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(54) IMPROVEMENTS IN OR RELATING TO RADIOGRAPHY

(71) We, EMI LIMITED, a British company of Blyth Road, Hayes, ~~Middlesex~~ 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 to medical radiographic apparatus of the type sometimes referred to as Computerised Axial Tomography (CAT) scanners.

In CAT scanners, such as that described in British Patent Specification No. 1,283,915, penetrating radiation, for example X-radiation, travels in a slice of a patient being examined. A source of the radiation orbits about the patient and projects the radiation in a plurality of different directions angularly distributed in the slice. The intensity of radiation emerging from the slice is then measured along each of a plurality of narrow beam paths. For the purposes of examining the patient, at least a part of the slice is designated as a matrix of elemental areas, for each of which an estimate of the absorption of the radiation is to be obtained. The narrow beam paths are then distributed so that each elemental area is intersected by a suitably large number of them. The intensity measurement obtained for each path is then representative of the total absorption suffered by radiation in passing through all the elemental areas intersected by the path. The path, in practice, intersects only part of some elemental areas and due allowance is made for this.

The intensity measurements are then processed, for example as described in the said British Patent or in British Patent Specification No. 1,471,531 to generate a picture in which each point has a brightness corresponding to the absorption of radiation in the correspondingly positioned elemental area of the region. The said patent specifications are hereby incorporated herein by reference.

One source of error in this process results

from the fact that absorption is not uniform for radiation of different energies. Thus low energy radiation is preferentially absorbed leading to "hardening" of the radiation. For tissue having relatively low absorption this effect may not be significant. However for high absorption material, such as bone, the hardening is significant, leading to erroneous intensity measurements for other elemental areas on the respective paths.

It is an object of this invention to provide an arrangement for correcting for such hardness errors.

It is an alternative object of the invention to provide an arrangement for correcting for errors due to scattering of radiation in the patient's body.

According to the invention there is provided a method of correcting for errors introduced into a representation of attenuation of radiation, in elements of a region of a patient's body, derived from measurements of attenuation of the radiation along a plurality of paths passing therethrough at a plurality of angles, where the errors result from changes in the character of the radiation as a result of passage through different attenuation regions thereof, including the steps of:

(a) determining a first estimate, of the representation, susceptible to errors,

(b) determining the position of regions of attenuation differing from a reference level by more than a predetermined amount,

(c) determining correction factors for the said changes of character in each of the paths passing through each said determined region, and

(d) correcting the attenuation values for the said elements by means of said factors.

According to another aspect of the invention there is provided an apparatus for determining a representation of the attenuation of penetrating radiation in a region of the body of a patient, the apparatus including: means providing a plurality of attenuation data signals, each representing the attenua-

tion suffered by radiation in passing through the region along a respective one of a plurality of beam paths; means for processing the attenuation data signals to provide attenuation coefficients for individual elements of a matrix of elements defined in the region; means for identifying elements for which the attenuation values are within one or more predetermined ranges; means for reconstructing attenuation data signals for said paths for attenuation by said elements having attenuation in said ranges; means for determining correction attenuation data signals, for each beam path, representing corrections for changes of character of the radiation resulting from body material in the elements through which the beam path has passed; and means for using the correction attenuation data signals to provide attenuation coefficients corrected for errors resulting from the said changes of character.

According to a further aspect of the invention the said changes of character are changes in the energy distribution of said radiation.

In order that the invention may be clearly understood and readily carried into effect, an example thereof will now be described with reference to the accompanying drawings of which,

Figure 1 shows a radiographic apparatus suitable for use with the present invention,

Figure 2 illustrates the principle of the invention,

Figure 3 illustrates in block diagrammatic circuit form a radiographic processing arrangement incorporating the invention,

Figure 4 is a flow diagram illustrating one sequence of operations for implementing the invention, and

Figure 5 is an alternative for part of the diagram of Figure 4.

