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(54) **Title:** RECONFIGURABLE DETECTOR SYSTEM

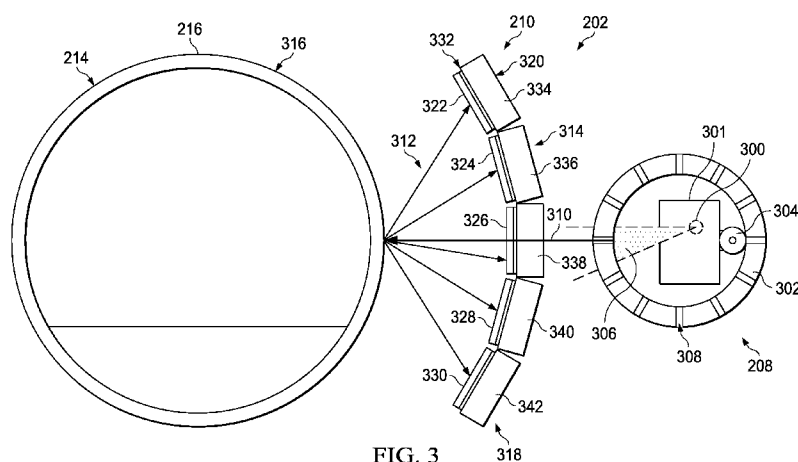


FIG. 3

(57) **Abstract:** A method and apparatus for inspecting an object using a backscatter inspection system. In one illustrative embodiment, an apparatus comprises a radiation source, a collimator, and a detector system. The radiation source is configured to emit radiation. The collimator is configured to form a beam using a portion of the radiation emitted by the radiation source. The beam is directed towards a surface of an object. The detector system is configured to detect backscatter formed in response to the beam encountering the object. A shape of the detector system is configured to be changed into a selected shape.

RECONFIGURABLE DETECTOR SYSTEM

BACKGROUND

The present disclosure relates generally to inspection systems, and in particular, to backscatter inspection systems. Still more particularly, the present disclosure relates to a method and apparatus for detecting backscatter off of an object using a detector having a shape capable of substantially conforming to a shape of the object.

A backscatter x-ray system is an example of a nondestructive inspection system (NDI) that uses x-rays to inspect an object. Some currently available backscatter x-ray systems include an x-ray tube, a collimator, and a detector. The x-ray tube generates and emits x-rays. The collimator filters these x-rays to form an x-ray beam using a portion of the x-rays that travel substantially parallel to a specified direction.

When the x-ray beam encounters the object, some or all of the x-rays in the x-ray beam are scattered by the object. In particular, the x-rays may be scattered off of the surface of the object and/or the subsurface of the object. The scattered x-rays are referred to as backscatter. The detector detects some or all of this backscatter. The detected backscatter may be used to generate image data for the object that can be used to form one or more images of the object. For example, the backscatter detected when the x-ray beam is directed at a particular location on the object may be used to generate an intensity value for a pixel in an image that corresponds to that particular location on the object.

The x-ray beam may be moved along the object in a selected pattern such as, for example, a raster pattern, such that image data may be generated for different locations on the object. In one illustrative example, the direction in which the x-ray beam is pointed may be changed such that the angle of incidence of the x-ray beam, with respect to the object, changes. This image data is used to form one or more images of the object that may be used to determine whether any inconsistencies are present in the object.

The detectors used in some currently available backscatter x-ray systems have a substantially planar shape. In other words, these detectors have a flat shape. The number of locations in which a backscatter x-ray system can be used may be

limited when the detector in the backscatter x-ray system has a flat shape. For example, positioning a backscatter x-ray system with a detector having a flat shape relative to an object having a curved shape may be more difficult than desired.

Further, with a detector having a flat shape, the amount of backscatter detected by the detector may be less than desired for different angles of incidence of the x-ray beam with respect to the object when the object has a curved shape. In other words, the amount of backscatter detected by the detector may be less than desired for different angles of incidence of the x-ray beam when the object has a curved shape.

Consequently, images formed using the image data generated by a detector having a flat shape may not have a desired level of quality when used to detect backscatter off of a curved object. Therefore, it would be desirable to have a method and apparatus that takes into account at least some of the issues discussed above, as well as other possible issues.

SUMMARY

In one illustrative embodiment, an apparatus comprises a radiation source, a collimator, and a detector system. The radiation source is configured to emit radiation. The collimator is configured to form a beam using a portion of the radiation emitted by the radiation source. The beam is directed towards a surface of an object. The detector system is configured to detect backscatter formed in response to the beam encountering the object. A shape of the detector system is configured to be changed into a selected shape.

In another illustrative embodiment, a backscatter x-ray system comprises an x-ray tube, a collimator, and a detector system. The x-ray tube is configured to emit x-rays. The collimator is configured to form an x-ray beam using a portion of the x-rays emitted by the x-ray tube. The x-ray beam is directed towards a surface of an object. The detector system comprises a number of sensor arrays and a structure. The number of sensor arrays is configured to detect backscatter formed in response to the x-ray beam encountering the object. A shape of the detector system is configured to be changed into a selected shape using the structure.

In yet another illustrative embodiment, a method for inspecting an object is provided. A selected shape for a detector system in a backscatter inspection system is identified. A shape of the detector system is changed into the selected shape. A beam

is emitted towards a surface of a object. The beam is formed using a portion of radiation emitted from a radiation source. Backscatter formed in response to the beam encountering the object is detected using the detector system having the selected shape.

The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

Figure 1 is an illustration of an inspection environment in the form of a block diagram in accordance with an illustrative embodiment;

Figure 2 is an illustration of an inspection environment in accordance with an illustrative embodiment;

Figure 3 is an illustration of a cross-sectional view of an aircraft being inspected by a backscatter inspection system in accordance with an illustrative embodiment;

Figure 4 is an illustration of a cross-sectional view of an aircraft being inspected by a backscatter inspection system in accordance with an illustrative embodiment;

Figure 5 is an illustration of a detector system in accordance with an illustrative embodiment;

Figure 6 is an illustration of a sensor array in accordance with an illustrative embodiment; and

Figure 7 is an illustration of a process for inspecting an object, in the form of a flowchart, in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

The different illustrative embodiments recognize and take into account that images formed using the image data generated by some currently available backscatter x-ray systems may not have the desired amount of contrast. Without this desired amount of contrast, identifying inconsistencies in an object inspected using these backscatter x-ray systems may be more difficult than desired. In particular, the different illustrative embodiments recognize and take into account that a detector having a substantially planar shape may be unable to detect a desired amount of the backscatter formed when an x-ray beam encounters an object having a substantially non-planar shape.

For example, the angle of incidence of an x-ray beam with respect to an object that has a curved shape may change when the x-ray beam is moved along the object. A detector having a flat shape may be unable to detect a desired amount of backscatter for these different angles of incidence of the x-ray beam with respect to the object. In other words, the detector may miss a portion of the backscatter when the object has a curved shape and the detector has a flat shape.

The different illustrative embodiments also recognize and take into account that the amount of backscatter detected by a detector determines the intensity value for a pixel in an image corresponding to the location at which the x-ray beam encounters the object. The intensity values for the pixels in an image may determine the level of contrast in the image and the level of detail in the image.

