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(54) Phased array MR RF coil which is not visible in X-ray image

Auf einem Röntgenbild unsichtbare phasengesteuerte MR-RF-Spule

Bobine rf rm à réseau à commande de phase non visible dans une image à rayons x

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Description

[0001] This invention relates to a phased array RF coil formed of a series of separate coil elements or individual loops for use in magnetic resonance imaging which can be used to obtain MR images of a body part of a patient and can remain in place during electromagnetic radiation imaging of the body part without interfering with the radiation image. The coil array can be used for receive functions, transmit functions or can carry out both functions.

BACKGROUND OF THE INVENTION

[0002] Magnetic resonance imaging (MRI) is commonly employed for medical imaging. In addition, combined use of MRI with radiation (X-Ray) therapy and with radiation imaging have both been used in a number of prior situations. Such systems provide significant advantages compared to single modality systems for obtaining information of the patient. However in such prior dual imaging systems, the patient may need to be moved or transferred from one system to another system. Such transfers can be difficult and time-consuming, and they can compromise results by complicating image registration.

[0003] MRI in combination with a radiotherapy accelerator has been used. Thus the X-Rays must be transmitted through the RF coil of the MR imaging system which remains in place during the radiotherapy. Although the RF coils of the MRI system are in the radiation path, they do not cause enough absorption to significantly degrade therapy or require a higher dose for imaging. For example the RF coils may have an equivalent Al thickness of about 2.3 mm, which is sufficiently low for the therapy to be carried out without interference from the coil and low enough not to affect the optimal dose of X-Ray radiation.

[0004] The combination of MRI with radiation imaging or more specifically X-Ray imaging causes unique problems. Specifically, if a conventional surface MRI Receive Coil is placed in the imaging path of a X-Ray system, the coil will be visible in the image and will cause artifacts or edges or components of the receive coil may cover important features in the X-Ray image which are required to be seen by the surgeon. For this reason, when MRI is performed in combination with radiation imaging, all coils of the MRI system, including the RF coils, are typically disposed out of or removed from the radiation path so as to be outside the field of view.

[0005] For example, US patent No. 6,925,319 (McKinnon) issued August 2, 2005 considers a split magnet MRI system having all MRI coils disposed out of the radiation path of an X-Ray system.

[0006] Unfortunately, MRI performance can be undesirably degraded by a requirement to place the MRI RF coils outside the field of view of a radiation imaging system. For example, surface RF coils are often placed directly on a subject being imaged for maximum MRI image quality. Such a surface coil is in the field of view of any radiation imaging system that is directed to the same part of the subject as the MRI system. Thus conventional combined MRI and radiation imaging can require an undesirable choice among accepting reduced MRI image quality by placing the RF coils out of the radiation system field of view, accepting RF coil artifacts in the radiation images by placing the RF coils in the radiation system field of view, or by moving the MRI RF coils to one position for MRI imaging and to another position out of the field of view for radiation imaging.

[0007] US patent 7,394,254 (Rieke) issued July 1st 2008 discloses using aluminum for the RF coils to render them "transparent" to X-Ray. More particularly, the patent discloses an arrangement in which improved compatibility of MRI with radiation imaging is provided by MRI RF coils having transmissive coil sections. The transmissive coil sections are substantially transparent to the penetrating radiation employed by the radiation imaging system. Thus the transmissive coil sections can be disposed in a field of view of the radiation imaging system without introducing artifacts into the radiation images. Transparency to penetrating radiation can be achieved by substantially including only low atomic number (i.e., $Z<29$) elements in the transmissive coil sections. Preferably, the transmissive coil sections are fabricated substantially from aluminum.

[0008] However it is accepted that the use of aluminum for the traces of an RF coil leads to a degradation in the MR imaging relative to the use of copper. However copper cannot be used in a trace which is sufficiently thin to generate the "transmissive" coil sections of Rieke.

[0009] Related disclosures are made in published PCT Applications WO 2009/146521 and 2009/146522 both filed May 25 2009 and published December 10 2009 by the present Applicants/Assignees. In PCT Application WO 2011/000085 filed June 29 2010 and published 6 January 2011 by the present Applicants/Assignees is disclosed an RF coil where the conductive traces of the RF coil are arranged of a conductive material which has a thickness such that the traces cause an attenuation of the penetrating electromagnetic radiation which is visible in the radiation image and the support board includes non-conductive material in the field of view which has a thickness selected such that an attenuation of the penetrating electromagnetic radiation at locations on the board spaced from the traces is substantially equal to the attenuation at locations on the board at the conductive traces. However this arrangement does not disclose how to provide a phased array coil of this type where the attenuation is constant which has individual loops which, as is previously known, must overlap for decoupling mutual inductance between the coil loops.