Referring now to Figure 1, the apparatus shown therein is similar in principle to the apparatus described in the aforementioned British Patent Specification. A turntable member 1 having a central aperture 2, to accommodate a body 3 which is to be examined is mounted vertically for rotation about an axis 4. Axis 4 is disposed centrally in the aperture 2. The member 1 is supported on three rotatable bearings 5, 6 and 7 which are journaled in the main frame 8 of the apparatus. The frame 8 remains stationary, being rigidly secured to a pedestal 9, and can take any suitable form, although it must of course be formed with an aperture coincident with the aperture 2.

The member 1 can be rotated in angular steps, as will be described hereinafter by means of a cog wheel 10 cooperating with gear teeth, not shown, cut into the periphery of the member 1. Cog wheel 10 is driven by a motor 11 which is fixed to main frame

8. If desired the gear teeth may take the form of slots so that the arrangement takes the form of a so called "Geneva mechanism" with cog wheel 10 being replaced by a rotating peg such as is used with that mechanism.

Mounted on the turntable 1, and capable of performing a reciprocating lateral scanning motion relative thereto, is a lightweight but rigid scanning yoke 16. Yoke 16 can run on linear runners 17 and 18 which are fixedly mounted on the rotatable member 1 and are disposed chordally thereof. The lateral scanning motion is imparted to the yoke 16 by virtue of a toothed belt 19, which is stretched between a pair of toothed rollers 20 and 21 journaled in respective brackets, not shown, secured to the member 1. Yoke 16 is attached to belt 19 by means of a bracket, not shown. The roller 20 is merely an idler roller, but roller 21 is driven by a reciprocating motor 22 which is attached by a strap-like bracket 33 to the member 1.

A counter-balance weight 24 is secured to the opposite run, of belt 19, to the yoke 16 and thus moves in opposition thereto to compensate for out-of-balance forces which would otherwise be set up by the lateral scanning motion of the yoke 16 and certain equipment mounted thereon, which will now be described.

Attached to the yoke 16 is a source 25 of a beam 26 of penetrating radiation, in this example X-radiation. On the opposite side of yoke 16, with respect to the aperture 2, to the source 25 is a detector 27 sensitive to the radiation generated by the source 25 and viewing the source through a collimator 28.

The body 3 is supported on a semicylindrical, one part bed 29 and is secured thereon by means of straps such as 30. Gaps between the body and the bed are filled with a suitable packing material 31 which is preferably of dough like consistency and absorbs the X-radiation to substantially the same extent as does human tissue. The material 31 is preferably contained in one or more plastic bags. The bed 29 is supported by legs 32 which stand on the pedestal 9.

For efficient operation the rotational scanning motion, imparted by the cog wheel 10 to the member 1, should be synchronised with the lateral scanning motion imparted to the yoke 16 by the reciprocating motor 22. To this end the member 1 is formed with an annular graticule, part of which is shown at 33, and a fixed photodetector 34 which with a light source, not shown, is mounted on main frame 8. Photodetector 34 provides timing pulses indicative of the passage past it of markings on the graticule 33. Thus the rotational scanning motion of member 1 is monitored. Similarly a linear graticule 35 is fixedly attached to the yoke

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16 and cooperates with a second photodetector 36, which is mounted on the member 1 so as to rotate therewith, and a similarly mounted light source, not shown, to produce timing pulses indicative of the progress of the lateral scanning. Both grati-
 5 cules 33 and 35 comprise translucent or transparent members bearing opaque lines printed, etched or otherwise provided thereon. The two sets of timing pulses are fed
 10 to a control circuit 37 which controls the motor 22 and the motor 11 in such a way that, after each step of rotational motion, a single lateral scan is carried out to traverse
 15 the source 25 and the detector 27 in one direction or the other across the aperture 2. Thus a single lateral scan is carried out for each dwell angle of the member 1.