The image data generated by a detector having a flat shape may have a lower level of contrast and/or a lower level of detail than desired when the detector misses a portion of the backscatter formed as an x-ray beam moves along an object having a curved shape. Consequently, the different illustrative embodiments recognize and take into account that it may be desirable to have a detector configured to capture a greater portion of the backscatter formed as compared to currently available detectors.

Thus, the different illustrative embodiments provide a method and apparatus for inspecting an object using a backscatter x-ray system. In particular, the different illustrative embodiments provide a backscatter x-ray system with a detector having a shape that may be changed to substantially conform to a shape of a surface of the object being inspected.

With reference now to the figures and, in particular, with reference to **Figure 1**, an illustration of an inspection environment in the form of a block diagram is depicted in accordance with an illustrative embodiment. In these illustrative examples, inspection environment **100** includes backscatter inspection system **102**, computer system **103**, and object **104**.

Backscatter inspection system **102** is one example of nondestructive inspection (NDI) system **106**. As used herein, a “nondestructive inspection system”, such as nondestructive inspection system **106**, is a system configured to inspect an object, such as object **104**, without causing any undesired effects to the object. In particular, a nondestructive inspection system is configured to inspect an object without causing any physical alterations to the object.

In these illustrative examples, backscatter inspection system **102** may be used to inspect object **104**. Object **104** may be selected from any number of different types of objects. For example, without limitation, object **104** may take the form of a mobile platform, a stationary platform, an air-based structure, a land-based structure, an aquatic-based structure, a space-based structure, or some other suitable type of structure. More specifically, object **104** may be a an aircraft, a ship, a tank, a personnel carrier, a spacecraft, a space station, a satellite, a submarine, a vehicle, a manmade structure, a building, or some other suitable type of object.

In some cases, object **104** may be a part in another object. For example, in some cases, object **104** may be a section of a fuselage for an aircraft, a wing, a fuel tank, a structural support on a bridge, a section of a space station, the hull of a ship, a skin panel, a wall, a door, or some other suitable type of part.

Backscatter inspection system **102** generates data **107** for object **104** during inspection of object **104**. Data **107** may include, for example, without limitation, image data **108** for object **104**. Backscatter inspection system **102** sends data **107** to computer system **103**. Computer system **103** is configured to receive and process data **107** generated by backscatter inspection system **102**.

In this illustrative example, backscatter inspection system **102** includes moveable platform **110**, radiation generation system **112**, and detector system **114**. Radiation generation system **112** and/or detector system **114** may be associated with moveable platform **110**.

When one component is “associated” with another component, the association is a physical association in these depicted examples. For example, a first component, such as detector system **114**, may be considered to be associated with a second component, such as moveable platform **110**, by being secured to the second component, bonded to the second component, mounted to the second component, welded to the second component, fastened to the second component, and/or connected to the second component in some other suitable manner.

The first component also may be connected to the second component using a third component. Additionally, the first component may be considered to be associated with the second component by being formed as part of and/or an extension of the second component

Moveable platform **110** may be any platform configured to move over a surface. This movement may include translation and/or rotation. Moveable platform **110** may take various forms depending on the particular implementation. In one illustrative example, moveable platform **110** may be a cart.

Moveable platform **110** may include movement devices such as, for example, without limitation, wheels, rollers, sliders, a track system, and other types of movement devices. These movement devices may allow moveable platform **110** to move or be moved on a surface, such as, for example, without limitation, a floor, a rail system, or some other suitable type of surface.

In one illustrative example, moveable platform **110** may be moved by a human operator pushing moveable platform **110**. In another illustrative example, moveable platform **110** may be moved using a propulsion system in moveable platform **110**.

In these illustrative examples, radiation generation system **112** comprises radiation source **118** and collimator **120**. Radiation source **118** is configured to generate radiation **122**. Radiation **122** comprises a plurality of rays. Radiation **122** may take a number of different forms. In these illustrative examples, radiation **122** may take the form of x-rays, gamma rays, or some other suitable type of radiation configured to at least partially penetrate object **104**.

As one illustrative example, radiation source **118** may take the form of an x-ray tube configured to generate and emit x-rays **124**. X-rays **124** may be directed towards surface **126** of object **104**.

In these illustrative examples, collimator **120** may be associated with at least one of moveable platform **110** and radiation source **118**. Collimator **120** is a device configured to filter the plurality of rays in radiation **122** such that only the portion of rays traveling parallel to a specified direction are allowed to pass through collimator **120**.

In particular, collimator **120** uses a portion of radiation **122** to form beam **134**. Beam **134** may be directed towards surface **126** of object **104**. When radiation **122** takes the form of x-rays **124**, beam **134** is referred to as an x-ray beam.

In one illustrative example, collimator **120** takes the form of rotatable wheel **128**. Rotatable wheel **128** has number of apertures **130**. As used herein, a “number of” items means one or more items. For example, number of apertures means one or more apertures. In this manner, number of apertures **130** may be one aperture in some cases and may be two, three, five, or some other suitable number of apertures in other cases.

Rotatable wheel **128** is configured to rotate around radiation source **118** while radiation source **118** emits radiation **122**. As rotatable wheel **128** rotates, a portion of radiation **122** passes through an aperture in number of apertures **130** to form beam **134**.

Of course, in other illustrative examples, collimator **120** may have guide **132**. Guide **132** is a channel within collimator **120** through which rays may pass. In particular, collimator **120** may absorb a portion of the rays in radiation **122**, scatter a portion of the rays in radiation **122**, or perform a combination of the two such that only rays that travel in the direction of a center axis through guide **132** may pass through collimator **120**.

Detector system **114** is configured to detect backscatter **136** formed in response to beam **134** encountering object **104**. Backscatter **136** may be formed in response to at least a portion of beam **134** being scattered when beam **134** encounters surface **126** of object **104** and/or the subsurface of object **104**. In these illustrative examples, detector system **114** has shape **138**. Shape **138** of detector system **114** is configured to be changed into selected shape **140**.

For example, selected shape **140** may be a surface shape for surface **126** of object **104** being inspected. The surface shape of surface **126** of object **104** may comprise, for example, without limitation, at least one of a convex shape, a concave

shape, a wavy shape, a curved shape, an L-shape, a U-shape, a toroidal shape, or some other suitable type of substantially non-planar shape.

As used herein, the phrase “at least one of”, when used with a list of items, means different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, “at least one of item A, item B, and item C” may include, without limitation, item A or item A and item B. This example also may include item A, item B, and item C, or item B and item C. In other examples, “at least one of” may be, for example, without limitation, two of item A, one of item B, and ten of item C; four of item B and seven of item C; or some other suitable combination.

In these illustrative examples, selected shape **140** for detector system **114** may be identified in a number of different ways. As one illustrative example, selected shape **140** may be identified from a database of known geometries for different types of objects to be inspected. For example, selected shape **140** may be identified using a digital computer aided design (CAD) model of the object **104** stored in a database.

In some illustrative examples, selected shape **140** may be identified using images of object **104** to be inspected. Selected shape **140** may also be identified using sensor data generated while detector system **114** is positioned relative to object **104** being inspected. For example, a number of sensor systems may be used to generate images, ultrasound images, acoustic data, radar images, infrared images, and/or other suitable types of sensor data that can be used to identify selected shape **140**. Of course, selected shape **140** may be identified in other ways not described above.

In one illustrative example, detector system **114** comprises number of sensor arrays **142** and structure **144**. Number of sensor arrays **142** is associated with structure **144** in this illustrative example. Sensor array **146** is an example of one of number of sensor arrays **142**. Sensor array **146** comprises number of sensors **148** arranged in a number of rows and in a number of columns. Sensor **150** is an example of one of number of sensors **148**.