[0010] In PCT Application WO 2011/022896 published 3 March 2011 by the present assignees is disclosed an RF coil loop including arrangements for decoupling and pre-amplification.

[0011] US patent application 5 491 415 A discloses an

RF phased array coil according to the preamble of claim 1.

SUMMARY OF THE INVENTION

[0012] It is one object of the present invention to provide an phased array RF coil suitable for use in a dual imaging system using MRI and penetrating electromagnetic radiation such as X-Rays.

[0013] According to the invention there is provided an RF phased array coil for use in an MR imaging system for generating an MR image of a subject for use in a radiation imaging system for generating a radiation image of said subject using penetrating electromagnetic radiation, the phased array coil comprising conductive traces; a support defined by at least one substrate sheet;and a plurality of coil loops formed by said conductive traces mounted on said support; one of said coil loops overlapping another one of the coil loops so that a leg of said one coil loop lies adjacent to a leg of said other coil loop with two sections at opposite ends of the leg of said one coil loop crossing two corresponding sections at opposite ends of the leg of said other coil loop; wherein

(i) each of the crossing sections and each of the corresponding sections has a thickness in a direction at right angles to the support which is less than that of the legs; and

(ii) wherein the support is formed of non-conductive material which has a thickness selected such that an attenuation of the penetrating electromagnetic radiation at locations on the support spaced from the traces is substantially equal to the attenuation at locations on the support at the conductive traces;

such that an attenuation of the penetrating electromagnetic radiation caused by the RF coil within said radiation image is substantially constant throughout a field of view of the radiation imaging system, when the RF phased array coil is kept in place during radiation imaging within said field of view, to avoid a visible artefact within said radiation image caused by the presence of the RF phased array coil. Preferably each of the crossing sections and each of the corresponding sections has a thickness in a direction at right angle to the support which is equal to one half of that of the legs.

[0014] Preferably each of the coil loops has a thickness along the full length thereof, with the exception of crossing sections and corresponding sections, which is constant.

[0015] Preferably said one of said coil loops is arranged on a first surface of the substrate sheet and said other of the coil loops is arranged on a second opposed surface of the substrate sheet.

[0016] Preferably the support comprises first and second overlying laminated substrate sheets and wherein said one of said coil loops is arranged on a first surface of the first substrate sheet and said other of the coil loops is arranged on a second opposed surface of the first substrate sheet so as to be located between the first and second substrate sheets.

[0017] Preferably there is provided a third of the coil loops which is located on a second opposed surface of the second substrate sheet and wherein the third coil loop is overlapped with said one and said other of the individual coil loops.

[0018] In one arrangement the support is formed from common material.

[0019] In another arrangement the support is formed from a base material and an additional material different from the base material is added to the support where the base material and the additional material are preferably laminated to form a common structure.

[0020] Preferably the support is flexible.

[0021] Preferably the conductive traces are formed of copper.

[0022] The conductive traces are preferably formed of aluminum to reduce the attenuation but the same concepts can be used where the conductive traces are formed of copper.

[0023] Preferably the support substrate sheet is formed of fiber reinforced resin such as FR-4.

[0024] While taking X-ray images, if a coil is present then the components and conductive traces are visible in the X-Ray Image. For a MR phased coil array, the conductive elements or loops must be overlapped to provide decoupling of adjacent elements. Where the traces overlap, the x-ray sees a double thickness, and thus raises the total aluminum equivalence that we would have to match. This is true for any conductive material whether that be aluminum where the attenuation is low or copper where it is much higher.

[0025] Various materials give different attenuation based on their thickness. Copper traces on a MR coil element appear as grey bars in an X-Ray image. A similar attenuation can be given by plastic or other non-conductive material based on its thickness.

[0026] Where conduction coil element traces overlap, the trace is reduced in thickness to approximately one-half the metal thickness giving a uniform x-ray aluminum equivalence across the region. The technique can be applied to any material with an atomic number less than 30.