The detector 27 is, for example, a scintillator crystal, such as sodium iodide, with an associated photomultiplier tube, or a photodiode, and thus provides electrical signals indicative of the amount of radiation detected thereby. The electrical signals so provided are applied to a pre-processing circuit
 20 38, which contains an amplifier 39, a resettable integrator 40, an analogue-to-digital converter 41 and a logarithmic converter 42. The integrator 39 to read and reset
 25 synchronously and periodically by means of timing pulses derived from the photodetector 36; the arrangement in this example being such that the reading and re-setting occurs
 30 some one hundred and sixty times during each lateral scan in either direction to provide data for a set of parallel beam paths
 35 across the body. After one lateral scan the member 1 is rotated through a predetermined angle and a second lateral scan provides data for a further set of parallel paths. The process is repeated until sufficient such
 40 sets have been provided over about 180° and all of the output signals obtained during the scanning are processed in a processing
 45 circuit 43 to evaluate the absorption coefficient, with respect to the radiation used, at a plurality of locations distributed over the slice of the body 3 which lies in the
 50 plane of the beam of X-rays generated by the source 25. The distribution of absorption coefficients thus derived is then displayed on a display unit 44.

Preferably the processing is carried out in accordance with the technique described and claimed in our Patent Specification
 55 1,471,531. This technique involves a form of convolution for which the output signals are assembled in sets relating to sets of paths, preferably parallel, through the body. Each
 60 output signal is then modified by combining it with weighted components of other output signals of its own set; the weighting being in accordance with a function which is negative, and decreases in amplitude as the
 65 distance from the path giving rise to the

output signal being modified increases. The modified output signals are then additively combined in accordance with a layergramming procedure; the modification of the
 70 output signals being such as to compensate for the known inaccuracies of conventional layergrams. In relation to a predetermined point in the slice being examined the arrangement
 75 is such that the modified absorption values for all beam paths passing through, or near to, that point are combined to give an absorption coefficient for the point. In
 80 practice beams at the angular dispositions of all of the parallel sets of paths may not pass sufficiently close to each such evaluation point. For this reason interpolation is
 85 applied to the modified data for each parallel set of paths to obtain modified data for a new set of an increased number of such paths to ensure that at least one passes
 sufficiently close to each evaluation point.

Figure 1 also shows modifications which can be made to the apparatus to operate according to an alternative arrangement, as
 90 described in British Patent Specification No. 1,478,124. In such an arrangement source 25 is arranged to provide the radiation as a planar, fan-shaped distribution between
 95 limits 26¹ and 26². The detector 27 is replaced with an array of detectors, typically thirty, cooperating with respective collimators to define a corresponding number of
 100 beams in the fan distribution. In one example the neighbouring collimators are inclined to each other at angles of ½°. Thus the angular spread for thirty detectors is
 105 93° between the centrelines of the extreme beams. Thus, for one hundred and sixty integration intervals during a lateral scan, output signals are provided which are
 110 indicative of the absorption suffered by the radiation on traversing thirty sets of parallel paths, each set displaced by ½° from its neighbour. The rotation at the end of each lateral scan is then by the ten degrees of
 the fan distribution. For processing an individual circuit 38 is provided for each detector channel, to provide data to processing
 circuits 43.

Although the apparatus described in relation to Figure 1 is essentially that described
 115 in the said British Patent No. 1,283,915 and Patent Specification No. 1,471,531, or, with the appropriate changes, the alternative version of British Patent Specification No.
 120 1,478,124, it will be understood that the invention to be described can be applied to other forms of apparatus providing absorption data of the same nature.

For the purposes of explanation there is shown in Figure 2 a simplified section of a
 125 slice 45, of the patient's body 3, on which is shown a designated matrix of elemental areas such as 46. In this example forty five elements of the matrix are shown, extend-
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ing beyond the slice. It should be understood that this example is chosen for clarity of illustration and in practice the matrix would comprise a much larger number of elements, typically greater than 100,000 and that they may lie in only a restricted region of such a slice. Also for the purposes of clarity the section of the body will be assumed to include only a region 47 of bone, a region 48 of air and other regions 49 of intermediate density. However in practice it would be considerably more complex.

