said first curved mirror forming a virtual image of said curved right intermediate image, and said first curved mirror disposed to form:

(i) through said first and second beamsplitters, a real image of the pupil of said right ball lens segment at the right viewing pupil of the first viewer; and

(ii) through said second beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the second viewer.

7. An autostereoscopic optical apparatus according to claim 6 further comprising a folding mirror disposed in the optical path of the second viewer.

8. An autostereoscopic optical apparatus according to claim 6 wherein said left ball lens segment comprises an hemispheric lens and a reflective surface.

9. An autostereoscopic optical apparatus according to claim 6 wherein said left image generation system comprises a liquid crystal display component.

10. An autostereoscopic optical apparatus according to claim 6 wherein said right ball lens segment comprises an hemispheric lens and a reflective surface.

11. An autostereoscopic optical apparatus according to claim 6 wherein said right image generation system comprises a liquid crystal display component.

12. An autostereoscopic optical apparatus for displaying a stereoscopic virtual image to a first viewer and to a second viewer, wherein the stereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the apparatus comprising:

(a) a left image generation system for forming a curved left intermediate image;

(b) a left projection system comprising a left ball lens segment, wherein the pupil of said left ball lens segment is substantially concentric with said curved left intermediate image, said left ball lens segment forming a real image of said curved left intermediate image;

(c) a first beamsplitter disposed to direct said curved left intermediate image toward a second beamsplitter, said second beamsplitter then

directing said curved left intermediate image toward a focal surface of a curved mirror for forming a virtual image of said curved left intermediate image thereby, and said curved mirror disposed to form:

(i) through said first and second beamsplitters, a real image of the pupil of said left ball lens segment at the left viewing pupil of the first viewer; and

(ii) through said second beamsplitter and a third beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the second viewer;

(d) a right image generation system for forming a curved right intermediate image;

(e) a right projection system comprising a right ball lens segment, wherein the pupil of said right ball lens segment is substantially concentric with said curved right intermediate image, said right ball lens segment forming a real image of said curved right intermediate image;

(f) said third beamsplitter disposed to direct said curved right intermediate image toward the focal surface of said curved mirror for forming a virtual image of said curved right intermediate image thereby, and said curved mirror disposed to form

(i) through said third beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the second viewer; and

(ii) through said second beamsplitter and said first beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the first viewer.

13. An autostereoscopic optical apparatus for displaying a stereoscopic virtual image to a first viewer and to a second viewer, wherein the stereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the apparatus comprising:

(a) a left image generation system for forming a curved left intermediate image;

(b) a left projection system comprising a left ball lens segment, wherein the pupil of said left ball lens segment is substantially concentric with said curved left intermediate image, said left ball lens segment forming a real image of said curved left intermediate image;

(c) a first beamsplitter disposed to direct said curved left intermediate image through a second beamsplitter and toward a focal surface of a curved mirror, said curved mirror forming a virtual image of said curved left intermediate image thereby, and said curved mirror disposed to form:

(i) through said first and second beamsplitters, a real image of the pupil of said left ball lens segment at the left viewing pupil of the first viewer; and

(ii) through said second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the second viewer;

(d) a right image generation system for forming a curved right intermediate image;

(e) a right projection system comprising a right ball lens segment, wherein the pupil of said right ball lens segment is substantially concentric with said curved right intermediate image, said right ball lens segment forming a real image of said curved right intermediate image;

(f) said first beamsplitter disposed to direct said curved right intermediate image toward the focal surface of said curved mirror, said curved mirror forming a virtual image of said curved right intermediate image thereby, and said curved mirror disposed to form:

(i) through said second beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the second viewer; and

(ii) through said second beamsplitter and said first beamsplitter, a real image of the pupil of said right ball

lens segment at the right viewing pupil of the first viewer.

14. A method for displaying an autostereoscopic virtual image to a first viewer and to a second viewer, wherein the autostereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the method comprising:

(a) forming a curved left intermediate image;

(b) projecting a real image of said curved left intermediate image through a left ball lens segment toward a focal surface of a first curved mirror, said first curved mirror forming a virtual image of said curved left intermediate image, and said first curved mirror disposed to form:

(i) through a first beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the first viewer; and

(ii) through a second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the second viewer;

(c) forming a curved right intermediate image;

(d) projecting a real image of said curved right intermediate image through a right ball lens segment toward a focal surface of a second curved mirror, said second curved mirror forming a virtual image of said curved right intermediate image, and said second curved mirror disposed to form:

(i) through a third beamsplitter, a real image of a the pupil of said right ball lens segment at the right viewing pupil of the second viewer; and

(ii) through said second beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the first viewer.

15. A method for displaying an autostereoscopic virtual image according to claim 14 wherein the step of forming said curved left intermediate image comprises the step of controlling an area spatial light modulator.

16. A method for displaying an autostereoscopic virtual image wherein the step of projecting a real image of a curved left intermediate image through a left ball lens segment comprises the step of projecting said real image through an hemispheric lens and a reflective surface.

17. A method for displaying an autostereoscopic virtual image to a first viewer and to a second viewer, wherein the autostereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the method comprising:

(a) forming a curved left intermediate image;

(b) projecting a real image of said curved left intermediate image through a left ball lens segment toward a focal surface of a first curved mirror, said first curved mirror forming a virtual image of said curved left intermediate image and said first curved mirror disposed to form:

(i) through a first and a second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the first viewer; and

(ii) through said second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the second viewer;

(c) forming a curved right intermediate image;

(d) projecting a real image of said curved right intermediate image through a right ball lens segment toward a focal surface of a second curved mirror, said second curved mirror forming a virtual image of said curved right intermediate image and said second curved mirror disposed to form:

(i) through said first and second beamsplitters, a real image of the pupil of said right ball lens segment at the right viewing pupil of the first viewer; and

(ii) through said second beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the second viewer.

18. A method for displaying an autostereoscopic virtual image to a first viewer and to a second viewer, wherein the autostereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the method comprising:

(a) forming a curved left intermediate image;

(b) projecting a real image of said curved left intermediate image through a left ball lens segment toward a focal surface of a curved mirror, said curved mirror forming a virtual image of said curved left intermediate image and said curved mirror disposed to form:

(i) through a first and a second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the first viewer; and

(ii) through said second beamsplitter and a third beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the second viewer;

(c) forming a curved right intermediate image;

(d) projecting a real image of said curved right intermediate image through a right ball lens segment toward said focal surface of said curved mirror, said curved mirror forming a virtual image of said curved right intermediate image and said curved mirror disposed to form:

(i) through said third beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the second viewer; and

(ii) through said second beamsplitter and said first beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the first viewer.