[0027] This can easily be achieved in standard printed circuit manufacturing starting with a board that has one-half the metal thickness, applying a mask layer resist over the conductor overlap region, and electroplating the board to form the traces to the desired thickness.

[0028] The coils traces are also interleaved from the front and the back of the substrate to maintain the same X-ray aluminum equivalency.

[0029] Preferably the non-conductive material of the support board is arranged relative to the conductive traces such that the attenuation of the penetrating electromagnetic radiation of substantially the whole of the RF coil located within the field of view is substantially constant throughout the field of view. There may however be points or areas where the attenuation is different and an alternative system is used to remove these points or areas from the image. It will be appreciated that such attenuation is not invisible in the image but is instead visible in the sense that it is sufficient to affect the image so that its presence can be determined. However the intention is that the attenuation is constant or homogeneous so that there is no visible artefact within the image and the presence of the RF coil within the image does not affect the changes of image intensity at the various locations within the image which are caused by the differences in attenuation caused by the part being imaged.

[0030] In one arrangement, preferably the support board is formed from common material and wherein the thickness of the common material is varied so that the attenuation of the penetrating electromagnetic radiation of substantially the whole of the RF coil located within the field of view is substantially constant throughout the field of view.

[0031] In another arrangement, the support board is formed from a base material and an additional material different from the base material is added to the support board.

[0032] In both cases the material can be machined to provide the required thicknesses as determined by analyzing the difference in attenuation caused by the materials themselves relative to the copper traces and calculating the required thickness.

[0033] Materials can be selected for the additional material or for the board itself which have a very high attenuation so that the thickness of the material is not significantly different from the copper traces.

[0034] Conventional techniques and materials for manufacturing the support board can be used including printing the traces or etching the traces as required. Thus the term "traces" is not intended to limit the conductors to any particular method of formation of the conductors on the support board.

[0035] Preferably the base material and the additional material are laminated to form a common structure.

[0036] Preferably the conductive traces are continuous throughout the field of view so as to have a constant thickness and therefore attenuation. Many techniques are available for forming such continuous traces with out the necessity for joints which may double the thickness at certain locations or may require connecting material such as solder. Thus preferably the conductive traces include no solder within the field of view.

[0037] Preferably there are no connector wires from the conductive traces within the field of view so that the connector wires such as coaxial connectors, wires and rods which connect from the traces to the pre-amplifier or other location are located outside the field of view.

[0038] In many cases it is necessary to locate the tuning capacitors required for such a coil to be located within the field of view and preferably it is arranged such that the capacitor has an attenuation of the penetrating electromagnetic radiation which is substantially equal to the attenuation of the conductive traces.

[0039] This can be achieved where the capacitor is formed from conductive traces with a dielectric material between the traces to define the required capacitance.

[0040] In many cases it is also necessary to locate a fuse required for such a coil to be located within the field of view and preferably it is arranged such that the attenuation of the penetrating electromagnetic radiation by the fuse is substantially equal to the attenuation of the conductive traces.

[0041] This can also be achieved where the fuse is formed from conductive traces.

[0042] Preferably the support board includes no mechanical mounting and support structures within the field of view.

[0043] The support board may be flexible.

[0044] In many cases it is also necessary to provide a diode for the RF coil and where possible this can be located outside the field of view.

[0045] In some cases it is necessary to locate within the field of view a diode or other similar element which has an attenuation different from the conductive traces. In this case the location of the diode in the field of view is arranged to be constant and the image of the diode or other element in the radiation image is removed by software image analysis.

[0046] Preferably the conductive traces are formed of copper but other similarly conductive materials can be used instead of aluminum which is effectively transparent to the X-Rays but is generally unsuitable for RF coil manufacture.

[0047] The support board can be formed of any suitable non-conductive material which is MR compatible and has an attenuation to X-Rays which is less than or around that of copper such as FR-4 fibreglass circuit board.

BRIEF DESCRIPTION OF THE DRAWINGS

[0048] The following Figures 1 to 5 are taken from the above mentioned PCT application WO 2011/000085 published 6 January 2011 and hence is prior art.

Figure 1 is an isometric view of an Angiography room showing a patient table, an MRI magnet movable into a position for imaging the patient on the table and an arrangement for moving an X-Ray system.

