

31

PATENT SPECIFICATION

(11) 1 539 685

1 539 685

- (21) Application No. 39968/77 (22) Filed 26 Sept. 1977
(31) Convention Application No. 726 556
(32) Filed 27 Sept. 1976 in
(33) United States of America (US)
(44) Complete Specification published 31 Jan. 1979
(51) INT CL² G01N 23/06
(52) Index at acceptance

H4F D18K D18X D27K D56X D61 D83B L



(54) TOMOGRAPHY SCANNING

(71) We, AMERICAN SCIENCE AND ENGINEERING, INC., of 955 Massachusetts Avenue, Cambridge, Massachusetts 02139, United States of America, a Corporation organised under the laws of the State of Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates in general to radiant energy imaging and more particularly concerns novel apparatus and techniques for obtaining cross sectional images of patients for diagnostic purposes. The invention is characterized by high resolution and speed and a number of other features which make it advantageous for use in computerized tomography.

Various techniques and measurement geometries may be used for high speed computerized tomography. One technique utilizes an X-ray source and a detector array, in fixed relationship, translated past the patient. A fan beam, impinging a detector array, produces a fan of measurements at varying angles at any given moment. During the translation, each detector records a set of parallel measurements at one of these angles. To acquire measurements at a new group of angles, the source-detector structure is rotated and then translated again. The advantages of this two-motion technique are: (1) high sampling resolution because each detector may be sampled many times as it scans across a patient, (2) no gain matching requirement because each detector scans across the entire patient, and (3) the feasibility of frequent calibration before and after each scan. The disadvantages are: (1) slowness due to the mechanical limitations of the two-motion technique and (2) the small fan beam angle, needed to enable faster translation, which wastes useful X-rays.

A different scanning technique again uses

a fan beam source and a detector array in fixed relationship, but the structure is rotated about the patient with no translating motion. Each detector records X-ray measurements tangent to a fixed circle. This one-motion technique has the advantages of (1) high scanning speeds because only one mechanical motion is required and (2) the feasibility of using a large fan angle. However, its disadvantages include (1) low sampling resolution due to the many tiny, closely spaced detectors required for fine sampling, (2) gain matching requirements because each detector does not scan across the entire patient, and (3) the impossibility of frequent calibration because calibration can only be achieved after removal of the patient as each detector does not scan across the entire patient.

It is an important object of this invention to provide an improved computerized tomography system.

It is another object of the invention to achieve the preceding object with a system that achieves high sampling resolution.

It is a further object of the invention to achieve one or more of the preceding objects with a system that does not require close matching in gain between detectors.

It is still a further object of the invention to achieve one or more of the preceding objects with a system that allows frequent calibration of detectors.

It is still a further object of the invention to achieve one or more of the preceding objects with a system that achieves high-speed scanning.

It is still a further object of the invention to achieve one or more of the preceding objects with a system that can utilize an X-ray fan beam of a large angle.

According to the invention, there is a source of penetrating radiant energy, such as gamma or X-ray, which revolves concentrically within or without a stationary circular array of detectors. The source emits a fan beam which passes through the patient circle centered at the axis of rotation and

32

illuminates a number of detectors simultaneously to provide a corresponding plurality of detected signals each representative of the radiant energy transmissivity between the source and a respective detector. Signal processing means combine the detected signals to provide a cross sectional image representative of the radiant energy transmissivity of the scanned region.

Numerous other features, objects and advantages of the invention will become apparent from the following specification when read in connection with the accompanying drawing in which:

FIG. 1 is a combined block-diagrammatic representation of rotating X-ray source and stationary detector array configuration according to the invention; and

FIG. 2 is a graphical representation of the geometry of the X-ray measurements recorded by one detector during one revolution of the X-ray source.

With reference now to the drawing and more particularly FIG. 1 thereof, there is shown a combined block-diagrammatic representation of a rotating X-ray source and stationary detector array configuration according to the invention. X-ray source 11 rotates about axis 12 and emits a fan beam 13 of X-rays through an angle sufficiently wide to illuminate patient circle 14 centered on axis 12. As X-ray source 11 revolves, fan beam 13 illuminates a concentric, stationary, circular array 15 of scintillation detectors 16. At a given moment, beam 13 illuminates a contiguous group of individual detectors 16 simultaneously to provide a corresponding number of detected electrical signals each representative of the X-ray transmissivity between source 11 and a respective one of detectors 16. Signal processing means 17 is connected to detectors 16 for combining the detected output signals to provide an image signal representative of the X-ray transmissivity of a cross section of the patient within patient circle 14 just scanned. Imaging means 21 is responsive to the image signal for providing a visual image of the scanned cross section. The scanning system and patient may be relatively displaced axially to produce a sequence of images of corresponding axially displaced cross sections.

Referring now to FIG. 2, there is shown a graphical representation of the geometry showing the sequence of radiation directions 22 between source 11 and one detector 16' during one revolution of X-ray source 11. Detector 16' is illuminated by fan beam 13 during a portion of a revolution of X-ray source 11. As X-ray source 11 moves through that portion of its revolution, detector 16' receives radiation primarily

along a sequence of directions 22 as source 11 moves along an arc that subtends an angle embracing the entirety of patient circle 14. A similar sequence occurs for each of detectors 16 during one complete revolution of X-ray source 11. Signal processing means 17 combines the signals from all detectors 16 to provide a high-quality cross sectional image signal or transverse axial tomogram according to well-known techniques using digital computer processing. Imaging means 21 displays a visual image of the tomogram.