19. A method for displaying an autostereoscopic virtual image to a first viewer and to a second viewer, wherein the autostereoscopic virtual image is imaged to each viewer at a left viewing pupil and a right viewing pupil, the method comprising:

(a) forming a curved left intermediate image;

(b) projecting a real image of said curved left intermediate image through a left ball lens segment toward a focal surface of a curved mirror, said curved mirror forming a virtual image of said curved left intermediate image and said curved mirror disposed to form:

(i) through a first and a second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the first viewer; and

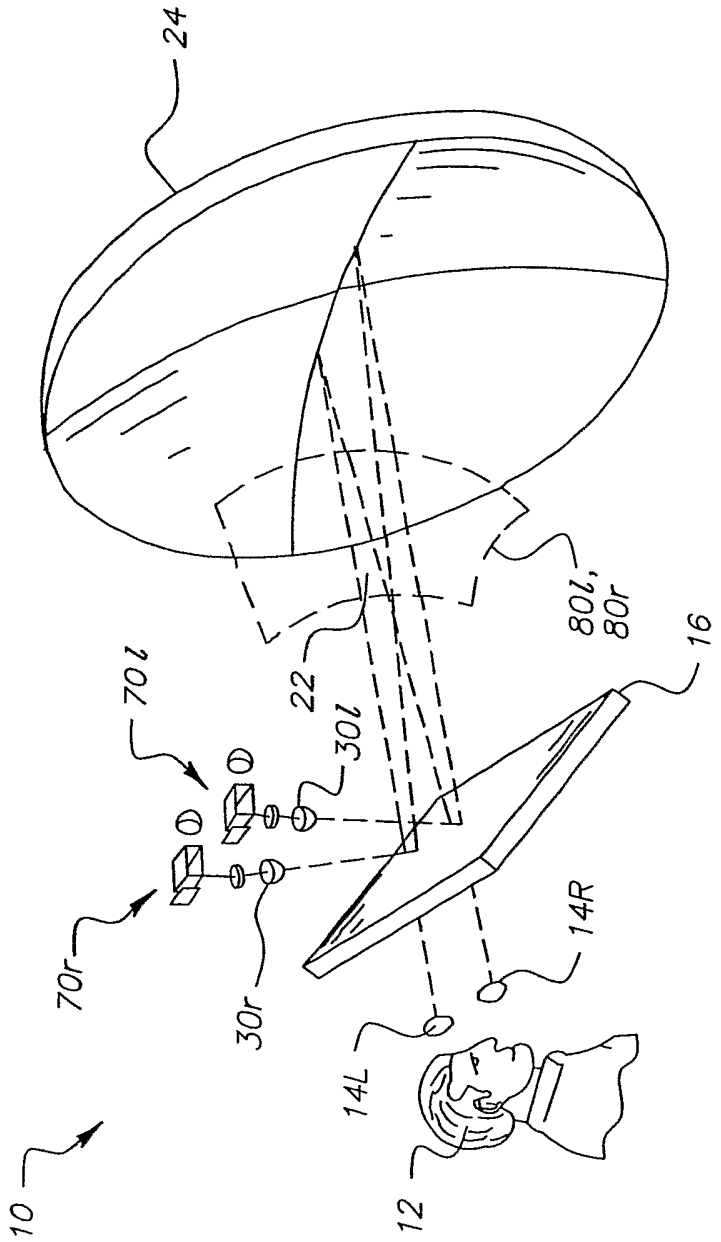
(ii) through said second beamsplitter, a real image of the pupil of said left ball lens segment at the left viewing pupil of the second viewer;

(c) forming a curved right intermediate image;

(d) projecting a real image of said curved right intermediate image through a right ball lens segment toward said focal surface of said curved mirror, said curved mirror forming a virtual image of said curved right intermediate image and said curved mirror disposed to form:

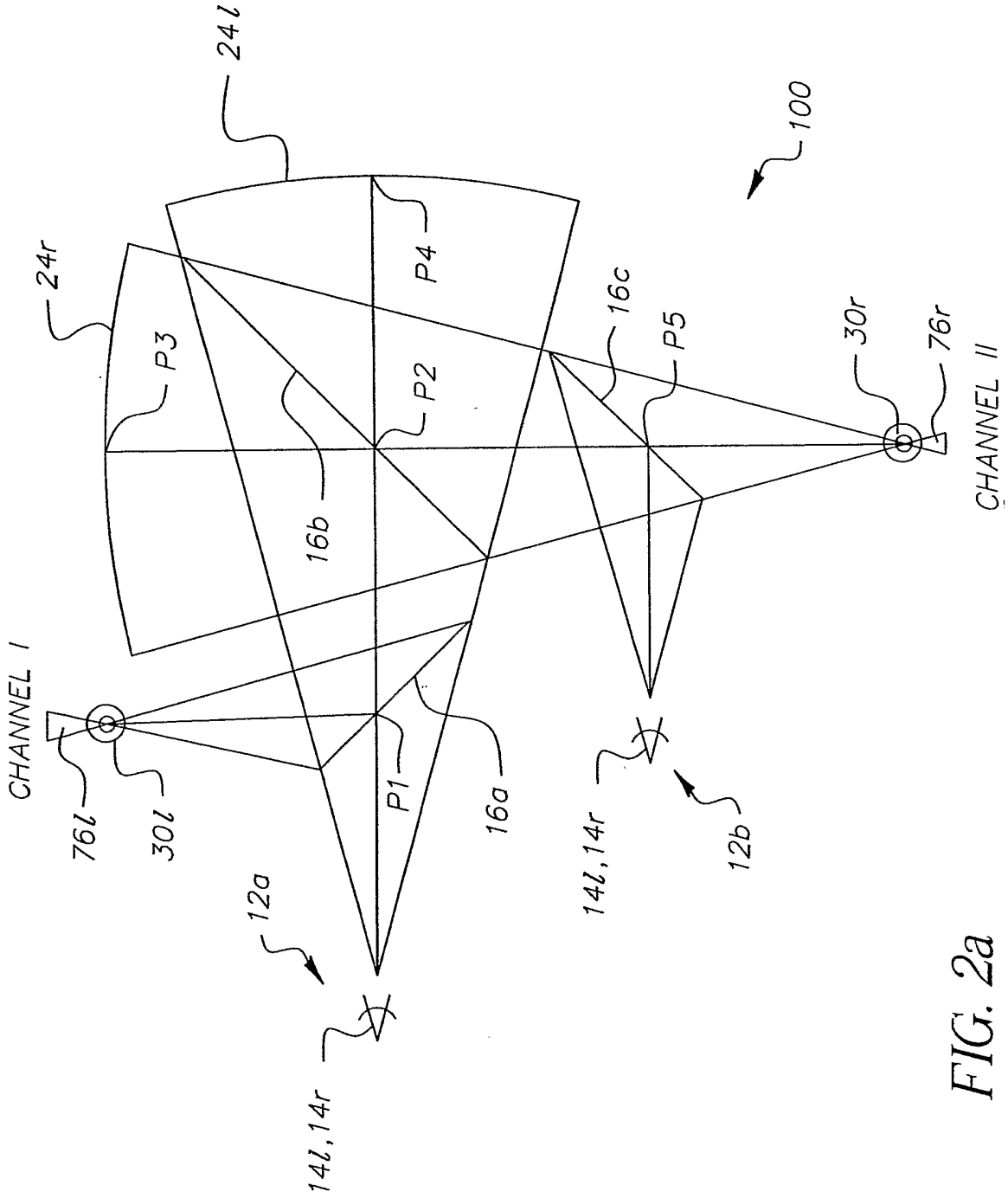
(i) through said second beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the second viewer; and