The beam 26 of radiation projected from source 25, is arranged to be incident on detector 27. The output signal representing the intensity of the radiation collected at detector 27 is related to the absorption along path 26. The signal, which will be called an "edge reading" is used together with similar absorption values for many other paths at many angles, to determine absorption coefficients for all elements, such as 46.

Considering beam path 26, however, it will be seen that it passes through, in sequence, intermediate region 49, air 48, more of intermediate region 49, bone 47 and further intermediate region 49. The bone 47 causes the hardness of the radiation to change, rendering the absorption reading to be in error in respect of regions 47, 48 and 49.

In applying the correction of the present invention, all edge readings obtained by detectors such as 27 at all positions of source 25 are processed by an appropriate method to obtain a first estimate of absorption values for the matrix of elements. Although these actual values are probably not entirely correct due to bone error, they are in approximately correct proportion so that the existence of regions of bone such as 47 can be seen therefrom. Taking beams such as 26 it is clearly possible to determine the extent of bone 47 through which beam 26 passed. This may be achieved by manual means but is preferably performed in a computer using, for example, known pattern recognition techniques. The calculation need only be approximate to yield at least an estimate of a correction. It can readily be known, either from calculation or previous measurement, how much hardening is obtained from any proportion of bone so that the edge reading of detector 26 can be corrected appropriately. The entire CAT picture may then be redetermined using such corrected edge readings.

However, in a simpler preferred embodiment, the correction factor is applied not to the edge reading but to the first calculated absorption values for elemental areas intercepted by beam 26 in proportion to their degree of interception thereby.

It will be understood that the correction is applied to elemental areas intercepted by

the beam 26 both before and after passage through bone 47. This is because the error is the same whether it is caused by an unexpected change of hardness of radiation already including absorption information from an elemental area or about to be used to obtain such information. In either case the effect at detector 27 cannot be distinguished.

There is shown in Figure 3 a simplified block diagram of the processing for obtaining the final picture. The edge readings from the detectors such as 27 are first applied to the pre-processing circuits indicated generally at 38. The data are then processed, as referred to hereinbefore, in processing circuits 43 to achieve a first estimate of a picture. This estimate can if desired be provided directly to display processing 50, comprising, for example, standards conversion, for display on the display unit 44. The picture is also provided to a hardness error processing circuit 51 together with data indicating the orientations of beam paths in the body region being examined. Circuits 51 determine the required hardness correction factors and either return appropriately corrected edge readings to circuits 43 for reprocessing, or provide corrected values for each matrix element to display processing 50. It will be understood that many detailed arrangements may be provided for calculating the hardness correction, according to the principles explained hereinbefore. Such arrangements may comprise specially constructed circuits or may use an appropriately programmed digital computer. In the latter case processing circuits 43 and 51 may conveniently be provided by a single computer.

The implementation of a computer program to apply the correction factors of the invention may readily be achieved by those skilled in computer programming. However, for clarification of the required procedure for processing in circuits 51 Figure 4 shows a block diagrammatic circuit. It should be understood that this schematic Figure does not represent a detailed arrangement of circuits but is more of the form of a flow diagram for a program. Of course a special purpose circuit could take a similar form.

Turning to Figure 4 the calculated absorption values are held in storage 52 in locations corresponding to their positions in the matrix. Further storage 53 holds data, in the form of stored co-ordinates for the matrix, representing the paths followed through the elemental areas by each beam for which an edge reading has been obtained. Clearly these beam paths can be the same for each examination and can be determined in advance as part of a setting up procedure for the equipment. Alternatively

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they can be calculated as required using data from photo detectors 34 and 36.