The invention is characterized by a number of features that enable it to produce high-quality computerized tomograms without the disadvantages of other systems. The invention achieves high sampling resolution because each detector 16 may be sampled many times as source 11 revolves around the patient. Close gain matching is not required because each detector 16 collects data across the entire patient. A mismatch in gain will cause only a small DC offset in the final reconstructed image.

Another advantageous feature is that calibration of detectors 16 may be accomplished during each scan, so that removal of the patient is not necessary for each calibration and frequent calibration is possible.

Further desirable features include high-speed data collection, due to the single mechanical motion (rotation of source 11), and the feasibility of using a large angle for fan beam 13, which reduces waste of useful X-rays and allows more efficient data collection. The high speed of the data collection is desirable to eliminate the effects of the patient's breathing motion and other body motions.

In an exemplary embodiment of the invention actually constructed and successfully operated to produce a high resolution tomogram there were 600 individual detectors in the array illuminated by an X-ray fan beam spanning an angle of substantially 50 degrees about the axis of rotation and about 2-10 mm. along its axis. An X-ray source of energy up to 150 kv at 100 ma. capable of completing a rotational scan in 5, 10 or 20 seconds is used. A Data General type Eclipse computer combined the 600 detected output signals converted into digital form by digital-to-analog converters using the techniques described in the State University of New York at Buffalo Computer Sciences Dept. Technical Report No. 92 dated January 1975 entitled "Reconstruction from Divergent Ray Data" by A. V. Lakshminarayanan.

While rotating the source with patient and circular array of detectors remaining stationary is the preferred form of the invention, it is within the principles of the

invention to allow the X-ray source to remain stationary, and rotate the object being examined and the stationary detectors together.

5 There has been described a novel radiant energy imaging system characterized by high resolution, high-speed data collection, and other features desirable in a computerized tomography system. It is evident
10 that those skilled in the art may now make numerous uses and modifications of and departures from the specific embodiments described herein without departing from the inventive concepts. Consequently, the invention
15 is to be construed as embracing each and every novel feature and novel combination of features present in or possessed by the apparatus and techniques therein disclosed and limited solely by the
20 spirit and scope of the appended claims.

WHAT WE CLAIM IS:—

1. Radiant energy imaging apparatus comprising, a source of a fan beam of penetrating radiant energy, an array of
25 contiguous radiant energy detecting means located about an axis of rotation for converting incident non-conforming radiant energy into a corresponding detected signal, and means for angularly relatively
30 displacing said source and said array about said axis to sequentially illuminate different groups of said detecting means to provide a sequence of detected signals representative of the radiant energy response of the region

between the path traveled by said source and said array. 35

2. Radiant energy imaging apparatus in accordance with claim 1 and further comprising.

means for combining all said detected signals to provide an image signal, 40

and means responsive to said image signal for producing an image representative of said radiant energy response.

3. Radiant energy imaging apparatus in accordance with claim 1 wherein said array encloses said axis of rotation and said source is located inside of said array and spaced from said axis. 45

4. Radiant energy imaging apparatus in accordance with claim 3 wherein said array is circular with its center on said axis and the path of relative displacement between said source and said array is a circle inside of and concentric with said array. 50

5. Radiant energy imaging apparatus in accordance with claim 4 wherein said array is stationary and said source rotates about said axis. 55

6. Radiant energy imaging apparatus according to claim 1, substantially as hereinbefore described and with reference to the accompanying drawings. 60

VENNER, SHIPLEY & CO.,
Chartered Patent Agents,
Rugby Chambers,
2, Rugby Street,
London, WC1N 3QU.,
Agents for the Applicants.



22

1,539,685

3

invention to allow the X-ray source to remain stationary, and rotate the object being examined and the stationary detectors together.

There has been described a novel radiant energy imaging system characterized by high resolution, high-speed data collection, and other features desirable in a computerized tomography system. It is evident that those skilled in the art may now make numerous uses and modifications of and departures from the specific embodiments described herein without departing from the inventive concepts. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features present in or possessed by the apparatus and techniques therein disclosed and limited solely by the spirit and scope of the appended claims.

WHAT WE CLAIM IS:—

1. Radiant energy imaging apparatus comprising, a source of a fan beam of penetrating radiant energy, an array of contiguous radiant energy detecting means located about an axis of rotation for converting incident non-conforming radiant energy into a corresponding detected signal, and means for angularly relatively displacing said source and said array about said axis to sequentially illuminate different groups of said detecting means to provide a sequence of detected signals representative of the radiant energy response of the region

between the path traveled by said source and said array.

2. Radiant energy imaging apparatus in accordance with claim 1 and further comprising,

means for combining all said detected signals to provide an image signal,

and means responsive to said image signal for producing an image representative of said radiant energy response.

3. Radiant energy imaging apparatus in accordance with claim 1 wherein said array encloses said axis of rotation and said source is located inside of said array and spaced from said axis.

4. Radiant energy imaging apparatus in accordance with claim 3 wherein said array is circular with its center on said axis and the path of relative displacement between said source and said array is a circle inside of and concentric with said array.

5. Radiant energy imaging apparatus in accordance with claim 4 wherein said array is stationary and said source rotates about said axis.

6. Radiant energy imaging apparatus according to claim 1, substantially as hereinbefore described and with reference to the accompanying drawings.

VENNER, SHIPLEY & CO.,
Chartered Patent Agents,
Rugby Chambers,
2, Rugby Street,
London, WC1N 3QU.,
Agents for the Applicants.