(ii) through said second beamsplitter and said first beamsplitter, a real image of the pupil of said right ball lens segment at the right viewing pupil of the first viewer.



PRIOR ART

FIG. 1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100
24r
P4
P3
16c
P5
30r
76r
P2
16b
CHANNEL II
CHANNEL I
76l
30l
P1
16a
12a
14l,14r
14l,14r
12b

FIG. 2a

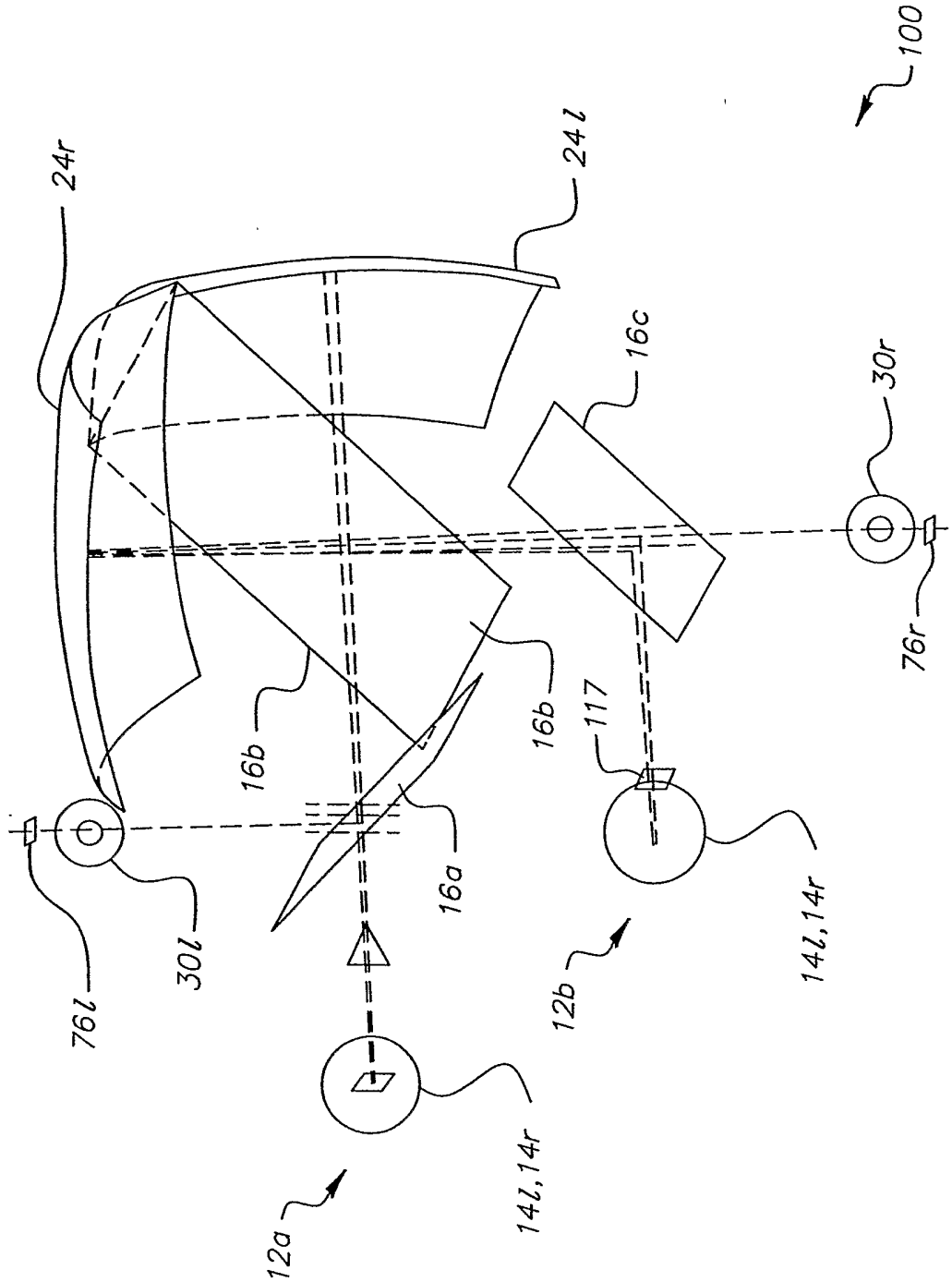

100
24r
24l
16c
30r
76r
16b
16b
117
16a
76l
30l
12b
14l,14r
12a
14l,14r

FIG. 2b

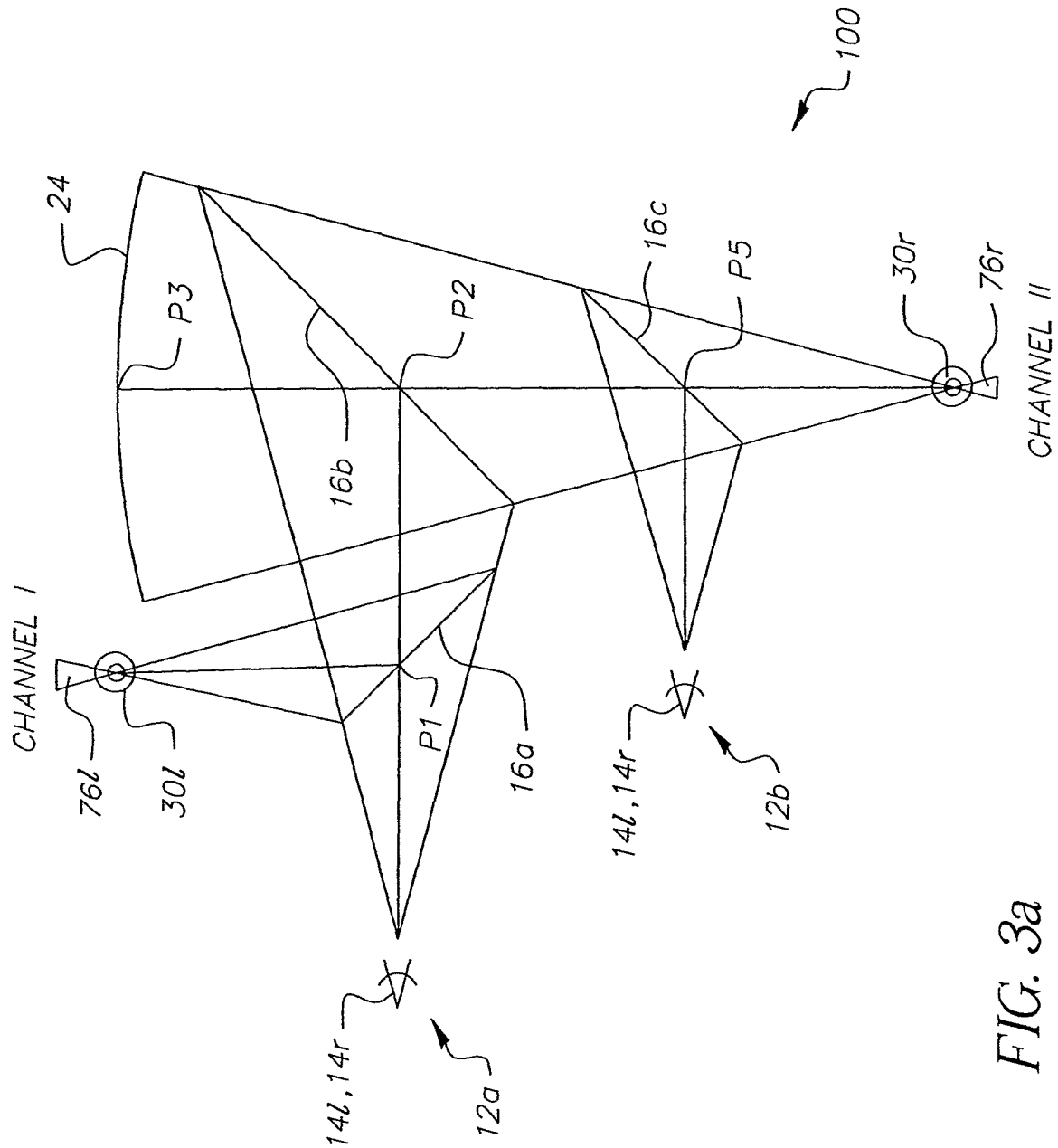
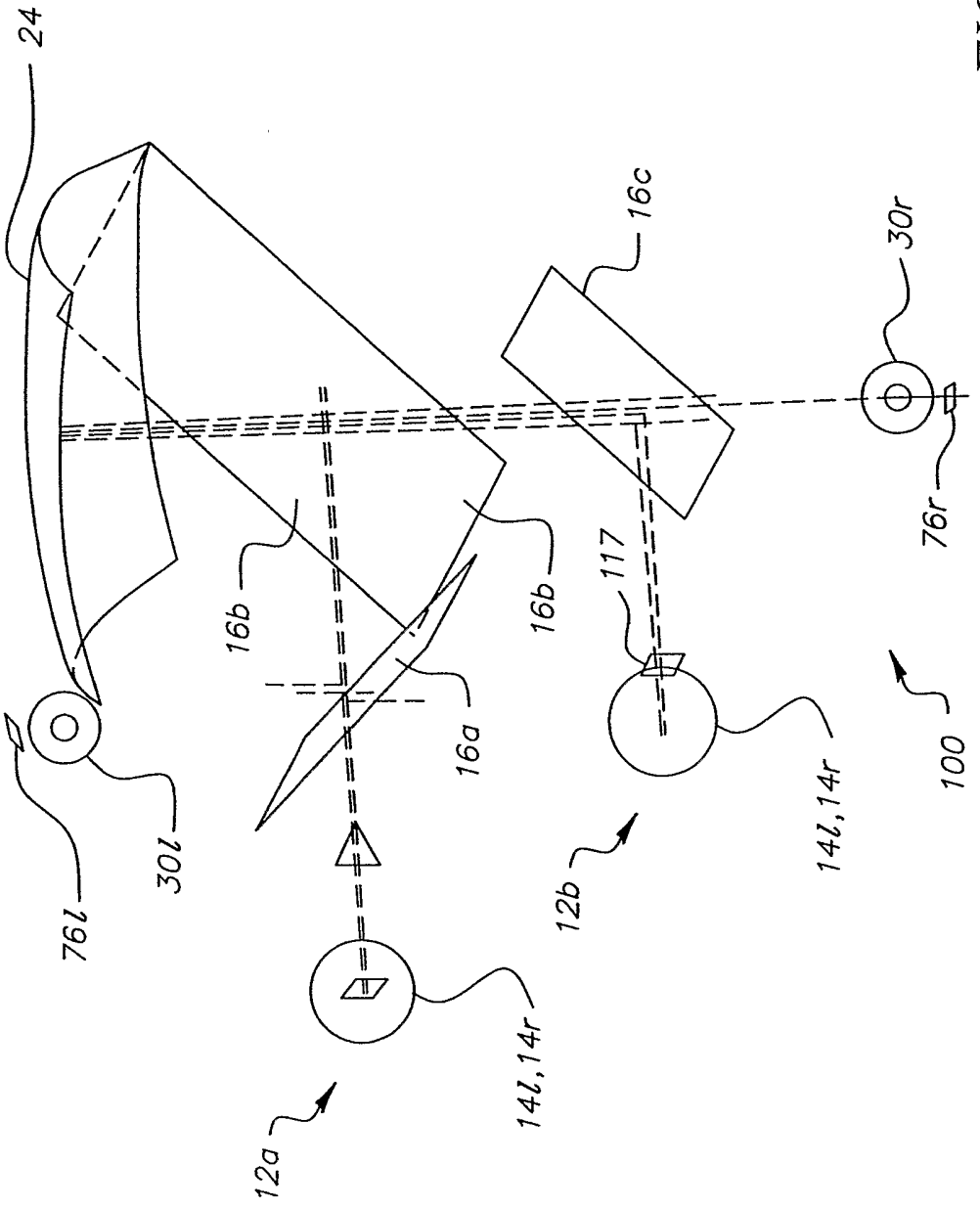