The beam path co-ordinates are provided to matrix storage 52 where values for all elements along a beam path are withdrawn progressively. In doing this it must be remembered that the beam path may only intersect a proportion of each element and that only a corresponding proportion of the respective correction factor should be added into the sum. The procedure is essentially the same as that described in British Patent No. 1,283,915 for summing absorption values along a beam path and may be carried out in the same manner. They are then subject to a threshold 54 to identify individual absorption values which exceed a predetermined absorption level, i.e. those which represent bone. The data for elements of each beam path, after threshold, are summed in summer 55 to provide high absorption beam path data signals which relate only to absorption of the radiation by elements above the threshold. These data signals represents the extent to which the radiation of the respective beam has been subject to absorption which will cause a hardness error.

There are also held in storage at 56 pre-calculated or premeasured hardness factors representative of hardness changes introduced by bone of different absorption levels. These may be determined by measurement from a phantom body of known absorption. There is a factor for each of a plurality of ranges of values of the high absorption beam path data. These are withdrawn from storage in response to a level analysis at 57 of the beam path data from 55 to provide a hardness correction factor for each beam path. The correction factor for each beam path is then provided to processing circuits 43 to be multiplied by, or added to as desired, the edge reading for the same path. The edge readings as corrected are then reprocessed to give a more accurate representation for display or for recalculation of hardness errors in a further cycle of correction.

Alternatively the hardness corrections for each beam path may be used directly to correct each element of the first estimate of the representation in matrix store 52. The representation from store 52 is provided to unit 58 in which the correction for each beam path is used, in appropriate proportions to correct the value to each element intersected or part intersected by that path. As before the correct proportioning can be achieved as described in British Patent No. 1,283,915. The corrected representation is then output directly at 59 for display.

In practice such correction takes a finite, though short, time. It may, therefore, be desirable to display the uncorrected matrix representation from store 52 while a correct

version is being evaluated. This first displayed picture can then be updated or replaced by the corrected picture when available.

Although the correction described is for hardness errors introduced by dense material such as bone, it should be noted that lesser errors are introduced by regions of intermediate density. Such lesser errors may be ignored but if desired they may also be corrected in the same manner as the bone but with appropriate correction factors. A desired procedure is to use an intermediate absorption value as a reference, to apply one correction to values above that level say by more than a predetermined amount and an opposing correction to values below that level by a similar amount. That means in effect applying a negative correction to values such as those for material which has an absorption significantly less than tissue mean.

One means of achieving this is shown in Figure 5 which is a modification of part of the circuit of Figure 4. The threshold 54 provides, at 60, values above the present level and, at 61, values below a lower level. If desired a single intermediate threshold level may be used. The values below the level, which may represent, say, regions of air in the body, are divided at 62 by a factor to reduce their significance compared with the high or bone corrections. The factor may be determined empirically but a typical value is 100. They are also summed, at 63, to provide low absorption beam path data which are also provided to circuits 57 at which their respective correction factors are determined. The corrections for the low absorption beam path data are opposite in sign to the high absorption data but are otherwise utilised in the same manner.

In some examples of the apparatus, such as that described in British Patent Application No. 1,478,124, is it known to include in the path of the X-rays saddle-shaped absorbing members. One typical such member is shown in Figure 1 at 60. The saddle shaped member, which may be disposed on both sides or only on one side of the body, serves to correct the absorbing path length of the body for variations caused by its substantially circular cross-section.

Members such as 60 also, however, introduce changes in hardness of the radiation in view of the material, typically aluminium, from which they are made. A method of compensating for errors introduced by these members has been described in British Patent No. 1,509,528. However, it will be apparent that such correction may be advantageously combined with the corrections of the present invention by holding in store 54 additional factors calculated for member

60 and applying them with the tissue error factors. Preferably the corrections for members 60 should be applied to the edge readings after they have been corrected for tissue hardness errors.

Since the corrections calculated for member 60 can be precalculated, it is advantageous to combine them with the tissue error factors as stored in storage 56. That is to say each beam path data signal from 55 (or 63) is allocated a correction factor not only on the basis of its amplitude but also on the basis of the position at which it intercepted 60, represented by its distance from the centre, and therefore the thickness of material through which it passed.