Figure 2 is an isometric view of a table for mounting the patient, the base being omitted for convenience of illustration, and showing the RF coil construction for imaging of the upper torso of the patient.

Figure 3 is a plan view of the RF coil including the components of the system attached thereto which are shown schematically.

Figure 4 is a cross sectional view through the RF coil.

Figure 5 is a cross sectional view through the RF coil showing a modified construction.

Figure 6 is a plan view of a phased array coil according to the present invention.

Figure 7 is a cross-sectional view along the lines 7-7 of Figure 6.

DETAILED DESCRIPTION

[0049] The following description is taken from the above PCT application and is included for completeness of disclosure herein.

[0050] In Figure 1 is shown an arrangement for carrying out Magnetic Resonance Imaging and X-Ray imaging of a patient while the patient remains stationary on a patient support table. The arrangement provides a room 1 in which is mounted a patient support table 10 with doors 2 at one side of the room for entry into the room of the magnet 3 of an MR imaging system from a magnet bay 1A. The room contains an X-Ray imaging system 4 mounted on rails 5 and includes an X-Ray transmitter 6 and receiver 7 mounted on a C-shaped support 8. The X-Ray system is of a conventional construction commercially available from a manufacturer such as Siemens. The table 10 described and illustrated herein is used in an arrangement where the patient remains in position on the table while imaging is effected using MRI and X-Ray.

[0051] The X-Ray system 4 which co-operates with the moving magnet described above such that the patient can be imaged by either modality on the same table. The patient does not move and at least one of the RF coils remains in place.

[0052] The MR is a high-field (e.g. 1.5T or 3T or more) magnet that moves on overhead rails between the two or more rooms as described above. In the system described, one or more of these rooms contains an X-Ray system, either a single-plane or a biplane. When the magnet is moved out of the X-Ray examination room and a set of RF and X-Ray shielded doors is closed, the examination room functions as a conventional X-Ray lab and can be used with conventional equipment. In particular, X-Ray guided interventions may be performed.

[0053] The arrangement may be used in a typical three room configuration with the Angiography Room (AR) on the left, a Diagnostic Room (DR) in the middle, and an Operating Room on the right. The magnet moves on overhead rails between the rooms and can image in each.

[0054] When MR imaging is required, the X-Ray equipment is safely stowed, the doors open, and the magnet is brought into the room over the patient on the table. The RF shield encompasses the AR so all the equipment in the X-Ray examination room is made RF-quiet. MR imaging can then be performed. Afterwards, the magnet is removed from the room, the doors closed, and the X-Ray equipment is returned to its working position.

[0055] The MR scanner is used to provide information complementary to that obtained using X-Ray. It can be used, for example, to perform a baseline assessment prior to intervention as well as to perform a post-intervention assessment. Such an assessment may include perfusion and viability studies of, for example, the heart or of the brain.

[0056] In the arrangement for moving the X-Ray system as shown in Figure 1 the MR enters the X-Ray examination room and moves over the head end of the table 10. Since the path of the MR passes right through the location of the C-arm stands, the latter must be moved before the magnet may enter. Depending on need, a floor-mounted C-arm stand may be moved on floor rails, floor turntable, or a boom mounted on the floor or wall. Depending on need, a ceiling-mounted C-arm stand may be moved using extended rails to park it at the foot end of the table, by mounting the stand rails on a platform suspended from the movable magnet rails, or by fixing the stand rails on a platform with a telescopic arm to move them laterally.

[0057] Using a solution to move a floor-mounted stand together with a mover for a ceiling mounted stand provides a mechanism to move a biplane system. The mover can provide a mounting position of the single plane or biplane at some non-zero angle to the MR rails, e.g., 90 degrees.

[0058] The Patient Handling System or support table is shown in Figure 2 as indicated generally at 10. The patient support table includes a base 11 of a conventional construction which allows the base to move a patient support portion 12 to required locations in height and in orientation. Suitable drive mechanisms and couplings are known in the art and thus are not required to be described herein. At the top of the base 11 is mounted the patient support portion in the form of a generally planar body 12 formed of a fiber reinforced plastics material so as to define a surface area sufficient for supporting the patient while lying on the patient support portion.

[0059] When the imaging is to be of the chest, an anterior chest coil 31 is arranged to be placed on top of the chest of the patient when in place for imaging on the mattress and also the posterior coil 32 is arranged to be place behind the patient. Similarly when imaging is to be of the head, coils are placed above and below the head of the patient.