100
24
P3
P2
16c
P5
30r
76r
CHANNEL II
16b
CHANNEL I
76l
30l
P1
16a
14l,14r
12b
14l,14r
12a

FIG. 3a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16c
30r
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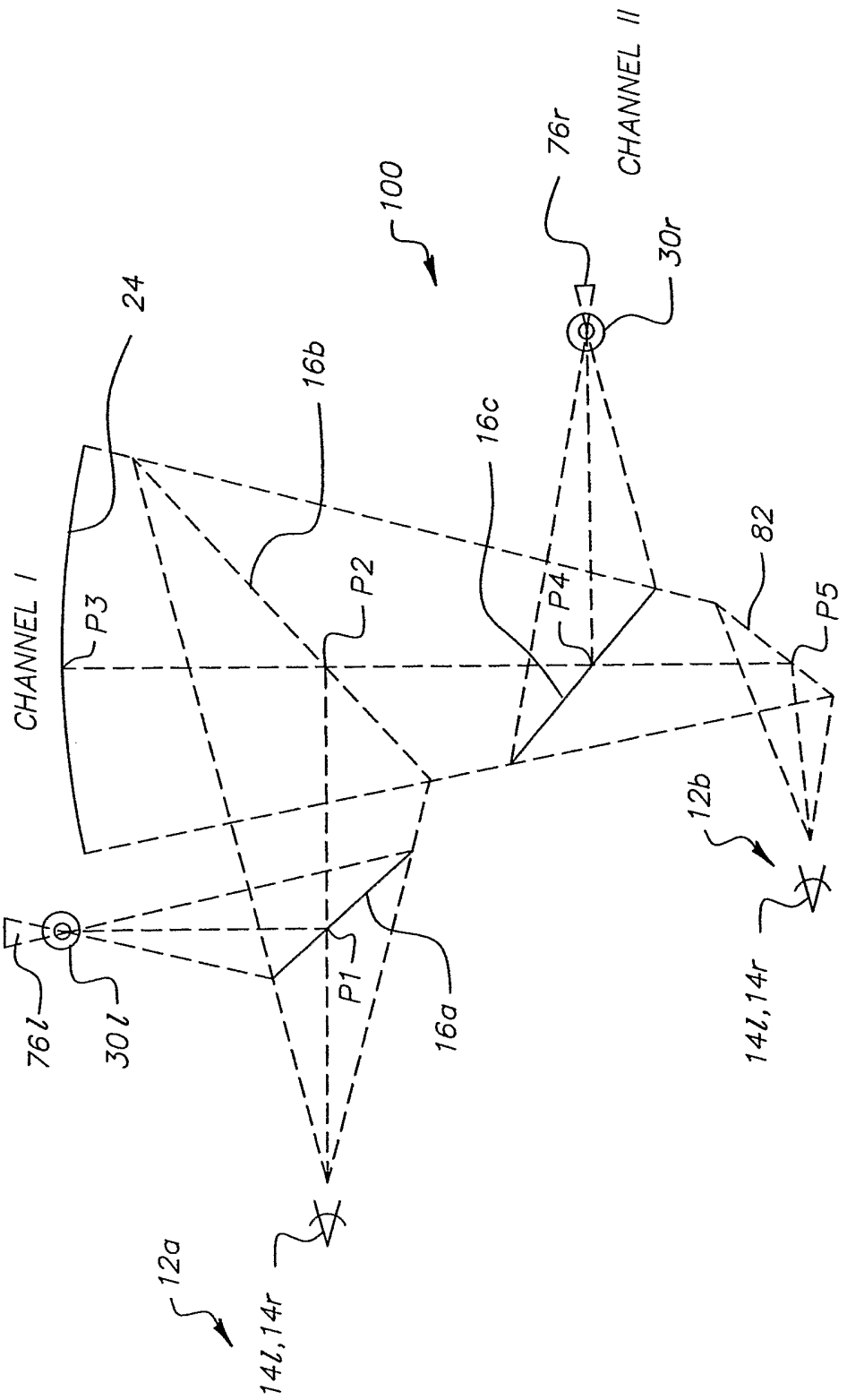
16b
117
76r
16a
30l
76l
12b
14l,14r
100
12a
14l,14r

FIG. 3b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24
16b
16c
76r
CHANNEL II
30r
CHANNEL I
P3
P2
P4
82
P5
12b
76l
30l
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16a
14l,14r
12a
14l,14r