The beam path data storage 53, when initiating a beam path data signal from 52 also indicates to storage 56, as shown by the broken line path, what the orientation of the next beam is. The orientation, which is predetermined when the apparatus is set up, has allocated to it a particular set of hardness factors for a beam in that position. One of these is then selected for the respective data signal on the basis of its amplitude. As mentioned hereinbefore, and as described in Patent No. 1,509,528, it is convenient to determine the respective factors by measurement using a phantom body.

It should be noted that hardness errors are not the only way in which the material of the body introduces errors into the readings. It is known that radiation is scattered from absorbing regions of the body so that not all data entering the detector 27 has travelled directly along path 26 from the source 25. In practice for a body of fairly uniform absorption, scattering is uniform and each detector position results in a similar scattered radiation input therefore giving, on balance, little error in the final picture. However high absorption regions such as bone upset this general balance by shielding a detector and reducing its scatter input below the mean. The effect is similar to the change of character produced by the hardness error and may be corrected in the same way. It is necessary to compute or measure an average scatter level and, knowing the approximate absorption of bone in each path such as 26, to uprate the appropriate edge reading by a factor accounting for the loss of scattered radiation.

Although the invention has been described in terms of particular scanning arrangement it should be understood that the error correction is not specific to the scanning by which the data was obtained.

WHAT WE CLAIM IS:—

1. A method of correcting for errors introduced into a representation of attenuation of radiation, in elements of a region

of a patients body, derived from measurements of attenuation of the radiation along a plurality of paths passing therethrough at a plurality of angles, where the errors result from changes in the character of the radiation as a result of passage through different attenuation regions thereof, including the steps of:

(a) determining a first estimate, of the representation, susceptible to errors,

(b) determining the position of regions of attenuation differing from a reference level by more than a predetermined amount,

(c) determining correction factors for the said changes of character in each of the paths passing through each said determined region, and

(d) correcting the attenuation values for the said elements by means of said factors.

2. A method according to claim 1 in which the regions of attenuation determined are those for which the attenuation measurements exceed the reference level by more than the predetermined amount.

3. A method according to claim 1 in which the regions of attenuation determined are those for which the absorption measurements exceed the reference level by a predetermined amount and those which are exceeded by the reference level by a predetermined amount.

4. A method according to claim 3 in which the attenuation measurements for regions exceeded by the reference level are divided by a predetermined factor prior to determination of the correction factors.

5. A method according to any of the preceding claims in which the attenuation values are corrected by correcting the measured attenuation values for each path by the correction factor determined for the path and deriving a new representation of attenuation from the corrected attenuation values.

6. A method according to claim 5 in which the attenuation values are corrected by multiplication by the correction factors for respective paths.

7. A method according to either of claims 1 to 4 in which the attenuation values are corrected by applying to each attenuation value a proportion of the correction value for each path intersecting the respective element.

8. A method according to claim 7 in which the attenuation values are corrected by multiplication by the respective proportion.

9. A method according to any preceding claim in which the said changes of character are changes in the energy distribution of said radiation.

10. A method according to any preceding claim including the step of correct-

60 and applying them with the tissue error factors. Preferably the corrections for members 60 should be applied to the edge readings after they have been corrected for tissue hardness errors.

Since the corrections calculated for member 60 can be precalculated, it is advantageous to combine them with the tissue error factors as stored in storage 56. That is to say each beam path data signal from 55 (or 63) is allocated a correction factor not only on the basis of its amplitude but also on the basis of the position at which it intercepted 60, represented by its distance from the centre, and therefore the thickness of material through which it passed.

The beam path data storage 53, when initiating a beam path data signal from 52 also indicates to storage 56, as shown by the broken line path, what the orientation of the next beam is. The orientation, which is predetermined when the apparatus is set up, has allocated to it a particular set of hardness factors for a beam in that position. One of these is then selected for the respective data signal on the basis of its amplitude. As mentioned hereinbefore, and as described in Patent No. 1,509,528, it is convenient to determine the respective factors by measurement using a phantom body.