In some illustrative examples, sensor **150** may also be referred to as a detector. In this manner, number of sensors **148** may be a number of detectors, sensor array **146** may be a detector array, and number of sensor arrays **142** may be a number of detector arrays.

In this illustrative example, sensor **150** may comprise scintillator **152** and light detector **154**. Scintillator **152** may comprise a material configured to luminesce when hit by ionizing radiation, such as, for example, the particles of backscatter **136**. This material is referred to as a scintillating material. When scintillator **152** luminesces, photons are emitted from the scintillator **152**.

Light detector **154** is configured to measure the number of photons emitted from scintillator **152**. The number of photons detected by all of the light detectors in number of sensor arrays **142** may determine the value generated by detector system **114** for the particular location on object **104** at which beam **134** was pointed. This value may be an intensity value for a pixel in an image of object **104** corresponding to the location at which beam **134** was pointed. Shape **138** of detector system **114** may be changed such that the number of photons detected by the different light detectors in number of sensor arrays **142** as beam **134** moves along surface **126** of object **104** allows image data having a desired level of detail and a desired level of contrast to be generated.

In this illustrative example, light detector **154** may have a configuration based on micro-electromechanical systems (MEMS) technology. For example, light detector **154** may be selected from one of a photomultiplier tube (PMT), a photoelectric sensor, a photodiode, or some other type of light detector implemented using micro-electromechanical systems technology. In one illustrative example, light detector **154** takes the form of a micro-photomultiplier tube (micro-PMT or μ -PMT).

When sensor **150** includes scintillator **152** and light detector **154**, sensor **150** may take the form of a scintillation detector or a scintillation counter. Of course, in other illustrative examples, sensor **150** may take the form of a solid-state detector, a semiconductor radiation detector, or some other suitable type of detector.

In this illustrative example, shape **138** of detector system **114** may be changed using structure **144**. For example, structure **144** may comprise plurality of segments **156** connected to each other through number of flexible joints **158**. Movement of at least one segment in plurality of segments **156** relative to another segment in plurality of segments **156** about a flexible joint in number of flexible joints **158** changes shape **138** of detector system **114**. When structure **144** has this type of configuration, structure **144** may be referred to as an "articulated structure."

A segment in plurality of segments **156** may be moved relative to another segment in plurality of segments **156** in a number of different ways. For example, these segments may be moved manually. A human operator may use his hands to move one or more of plurality of segments **156** about one or more of number of flexible joints **158**. In some cases, plurality of segments **156** may be moved by an electromechanical system configured to receive commands from a control system.

In another example, structure **144** may take the form of deformable material **160**. Deformation of deformable material **160** changes shape **138** of detector system **114**. Deformable material **160** may comprise, for example, without limitation, an organic material, a silicon-based material, or some other suitable type of material capable of being deformed. Deformable material **160** may be deformed manually in these illustrative examples.

In some illustrative examples, structure **144** may take the form of flexible circuit **162**. Flexible circuit **162** may comprise any number of lines and controls having a configuration that may be changed when power is supplied to these lines and controls. Changing a configuration of flexible circuit **162** changes shape **138** of detector system **114**.

In this manner, shape **138** of detector system **114** may be changed in a number of different ways. Shape **138** of detector system **114** may be reconfigurable using structure **144**. In particular, shape **138** may be changed into selected shape **140** such that shape **138** of detector system **114** substantially conforms to a surface shape for surface **126** of object **104**.

In some illustrative examples, an electromechanical system may be used to reconfigure structure **144** based on input received from a digital model of object **104**. In other illustrative examples, structure **144** may be reconfigured manually to substantially match selected shape **140**. Further, depending on the implementation, structure **144** may be repeatedly reconfigured as moveable platform **110** moves relative to object **104**. Sensor data, such as images or video of object **104**, may be used to change shape **138** of detector system **114** such that shape **138** substantially conforms to a surface shape for surface **126** of object **104** as moveable platform **110** with detector system **114** moves relative to object **104**.

Detector system **114** generates data **107** in response to detecting backscatter **136**. Image data **108** in data **107** may include, for example, an intensity

value for a pixel corresponding to each of a plurality of locations on object **104** at which beam **134** was directed.

Detector system **114** sends data **107** to computer system **103** for processing using communications link **164**. Communications link **164** may be a wireless communications link, a wired communications link, an optical communications link, or some other suitable type of communications link.

Computer system **103** may include one or more computers, depending on the implementation. When more than one computer is present in computer system **103**, these computers may be in communication with each other using a medium such as a network. The network may employ wired communications links, wireless communications links, and other suitable types of links for exchanging information.

Data **107** may be used to determine whether inconsistency **166** is present in object **104**. Inconsistency **166** may be present at surface **126** of object **104** or within an interior of object **104**. In one illustrative example, computer system **103** uses data **107** to form number of images **168** of object **104**. Number of images **168** may be analyzed by computer system **103** and/or a human operator to detect the presence of, and identify the location of, inconsistency **166** in object **104**. Of course, in other illustrative examples, image data **108** in data **107** generated by detector system **114** may take the form of number of images **168**.

Depending on the implementation, computer system **103** may be configured to control at least one of radiation generation system **112**, moveable platform **110**, and detector system **114**. For example, computer system **103** may send commands to moveable platform **110** and/or collimator **120** to control the steering of beam **134**. In some cases, computer system **103** may send commands to detector system **114** to control shape **138** of detector system **114**. For example, computer system **103** may send commands to flexible circuit **162** to change shape **138** of detector system **114**.

With the different configurations for detector system **114** described in **Figure 1**, less radiation **122** may need to be emitted from radiation source **118**. Further, the size of radiation source **118** as well as the overall size of backscatter inspection system **102** may be reduced with detector system **114** having shape **138** that is reconfigurable. Additionally, using micro-electromechanical systems technology may

allow number of sensor arrays **142** to be manufactured in a cost-effective and efficient manner.

The illustration of inspection environment **100** in **Figure 1** is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

In some illustrative examples, the different sensors in number of sensor arrays **142** may not include scintillators. Instead, a single piece of scintillating material may be placed over each sensor array in number of sensor arrays **142**. In some cases, a single piece of scintillating material may be placed over all of the sensor arrays in number of sensor arrays **142**.

With reference now to **Figure 2**, an illustration of an inspection environment is depicted in accordance with an illustrative embodiment. In **Figure 2**, inspection environment **200** is an example of one implementation for inspection environment **100** in **Figure 1**. Backscatter inspection system **202** is configured to perform an inspection of aircraft **204** in inspection environment **200**.

Backscatter inspection system **202** is an example of one implementation for backscatter inspection system **102** in **Figure 1**. In this illustrative example, backscatter inspection system **202** is a backscatter x-ray system. Further, aircraft **204** is an example of one implementation for object **104** in **Figure 1**.

As depicted, backscatter inspection system **202** includes moveable platform **206**, radiation generation system **208**, detector system **210**, and computer system **212**. Moveable platform **206**, radiation generation system **208**, detector system **210**, and computer system **212** are examples of implementations for moveable platform **110**, radiation generation system **112**, detector system **114**, and computer system **103**, respectively, in **Figure 1**.