FIG. 4a

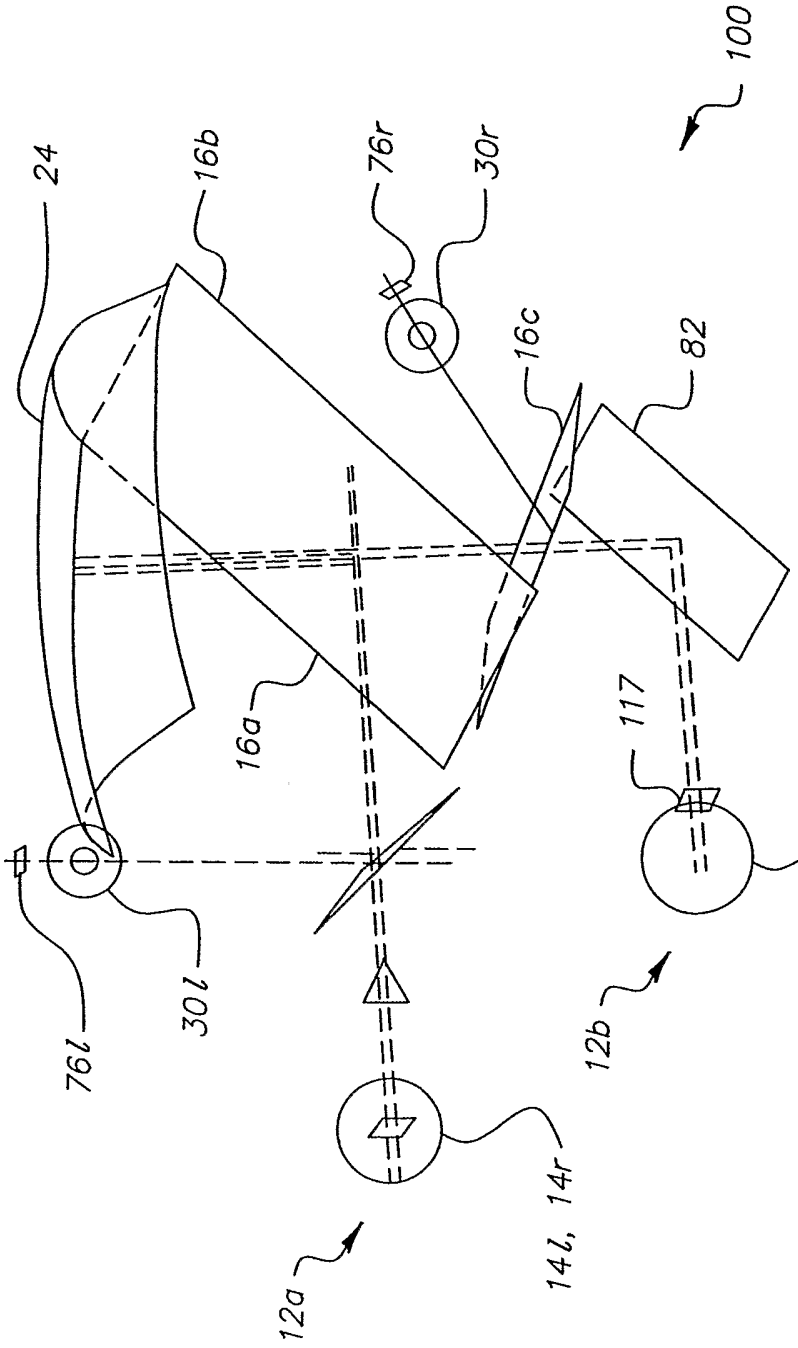


FIG. 4b

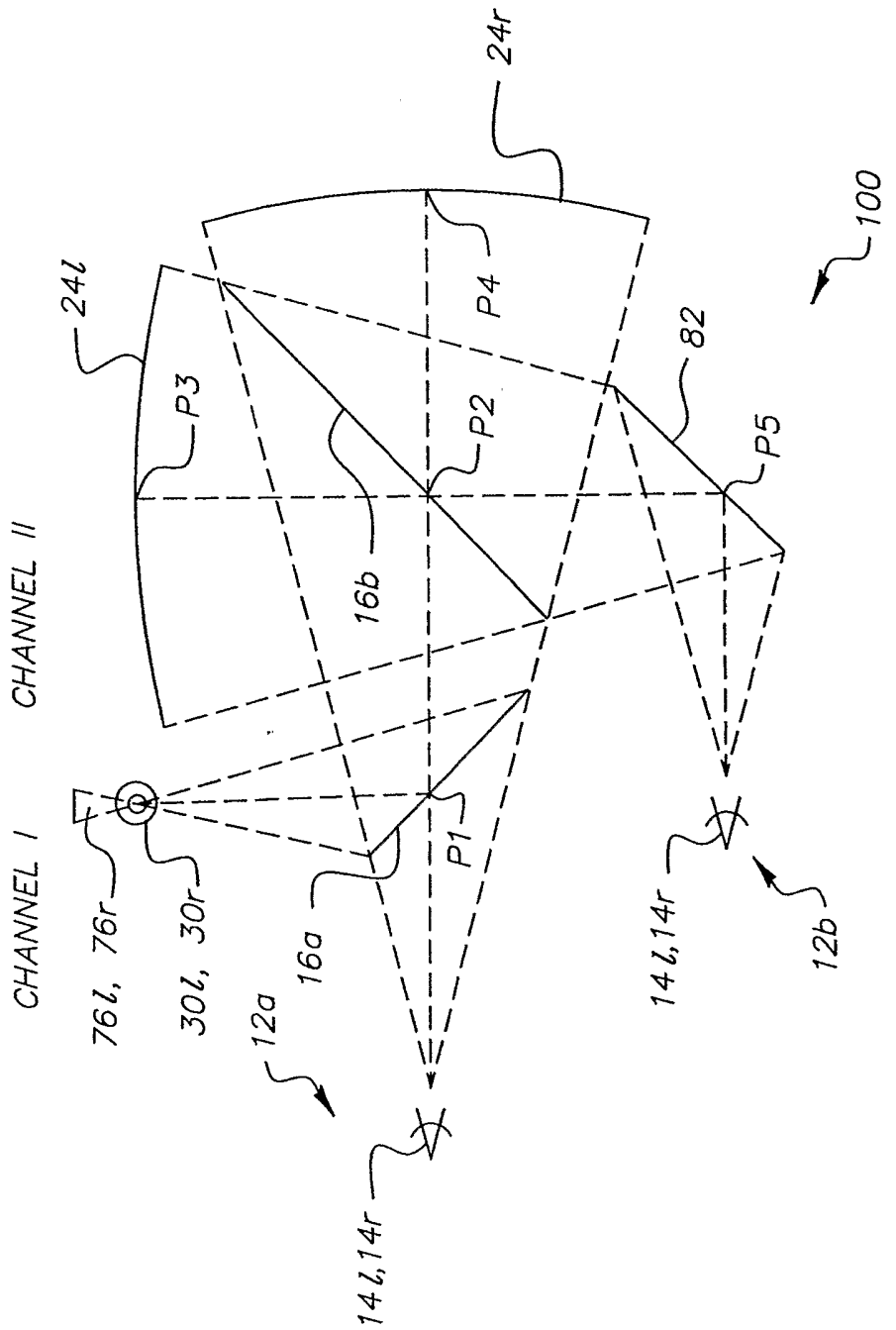

CHANNEL I
CHANNEL II
76l, 76r
30l, 30r
12a
16a
16b
P1
P2
P3
P4
P5
24l
24r
82
100
14l,14r
12b
14l,14r