[0060] In order to avoid moving the patient when changing from the MR imaging system to the X-Ray imaging system, at least the posterior coil remains in place. Thus this coil will be visible in the X-Ray image. The imaging system may be a simple linear X-Ray system or more preferably is a bi-planar rotating system of the type illustrated which takes multiple images around the patient.

[0061] Thus the apparatus for use in imaging of a part of a patient as shown in Figure 1 includes the radiation imaging system 4 for generating a radiation image of a subject in the field of view using penetrating electromagnetic radiation and the magnetic resonance imaging system for generating an image of the subject including the magnet 3 and the RF coils 31, 32.

[0062] A schematic illustration of the RF coil 32 is shown in Figures 3 and 4 and is arranged to remain in place during the radiation imaging using the X-Ray transmitter 50 and receiver 51 shown only schematically.

[0063] The RF coil includes a support board 33 having side edges 34 and the imaging system 4 defines a field of view 35 within the area of the board which can be seen in the X-Ray image with portions of the board outside the field of view being outside the image.

[0064] The circuitry of the coil includes conductive traces 36, capacitors 37, a fuse 41, a diode 38, a connecting wire 39, and a pre-amplifier 40. All of these elements are conventional in general construction and are well known to persons skilled in the art of coil design so that detailed explanation is not required here.

[0065] The conductive traces of the RF coil are arranged of a conductive material and typically copper which has a thickness T3 of at least 0.0018 cm (0.0007 inch) and preferably in the range 0.0036 cm to 0.0107 cm (0.0014 inch to 0.0042 inch) which is effective to receive the RF signals from the MR imaging system. Such traces typically cause an attenuation of the penetrating electromagnetic radiation which is clearly visible in the radiation image as compared with a uniform thickness support board material.

[0066] As shown in Figure 4, the support board is formed of a non-conductive material in the field of view which has a thickness T1 at locations on the board spaced from the traces selected such that an attenuation of the penetrating electromagnetic radiation at those locations is substantially equal to the attenuation at the conductive traces. Thus the attenuation of the board material at thickness T1 is arranged so that it is equal to the sum of the attenuation caused by the thickness T3 of the trace and thickness T2 of the board at the trace. In this way the attenuation of the penetrating electromagnetic radiation of substantially the whole of the RF coil located within the field of view is substantially constant throughout the field of view.

[0067] While the traces are shown in Figure 4 recessed into shallow areas of the board, the traces can be applied on top of the flat board and the variable thickness of the board applied at the rear. In addition, the board may be flat by filling recesses with a material which is transparent to X-Ray and thus does not affect the attenuation.

[0068] In Figure 5 is shown an alternative arrangement in which the board is formed of a base material 33A and an additional material 33B is added to the support board at areas separate from the traces, which material is non-conductive and has an attenuation factor that is it is not transparent to X-Ray and is different from the base material 33A. The base material and the additional material are laminated to form a common structure and the recesses may be filled by additional transparent material.

[0069] The conductive traces are arranged to be continuous throughout the field of view so as to have a constant attenuation. That is the conductive traces include no joints and therefore no solder within the field of view. Instead the traces are printed or otherwise applied as a constant continuous strip. Alternatively the traces are formed by etching away unwanted material from a continuous layer on the board leaving traces which are continuous and without joints.

[0070] As shown in Figure 3 all connector wires 39 from the coil are located outside the field of view 35 there are no connector wires from the conductive traces within the field of view.

[0071] The capacitors 37 and the fuse 41 for the coil are in most cases necessarily located within the field of view 35 and these are therefore arranged so that the attenuation of the penetrating electromagnetic radiation is substantially equal to the attenuation of the board at the conductive traces. Thus the capacitor and the fuse is itself formed from conductive traces which are designed and laid out on the board with the required amount of conductive material and the dielectric material to provide the required characteristics and values. The design of such components from conductive traces is known and within the skill of a person skilled in this art.

[0072] The support board includes mechanical mounting and support structures 42 for connection of the board to necessary elements but these are designed and arranged so that they are outside the field of view so that the board is generally constant and continuous and there are no mechanical structures within the field of view.

[0073] The necessary diode 38 is designed and arranged on the traces so that it is located outside field of view.