In this illustrative example, radiation generation system **208** and detector system **210** are connected to moveable platform **206**. Computer system **212** is located away from moveable platform **206**.

Radiation generation system **208** is configured to generate x-rays and direct a portion of these x-rays towards fuselage **214** of aircraft **204** in the form of an x-ray beam. In particular, radiation generation system **208** directs the x-ray beam towards surface **216** of fuselage **214** of aircraft **204**. Surface **216** is an exterior surface of fuselage **214**. Additionally, radiation generation system **208** may move the x-ray beam along surface **216** of fuselage **214** such that the angle of incidence of the x-ray beam with respect to surface **216** of fuselage **214** changes.

The x-ray beam may at least partially penetrate surface **216** of fuselage **214** of aircraft **204**. Detector system **210** is configured to detect backscatter formed in response to the x-ray beam encountering fuselage **214**. Detector system **210** may generate image data that is sent to computer system **212** over wireless communications link **218**. Detector system **210** is described in greater detail in **Figures 3-4**.

Turning now to **Figure 3**, an illustration of a cross-sectional view of an aircraft being inspected by a backscatter inspection system is depicted in accordance with an illustrative embodiment. In this illustrative example, a cross-sectional view of aircraft **204** from **Figure 2**, taken along lines **3-3**, is depicted along with backscatter inspection system **202**. Moveable platform **206** of backscatter inspection system **202** is not shown in this view such that radiation generation system **208** may be more clearly seen.

In this illustrative example, radiation generation system **208** includes radiation source **300**, housing **301**, rotatable wheel **302**, and motor **304**. Radiation source **300** is an example of one implementation for radiation source **118** in **Figure 1**. As depicted, radiation source **300** is located within housing **301**. Housing **301** may be connected to moveable platform **206** in **Figure 2**. Radiation source **300** is configured to generate and emit x-rays **306**.

Rotatable wheel **302** is associated with radiation source **300**. Rotatable wheel **302** is an example of one implementation for rotatable wheel **128** in **Figure 1**. Rotatable wheel **302** has number of apertures **308**. Operation of motor **304** is configured to rotate rotatable wheel **302** such that number of apertures **308** rotate around radiation source **300**.

As rotatable wheel **302** rotates, a portion of x-rays **306** is configured to pass through an aperture in number of apertures **308** to form x-ray beam **310**. X-ray beam **310** is directed towards surface **216** of fuselage **214**. The x-rays in x-ray beam

310 scatter in response to encountering fuselage **214**. These scattered x-rays form backscatter **312**.

Detector system **210** detects backscatter **312**. As depicted, detector system **210** has shape **314**. Shape **314** is reconfigurable. In other words, shape **314** of detector system **210** may be changed.

In this illustrative example, shape **314** is configured to substantially conform to surface shape **316** of surface **216** of fuselage **214**. In particular, shape **314** is a convex shape with respect to radiation generation system **208** that is similar to surface shape **316** of surface **216** of fuselage **214**, which is also a convex shape with respect to radiation generation system **208**.

In this illustrative example, detector system **210** includes number of sensor arrays **318** and structure **320**. As depicted, number of sensor arrays **318** includes sensor arrays **322**, **324**, **326**, **328**, and **330**. These sensor arrays are associated with structure **320**. The shape of structure **320** is shape **314** of detector system **210**. In this manner, both detector system **210** and structure **320** have shape **314**.

Structure **320** comprises plurality of segments **332**. Plurality of segments **332** includes segments **334**, **336**, **338**, **340**, and **342**. Sensor arrays **322**, **324**, **326**, **328**, and **330** are associated with segments **334**, **336**, **338**, **340**, and **342**, respectively. Segments **334**, **336**, **338**, **340**, and **342** may be connected to each other by flexible joints. For example, segment **334** may be configured to move relative to segment **336** about a flexible joint connecting segment **334** and segment **336**. When segment **334** moves relative to segment **336**, sensor array **322** also moves relative to sensor array **324**.

One or more segments in plurality of segments **332** may be moved relative to each other such that structure **320** may have shape **314** that substantially conforms to surface shape **316** of surface **216** of fuselage **214**. For example, structure **320** may be bent at one or more of the flexible joints connecting plurality of segments **332** such that shape **314** of structure **320** changes to substantially conform to surface shape **316** of surface **216** of fuselage **214**.

Turning now to **Figure 4**, an illustration of a cross-sectional view of an aircraft being inspected by a backscatter inspection system is depicted in accordance with an illustrative embodiment. In this illustrative example, the cross-sectional view of

aircraft **204** from **Figure 3** is depicted with backscatter inspection system **202** moved into interior **400** of fuselage **214**.

In this illustrative example, radiation generation system **208** is configured to direct x-ray beam **310** towards surface **402** of fuselage **214**. Surface **402** is an interior surface of fuselage **214**. Backscatter **404** is formed in response to x-ray beam **310** encountering fuselage **214**.

As depicted, shape **314** of detector system **210** has been changed such that shape **314** substantially conforms to surface shape **406** of surface **402** of fuselage **214**. In particular, surface shape **406** of surface **402** has a concave shape with respect to radiation generation system **208**. Structure **320** of detector system **210** has been bent at one or more flexible joints between plurality of segments **332** such that shape **314** of structure **320** has a concave shape with respect to radiation generation system **208** that is similar to the concave shape of surface **402** of fuselage **214**.

In this manner, when shape **314** of detector system **210** substantially conforms to surface shape **406** of surface **402** of fuselage **214**, detector system **210** and radiation generation system **208** in backscatter inspection system **202** may be moved closer to surface **402**. The amount of backscatter **404** detected by detector system **210** increases as detector system **210** moves closer to surface **402**.

With reference now to **Figure 5**, an illustration of a detector system is depicted in accordance with an illustrative embodiment. In this illustrative example, detector system **500** is an example of one implementation for detector system **114** in **Figure 1**. As depicted, detector system **500** includes number of sensor arrays **502** associated with structure **504**. Structure **504** takes the form of a deformable material in this example. Structure **504** is configured to be deformed such that structure **504** may have a desired shape. In this depicted example, structure **504** has wavy shape **506**.

Turning now to **Figure 6**, an illustration of a sensor array is depicted in accordance with an illustrative embodiment. In this illustrative example, sensor array **600** is an example of one sensor array in number of sensor arrays **502** in **Figure 5**. As depicted, sensor array **600** comprises number of sensors **602** arranged in two columns and three rows. Number of sensors **602** includes sensors **604**, **606**, **608**, **610**, **612**, and **614**.

Each sensor in number of sensors **602** includes a scintillator and a light detector. For example, sensor **604** includes scintillator **616** and light detector **618**. In

this illustrative example, light detector **618** is a micro-photomultiplier tube. Of course, in other illustrative examples, light detector **618** may be some other suitable type of light detector.

With reference now to **Figure 7**, an illustration of process for inspecting an object, in the form of a flowchart, is depicted in accordance with an illustrative embodiment. The process illustrated in **Figure 7** may be used to inspect an object, such as object **104** in **Figure 1**. This process may be implemented using, for example, without limitation, backscatter inspection system **102** in **Figure 1**.

The process begins by identifying a selected shape for a detector system in a backscatter inspection system (operation **700**). In operation **700**, the detector system may be detector system **114** in **Figure 1**. The process then changes a shape of the detector system into the selected shape (operation **702**). In operation **702**, the shape of the detector system may be changed in a number of different ways using a structure in the detector system. The structure may be, for example, structure **144** in **Figure 1**.