FIG. 5a

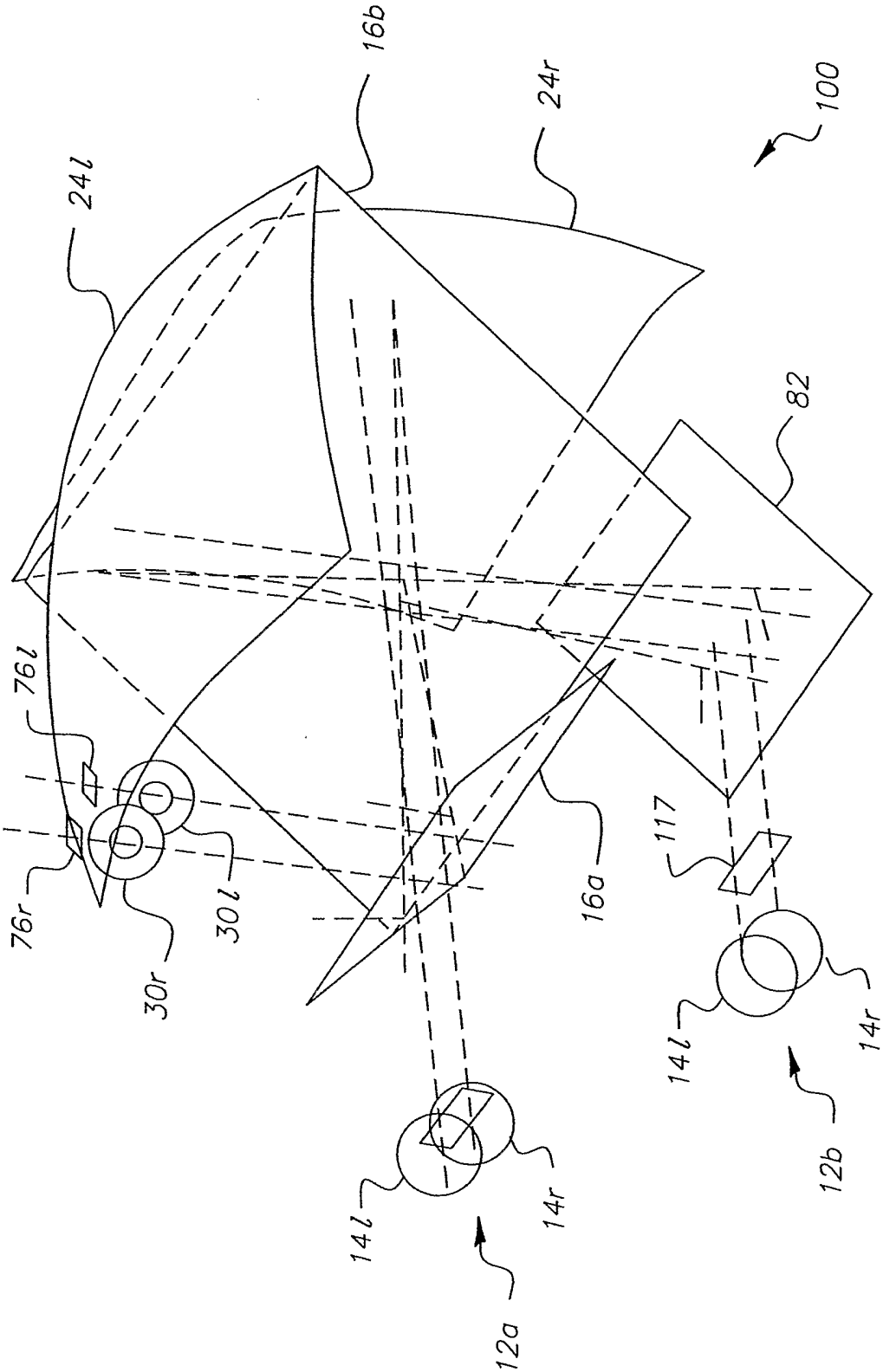
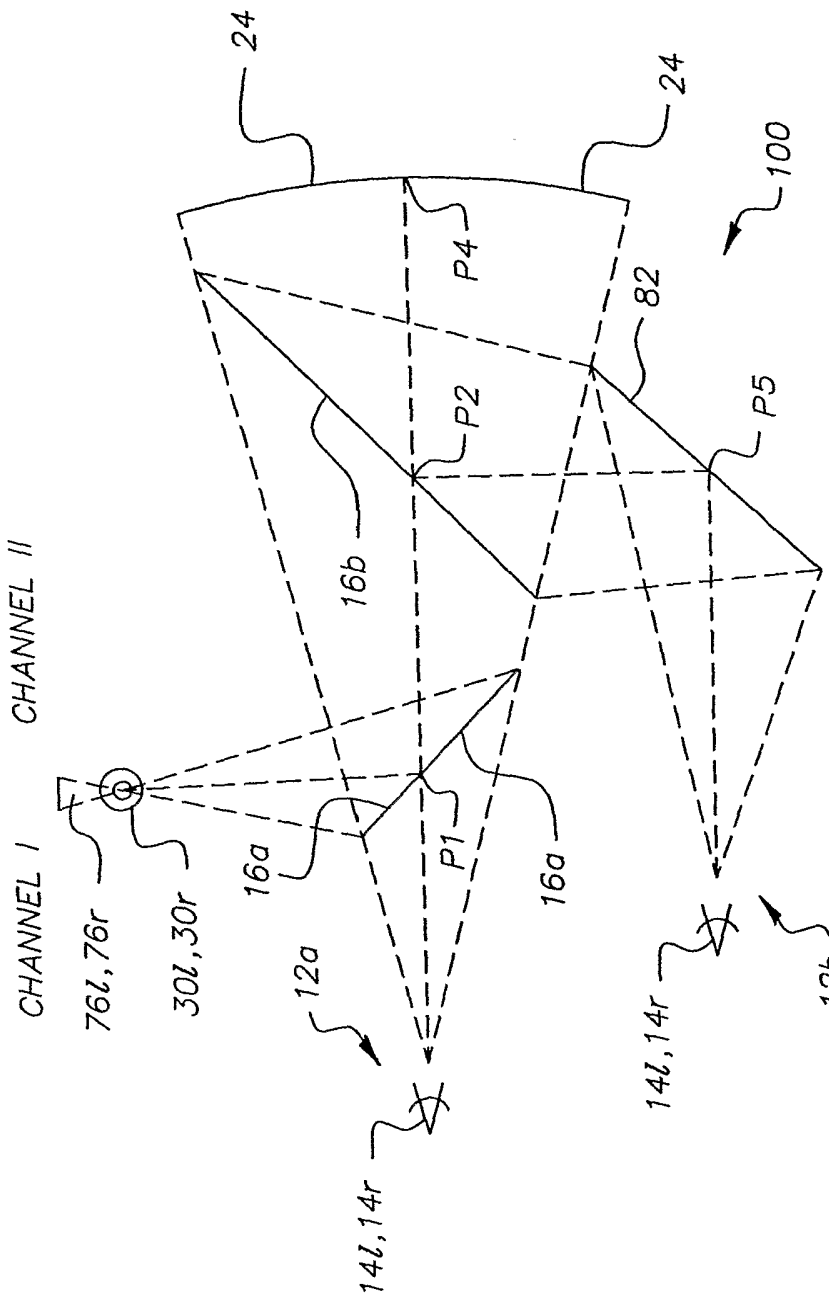