It should be noted that hardness errors are not the only way in which the material of the body introduces errors into the readings. It is known that radiation is scattered from absorbing regions of the body so that not all data entering the detector 27 has travelled directly along path 26 from the source 25. In practice for a body of fairly uniform absorption, scattering is uniform and each detector position results in a similar scattered radiation input therefore giving, on balance, little error in the final picture. However high absorption regions such as bone upset this general balance by shielding a detector and reducing its scatter input below the mean. The effect is similar to the change of character produced by the hardness error and may be corrected in the same way. It is necessary to compute or measure an average scatter level and, knowing the approximate absorption of bone in each path such as 26, to uprate the appropriate edge reading by a factor accounting for the loss of scattered radiation.

Although the invention has been described in terms of particular scanning arrangement it should be understood that the error correction is not specific to the scanning by which the data was obtained.

WHAT WE CLAIM IS:—

1. A method of correcting for errors introduced into a representation of attenuation of radiation, in elements of a region

of a patients body, derived from measurements of attenuation of the radiation along a plurality of paths passing therethrough at a plurality of angles, where the errors result from changes in the character of the radiation as a result of passage through different attenuation regions thereof, including the steps of:

(a) determining a first estimate, of the representation, susceptible to errors,

(b) determining the position of regions of attenuation differing from a reference level by more than a predetermined amount,

(c) determining correction factors for the said changes of character in each of the paths passing through each said determined region, and

(d) correcting the attenuation values for the said elements by means of said factors.

2. A method according to claim 1 in which the regions of attenuation determined are those for which the attenuation measurements exceed the reference level by more than the predetermined amount.

3. A method according to claim 1 in which the regions of attenuation determined are those for which the absorption measurements exceed the reference level by a predetermined amount and those which are exceeded by the reference level by a predetermined amount.

4. A method according to claim 3 in which the attenuation measurements for regions exceeded by the reference level are divided by a predetermined factor prior to determination of the correction factors.

5. A method according to any of the preceding claims in which the attenuation values are corrected by correcting the measured attenuation values for each path by the correction factor determined for the path and deriving a new representation of attenuation from the corrected attenuation values.

6. A method according to claim 5 in which the attenuation values are corrected by multiplication by the correction factors for respective paths.

7. A method according to either of claims 1 to 4 in which the attenuation values are corrected by applying to each attenuation value a proportion of the correction value for each path intersecting the respective element.

8. A method according to claim 7 in which the attenuation values are corrected by multiplication by the respective proportion.

9. A method according to any preceding claim in which the said changes of character are changes in the energy distribution of said radiation.

10. A method according to any preceding claim including the step of correct-



ing for changes in the energy distribution introduced externally of the body.

11. A method according to claim 10 in which the changes introduced externally of the body result from members arranged to approximately equalise attenuation across the body as a result of the approximately circular cross-section thereof.

12. A method of correcting for errors, introduced into a representation of attenuation in a patient's body, substantially as hereinbefore described with reference to the accompanying drawings.

13. An apparatus for determining a representation of the attenuation of penetrating radiation in a region of the body of a patient, the apparatus including: means providing a plurality of attenuation data signals, each representing the attenuation suffered by radiation in passing through the region along a respective one of a plurality of beam paths; means for processing the attenuation data signals to provide attenuation coefficients for individual elements of a matrix of elements defined in the region; means for identifying elements for which the attenuation values are within

one or more predetermined ranges; means for reconstructing attenuation data signals for said paths for attenuation by said elements having attenuation in said ranges; means for determining correction attenuation data signals, for each beam path, representing corrections for changes of character of the radiation resulting from body material in the elements through which the beam path has passed; and means for using the correction attenuation data signals to provide attenuation coefficients corrected for errors resulting from the said changes of character.

14. An apparatus according to claim 12 in which changes of character are changes in the frequency spectrum of the radiation resulting from passage through said elements.

15. An apparatus, for determining a representation of the attenuation of penetrating radiation in a region of the body of a patient, substantially as herein described with reference to the accompanying drawings.

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