When the structure is a plurality of segments connected to each other by a number of flexible joints, operation **702** may be performed by moving at least one of the segments in the plurality of segments relative to another segment in the plurality of segments about a flexible joint in the number of flexible joints. When the structure is a deformable material, operation **702** may be performed by deforming the deformable material.

Further, when the structure is a flexible circuit, operation **702** may be performed by sending commands to the flexible circuit to cause a configuration of the flexible circuit to change. Changing the configuration of the flexible circuit may change the shape of the detector system.

Thereafter, the process emits a beam towards a surface of an object (operation **704**). The beam is formed using a portion of radiation emitted from a radiation source in the backscatter inspection system. Next, the process detects backscatter formed in response to the beam encountering the object using the detector system having the selected shape (operation **706**). The backscatter may be formed in response to at least a portion of the beam being scattered when the beam encounters the surface of the object and/or the subsurface of the object.

The process generates image data in response to detecting the backscatter (operation **708**). The process then forms an image of the object using the image data (operation **710**). The process then determines whether an inconsistency is present in the object using the image of the object (operation **712**), with the process terminating thereafter.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatus and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, function, and/or a portion of an operation or step. For example, one or more of the blocks may be implemented as program code, in hardware, or a combination of the program code and hardware. When implemented in hardware, the hardware may, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

Thus, the different illustrative embodiments provide a method and apparatus for inspecting an object. In one illustrative embodiment, an apparatus comprises a radiation source, a collimator, and a detector system. The radiation source is configured to emit radiation. The collimator is configured to form a beam using a portion of the radiation emitted by the radiation source. The beam is directed towards a surface of an object. The detector system is configured to detect backscatter formed in response to the beam encountering the object. A shape of the detector system is configured to be changed into a selected shape.

The different illustrative embodiments provide a detector system that allows a smaller radiation source to be used in a backscatter inspection system. Further, with a detector system that has a shape that is reconfigurable, the size of the overall backscatter inspection system may be reduced. Still further, using light detectors based on micro-electromechanical systems technology in a detector system

may reduce the cost of the detector system as compared to currently available detector systems.

The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art.

Further, different illustrative embodiments may provide different features as compared to other desirable embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS:

What is claimed is:

1. An apparatus comprising:
 - a radiation source (118) configured to emit radiation (122);
 - a collimator (120) configured to form a beam (134) using a portion of the radiation (122) emitted by the radiation source (118), wherein the beam (134) is directed towards a surface (126) of an object (104); and
 - a detector system (114) configured to detect backscatter (136) formed in response to the beam (134) encountering the object (104) in which a shape (138) of the detector system (114) is configured to be changed into a selected shape (140).
2. The apparatus of claim 1, wherein the detector system (114) comprises:
 - a structure (144), wherein the shape (138) of the detector system (114) is configured to be changed into the selected shape (140) using the structure (144); and
 - a number of sensor arrays (142) associated with the structure (144), wherein the number of sensor arrays (142) is configured to detect the backscatter (136) formed in response to the beam (134) encountering the object (104).
3. The apparatus of claim 2, wherein the structure (144) comprises:
 - a plurality of segments (156) connected to each other by a number of flexible joints (158), wherein movement of at least one segment in the plurality of segments (156) relative to another segment in the plurality of segments (156) about a flexible joint in the number of flexible joints (158) changes the shape (138) of the detector system (114).
4. The apparatus of claim 2, wherein the structure (144) comprises:
 - a deformable material (160), wherein deformation of the deformable material (160) changes the shape (138) of the detector system (114).
5. The apparatus of claim 2, wherein the structure (144) comprises:

a flexible circuit (162), wherein changing a configuration of the flexible circuit (162) changes the shape (138) of the detector system (114).

6. The apparatus of claim 2, wherein a sensor array (146) in the number of sensor arrays (142) comprises:

a number of sensors (148) arranged in a number of rows and a number of columns.

7. The apparatus of claim 6, wherein a sensor (150) in the number of sensors (148) comprises:

a scintillator (152); and

a light detector (154).

8. The apparatus of claim 7, wherein the light detector (154) has a configuration based on micro-electromechanical systems technology.

9. The apparatus of claim 6, wherein a sensor (150) in the number of sensors (148) is selected from one of a scintillation detector, a scintillation counter, a solid-state detector, and a semiconductor radiation detector.

10. The apparatus of claim 1, wherein the selected shape (140) is a surface shape for the surface (126) of the object (104) in which the surface shape comprises at least one of a convex shape, a concave shape, a wavy shape, a curved shape, an L-shape, a U-shape, and a toroidal shape.

11. The apparatus of claim 1, wherein the radiation source (118) and the collimator (120) form a radiation generation system (112) and further comprising:

a moveable platform (110), wherein at least one of the radiation generation system (112) and the detector system (114) are associated with the moveable platform (110); and

a housing (301) connected to the moveable platform (110), wherein the radiation source (118) is located inside the housing (301).

12. The apparatus of claim 1, wherein the collimator (120) comprises:
a rotatable wheel (128) having a number of apertures (130), wherein the rotatable wheel (128) is configured to rotate while the radiation source (118) emits the radiation (122) in which the portion of the radiation (122) emitted by the radiation source (118) passes through an aperture in the number of apertures (130) to form the beam (134).
13. The apparatus of claim 1, wherein the radiation source (118) is an x-ray tube, the radiation (122) comprises x-rays (124), and the beam (134) is an x-ray beam.
14. A backscatter x-ray system comprising:
an x-ray tube configured to emit x-rays (124);
a collimator (120) configured to form an x-ray beam using a portion of the x-rays (124) emitted by the x-ray tube, wherein the x-ray beam is directed towards a surface (126) of an object (104); and
a detector system (114) comprising:
a number of sensor arrays (142) configured to detect backscatter (136) formed in response to the x-ray beam encountering the object (104); and
a structure (144), wherein a shape (138) of the detector system (114) is configured to be changed into a selected shape (140) using the structure (144).
15. The backscatter x-ray system of claim 14, wherein the structure (144) is an articulated structure comprising:
a plurality of segments (156) connected to each other by a number of flexible joints (158), wherein movement of at least one segment in the plurality of segments (156) relative to another segment in the plurality of segments (156) about a flexible joint in the number of flexible joints (158) changes the shape (138) of the detector system (114).
16. The backscatter x-ray system of claim 14, wherein a sensor array (146) in the number of sensor arrays (142) comprises:
a number of sensors (148), wherein a sensor (150) in the number of sensors (148) comprises:

a scintillator (152); and
a light detector (154).

17. The backscatter x-ray system of claim 16, wherein the light detector (154) has a configuration based on micro-electromechanical systems technology.