[0074] As an alternative, the diode or other necessary element is located within the field of view where the element has an attenuation different from the conductive traces and of a construction and high attenuation factor such that it cannot reasonably be compensated for by building the remainder of the board up to this high attenuation factor. In this arrangement, where element is located in the field of view, the location of the element in the field of view is constant and the image of the element in the radiation image is removed by software image analysis at the X-Ray receiver system 51.

[0075] Turning now to Figure 6 and 7 there is shown a modification according to the present invention, where the remaining parts of the coil not mentioned are as disclosed above.

[0076] The RF phased array coil shown in Figure 6 includes a support 60 defined by a single substrate sheet or as shown in Figure 7 two substrate sheets S1 and S2.

[0077] On the substrate 60 is mounted a plurality of individual coil loops 61 to 65 formed by conductive traces carried on the substrate.

[0078] The individual coil loops 61 and 62 are overlapped with each other so that a leg 62A of loop 62 lies adjacent to a leg 61A of loop 61 with two sections 62B and 62C at ends of the leg 62A of loop 62 crossing two corresponding sections 61 B and 61C at ends of the leg 61A of coil loop 61.

[0079] At each crossing such as crossings 61 B, 62B, the width of the trace is reduced from a width W1 at the remainder of the trace to a width W2 at the crossing. This is a known technique to reduce capacitive coupling between the loops for purposes of assisting in de-coupling the loops.

[0080] A review of the pattern shown in Figure 6 will show that loop 63 overlaps in symmetrical manner loops 61 and 62 to form leg 63D1 which lies alongside leg 61 D and leg 63D2 which lies alongside leg 62D. Each leg has crossing points at its ends. The legs 63D1 and 63D2 cross leg 62A at crossing 63D4 and leg 61A at crossing 63D5 forming a short section 63D3 between the crossings. The crossing section 63D4 crosses a corresponding section 62A4 of the leg 61. Also a symmetrical arrangement is made between coils 63, 64 and 65.

[0081] This general lay out of loops for phased array coils is previously known but the present invention provides a manner in which the individual loops can be decoupled using the known overlapping layout and also can be invisible in an X-ray image.

[0082] As shown in Figure 7, of the crossing sections 63D4 and 63D5 and each of the corresponding sections 62A4 and 61A4 has a thickness T2 in a direction at right angles to the substrate S1, S2 which is less than the thickness T1 of the legs 63D1, 63D2, 63D3, 62A and 61A.

[0083] Typically each of the crossing sections and each of the corresponding sections has the thickness T2 equal to one half of thickness T1 and each of the individual coil loops 61, 62 and 63 has the constant thickness T1 along the full length thereof, with the exception of crossing sections and corresponding sections.

[0084] As shown in Figure 6, individual coil loop 62 is arranged or printed on the first or top (in the orientation shown) surface S1T of the substrate sheet S1 and the individual coil loop 63 is arranged on a second opposed surface S1 B of the substrate sheet S1. In an arrangement wherein only loops 62 and 63 are provided with no additional overlapping loop 61, the substrate is formed by only the single sheet S1. However in the arrangement shown with the loop 61 included and overlapping with both, the second sheet S2 is provided on the bottom of the loop 63 so that its top surface S2T engages the loop 63 with the loop 62 on the bottom surface S2B of the sheet S2.

[0085] Thus the conductive traces 61, 62 and 63 of the RF coil arranged of a conductive material have a thickness such that the traces cause an attenuation of the penetrating electromagnetic radiation which is visible in the radiation image and, as explained above in relation to the cited prior application, the support substrate includes non-conductive material in the field of view which has a thickness selected such that an attenuation of the penetrating electromagnetic radiation at locations on the substrate sheet spaced from the traces is substantially equal to the attenuation at locations on the substrate sheet at the conductive traces. It will be noted that the overlapping sections are arranged with the thickness T2 over a length which matches almost so that the summation of the thickness of the loops measured over the whole coil surface is T!. Thus this can be matched with a thickness of the substrate or a material applied to eh substrate to provide a constant aluminum equivalent value over the whole coil structure within the intended field of view of the X-ray system.

[0086] As explained previously, the support substrate sheet can be formed of a single material of different thicknesses. Alternatively the support can be formed from a base material and an additional material different from the base material is added to the support substrate sheet so that the attenuation of the penetrating electromagnetic radiation of substantially the whole of the RF coil located within the field of view is substantially constant throughout the field of view.