FIG. 5b


24
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100
P4
82
P5
P2
16b
CHANNEL II
CHANNEL I
76l,76r
30l,30r
16a
P1
16a
12a
14l,14r
14l,14r
12b

FIG. 6a

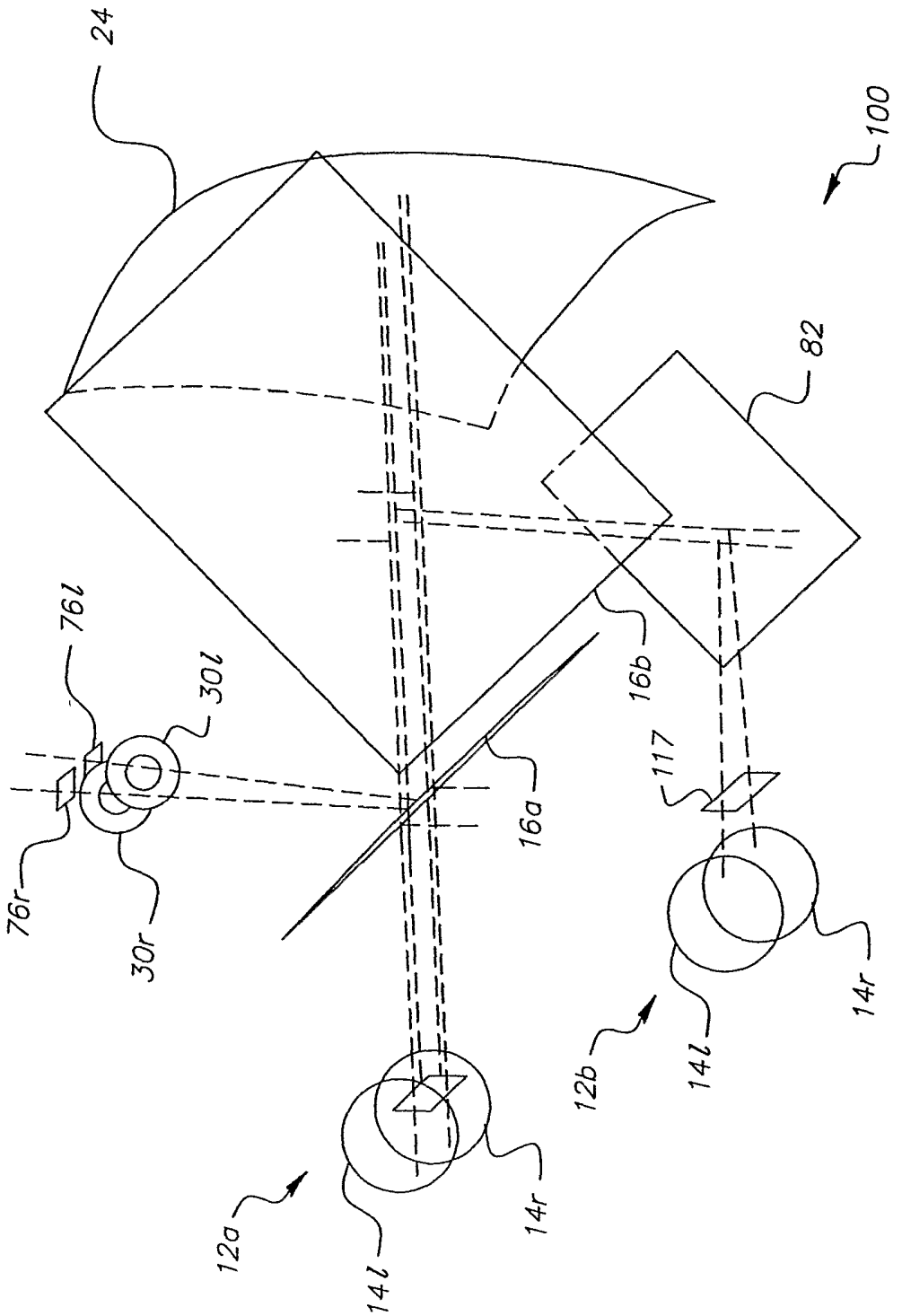

FIG. 6b

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/026138

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B27/24

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N G02B

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

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

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 522 474 B2 (COBB JOSHUA M ET AL) 18 February 2003 (2003-02-18) column 6, line 19 - column 7, line 35; figures 2a,2b	16
A	EP 0 602 934 A (SHARP KK) 22 June 1994 (1994-06-22) cited in the application column 7, lines 14-56; figure 11	1-19
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2005	21/01/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Casse, M

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/026138

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5 477 385 A (FREEMAN ROBIN J) 19 December 1995 (1995-12-19) column 1, line 38 - column 2, line 39; figure 1	1-5,14, 15,17
A	US 3 598 482 A (MILLER WENDELL S) 10 August 1971 (1971-08-10) column 5, line 18 - column 6, line 52; figures 1,5-9	16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US2004/026138

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Information on patent family members

International Application No
PCT/US2004/026138

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