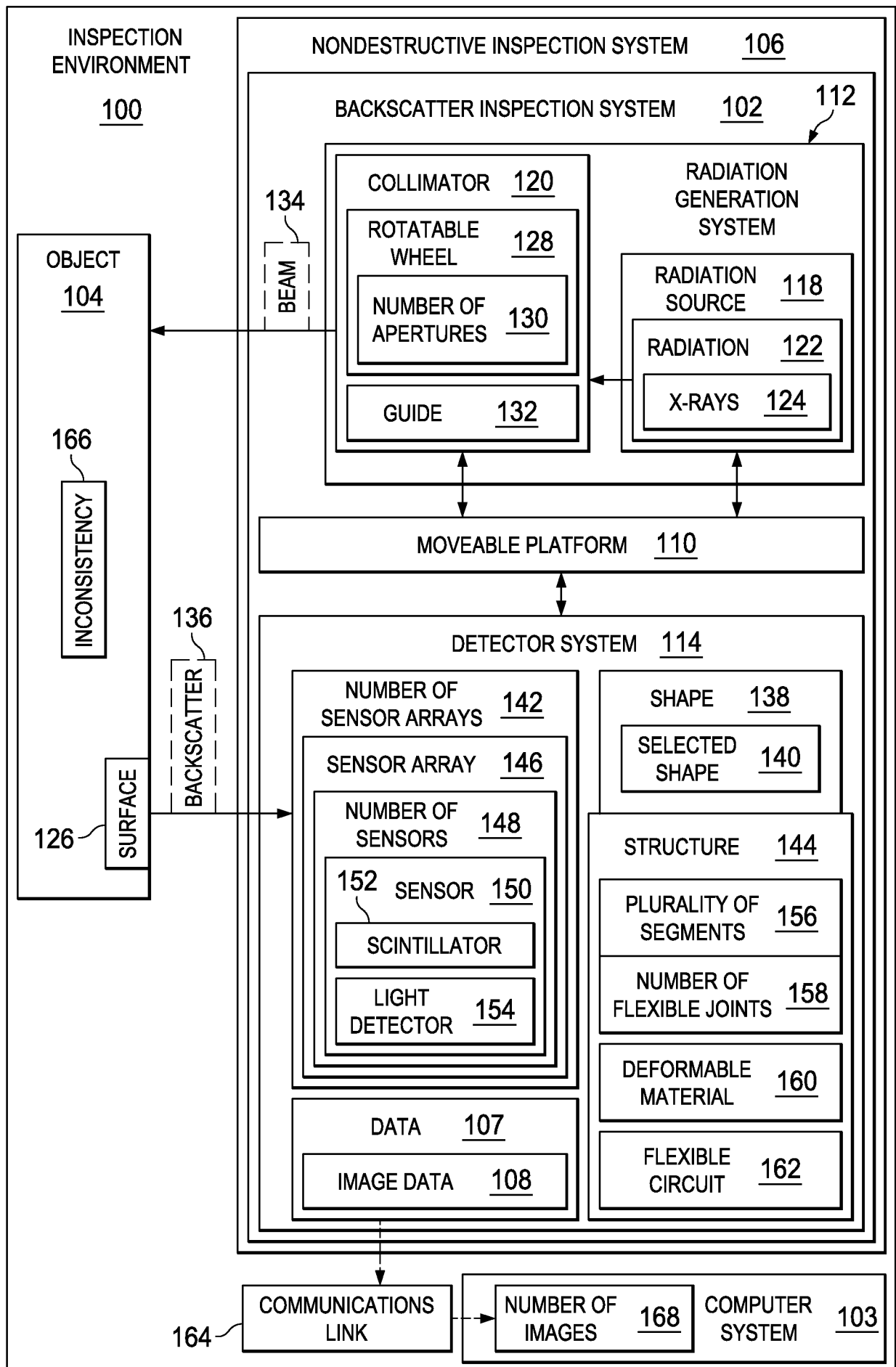
18. A method for inspecting an object (104), the method comprising:
identifying a selected shape (140) for a detector system (114) in a backscatter inspection system (102);
changing a shape (138) of the detector system (114) into the selected shape (140);
emitting a beam (134) towards a surface (126) of the object (104), wherein the beam (134) is formed using a portion of radiation (122) emitted from a radiation source (118); and
detecting backscatter (136) formed in response to the beam (134) encountering the object (104) using the detector system (114) having the selected shape (140).

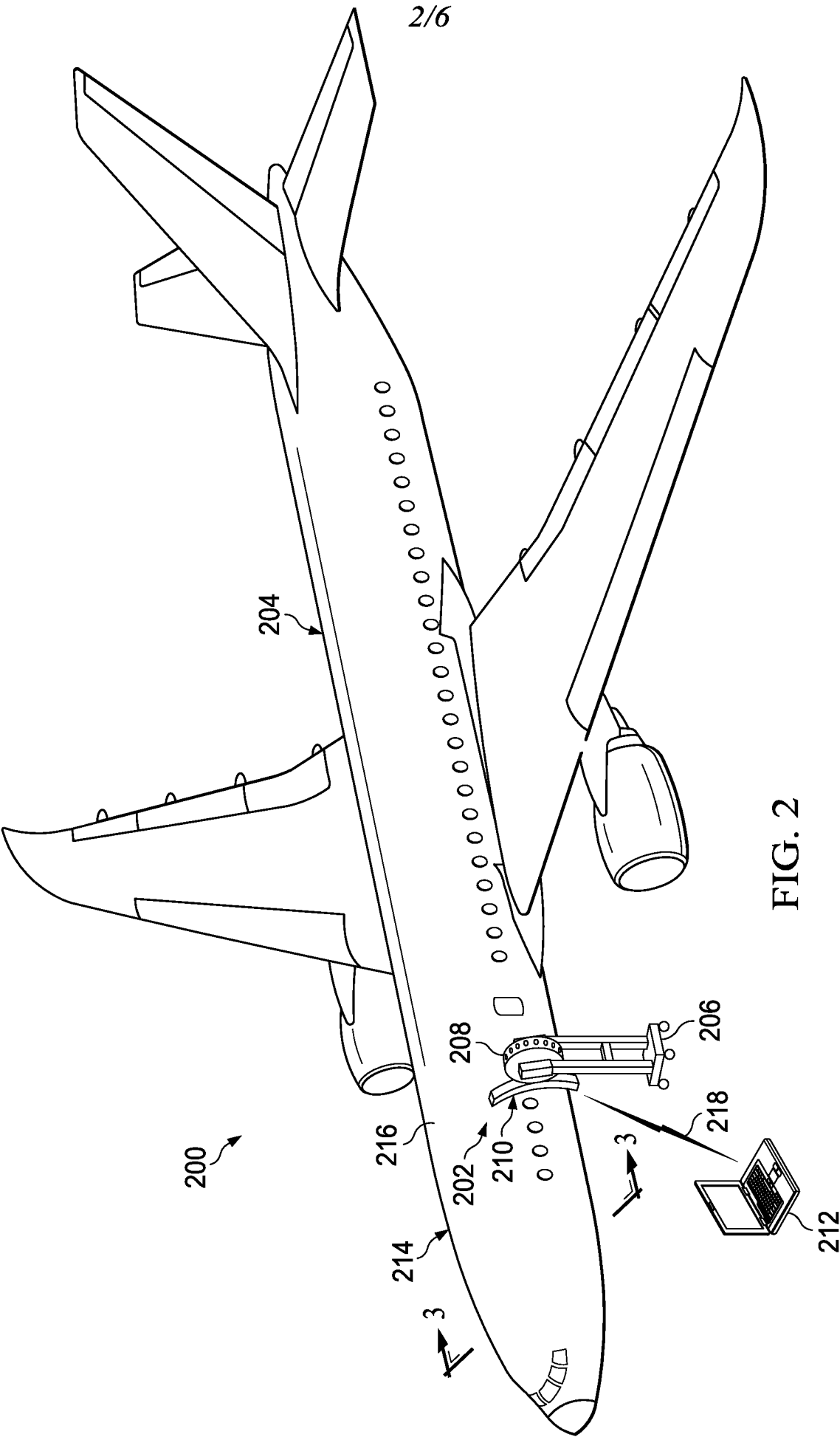
19. The method claim 18, wherein the step of changing the shape (138) of the detector system (114) into the selected shape (140) comprises:
changing the shape (138) of the detector system (114) into the selected shape (140) using a structure (144) in the detector system (114), wherein a number of sensor arrays (142) in the detector system (114) configured to detect the backscatter (136) are associated with the structure (144).

20. The method of claim 18 further comprising:
generating image data (108) in response to detecting the backscatter (136);
forming an image of the object (104) using the image data (108); and
determining whether an inconsistency (166) is present in the object (104) using the image of the object (104).

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FIG. 1





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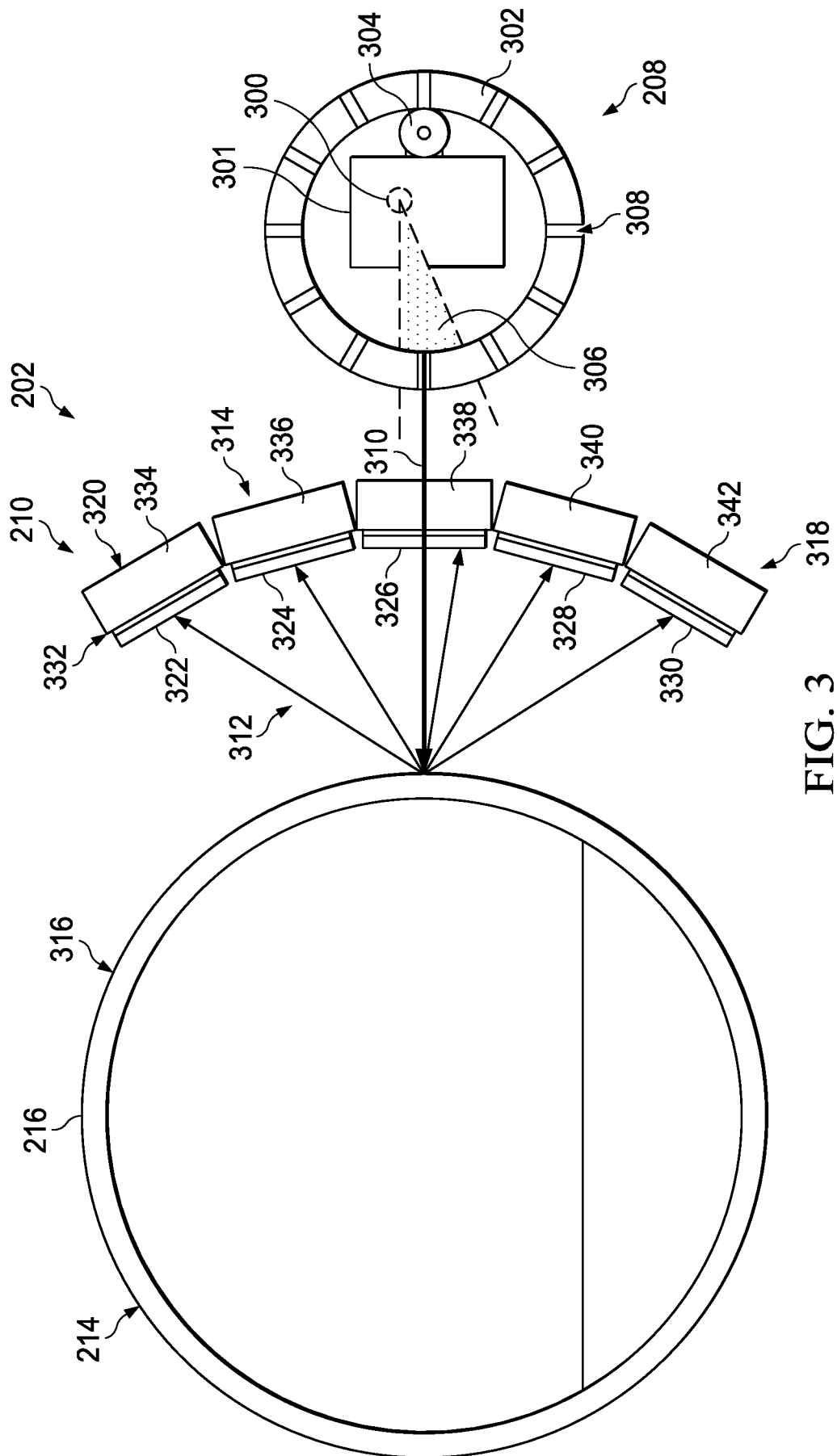
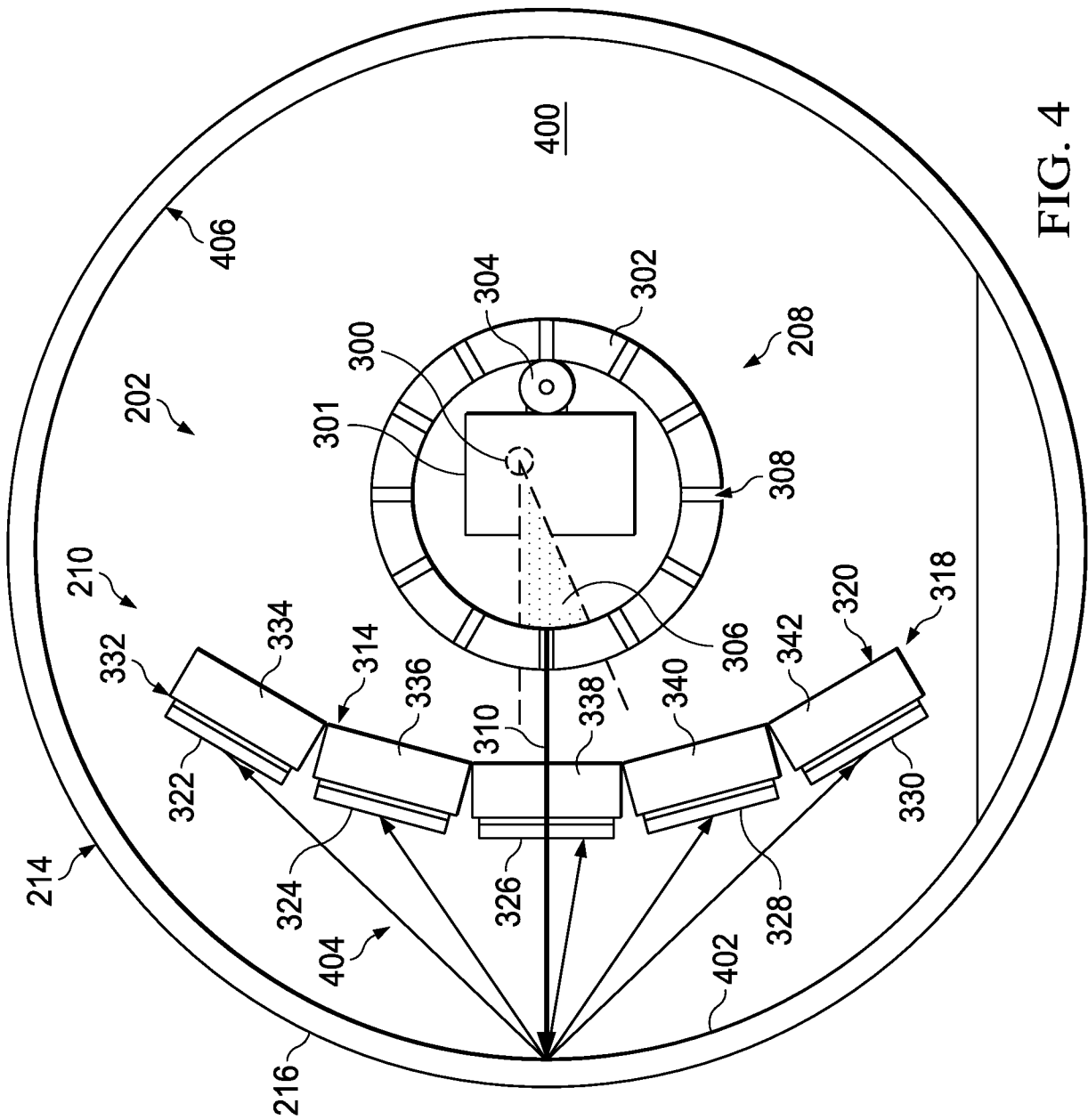


FIG. 3



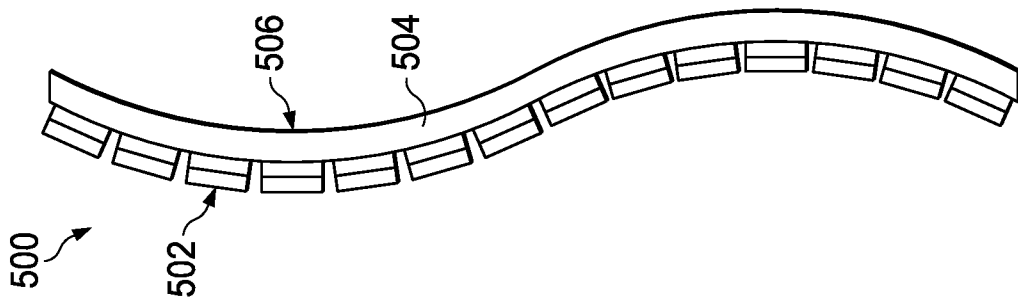


FIG. 5

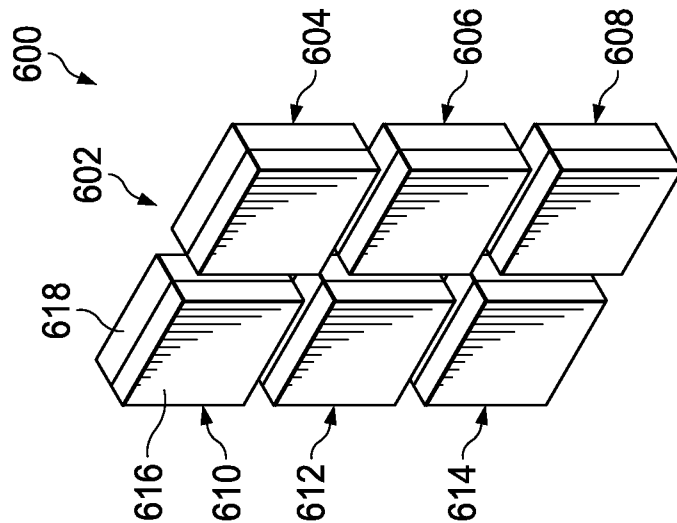


FIG. 6

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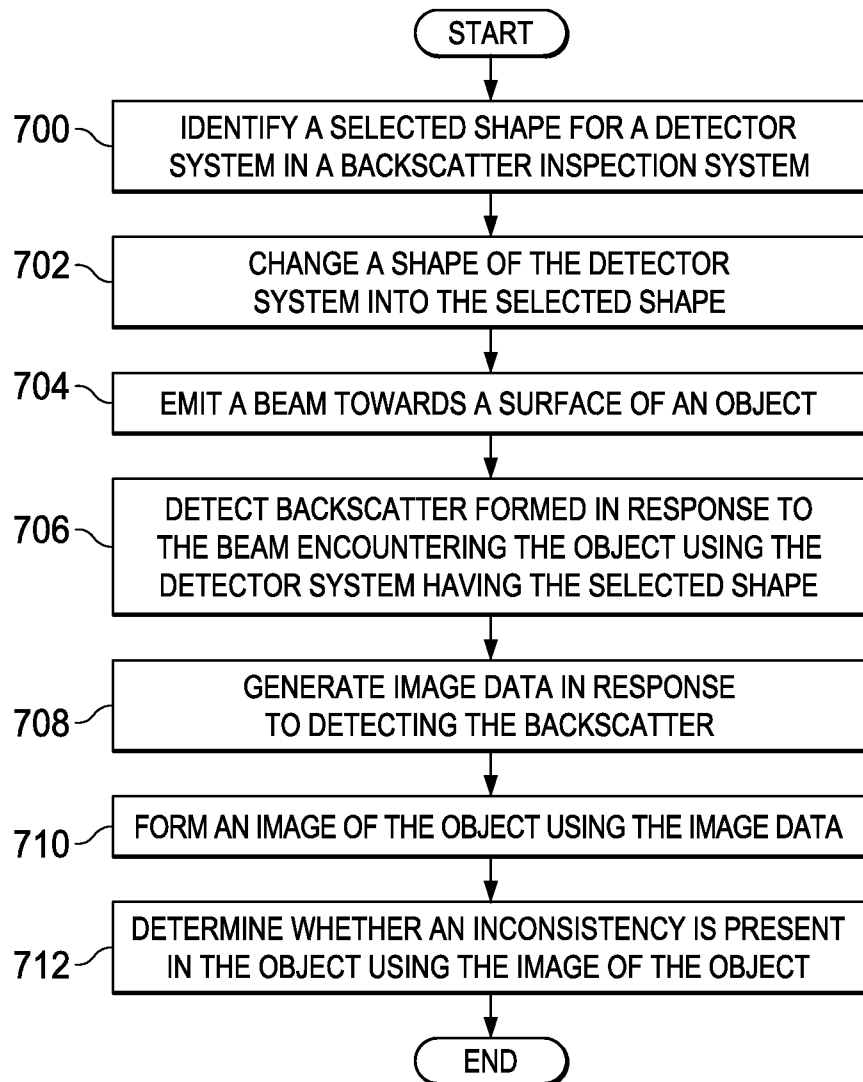


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/027173

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01N23/20 G01N23/203
ADD.

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)

G01N G01T

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/033791 A1 (MASTRONARDI RICHARD [US]) 9 February 2012 (2012-02-09)	1-3,6-20
A	the whole document	4,5
X	US 7 130 374 B1 (JACOBS ALAN M [US] ET AL) 31 October 2006 (2006-10-31)	1,2, 4-11,13, 14,16-19
	column 6, line 50 - column 10, line 41; figure 4	
A	US 2006/162456 A1 (KENNEDY JAMES C [US] ET AL) 27 July 2006 (2006-07-27) paragraphs [0011] - [0013], [0069] - [0073]; figures 13-17	1-20
A	US 7 567 649 B1 (SAFAI MORTEZA [US] ET AL) 28 July 2009 (2009-07-28) abstract; figure 8	1-20
	-/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

2 May 2013

Date of mailing of the international search report

08/05/2013

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/027173

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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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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