[0087] The support formed by substrate sheets S1 and S2 is preferably flexible but this is not essential.

[0088] The conductive traces can be formed of copper or aluminum or other suitable materials well known to a person skilled in this art.

[0089] The support substrate sheets S1 and S2 are formed of fiber reinforced resin such as FR-4.

Claims

1. An RF phased array coil (32) for use in an MR imaging system for generating an MR image of a subject and for use in a radiation imaging system for generating a radiation image of said subject using penetrating electromagnetic radiation, the phased array coil comprising:

   conductive traces;
   a support (60) defined by at least one substrate sheet (S1);
   and a plurality of coil loops (61, 62) formed by said conductive traces mounted on said support (60);
   one of said coil loops (61, 62) overlapping another one of the coil loops (61, 62) so that a leg (61A) of said one coil loop lies adjacent to a leg (62A) of said other coil loop with two sections (61 B, 61 C) at opposite ends of the leg of said one coil loop crossing two corresponding sections (62B, 62C) at opposite ends of the leg of said other coil loop;

   characterized in that

   (i) each of the crossing sections (61 B, 61 C) and each of the corresponding sections (62B, 62C) has a thickness (T2) in a direction at right angle to the support (60) which is less than that (T1) of the legs; and
   (ii) the support (60) is formed of non-conductive material which has a thickness selected such that an attenuation of the penetrating electromagnetic radiation at locations on the support (60) spaced from the traces is substantially equal to the attenuation at locations on the support at the conductive traces;

such that an attenuation of the penetrating electromagnetic radiation caused by the RF coil within said radiation image is substantially constant throughout a field of view (35) of the radiation imaging system, when the RF phase array coil is kept in place during radiation imaging within said field of view, to avoid a visible artefact within said radiation image caused by the presence of the RF phased array coil (32).

2. The apparatus according to Claim 1 wherein each of the crossing sections (61 B, 61 C) and each of the corresponding sections (62B, 62C) has a thickness (T2) in a direction at right angle to the support which is equal to one half of that (T1) of the legs.

3. The apparatus according to claim 1 or 2 wherein each of the coil loops (61, 62) has a thickness (T1) along the full length thereof, with the exception of crossing sections and corresponding sections, which is constant.

4. The apparatus according to any one of claims 1 to 3 wherein said one of said coil loops (61, 62) is arranged on a first surface of the substrate sheet (S1) and said other of the individual coil loops (61, 62) is arranged on a second opposed surface of the substrate sheet (S1).

5. The apparatus according to any one of claims 1 to 4 wherein the support comprises first and second overlying laminated substrate sheets (S1, S2) and wherein said one of said coil loops (61, 62) is arranged on a first surface of the first substrate sheet (S1) and said other of the individual coil loops is arranged on a second opposed surface of the first substrate sheet (S1) so as to be located between the first and second substrate sheets (S1, S2).

6. The apparatus according to Claim 5 wherein there is provided a third of the coil loops which is located on a second opposed surface of the second substrate sheet (S2) and wherein the third coil loop is overlapped with said one and said other (62) of the coil loops.

7. The apparatus according to Claim 1 wherein the support is formed from common material.

8. The apparatus according to Claim 1 wherein the support is formed from a base material (33A) and an additional material (33B) different from the base material and added to the base material (33A).

9. The apparatus according to Claim 8 wherein the base material (33A) and the additional material (33B) are laminated to form a common structure.

10. The apparatus according to any preceding claim wherein the support is flexible.

Patentansprüche

1. Spule (32) einer phasengesteuerten HF-Antennengruppe zur Verwendung in einem MR-Bildgebungssystem zum Erzeugen eines MR-Bilds einer Person und zur Verwendung in einem Strahlungsbildgebungssystem zum Erzeugen eines Strahlungsbilds der Person unter Verwendung durchdringender elektromagnetischer Strahlung, wobei die Spule der phasengesteuerten Antennengruppe umfasst:

Leiterbahnen;
einen Halter (60), der durch wenigstens eine Substratlage (S1) definiert ist;
und mehrere Spulenwindungen (61, 62), die durch die an dem Halter (60) angebrachten Leiterbahnen gebildet sind;
wobei eine der Spulenwindungen (61, 62) eine andere der Spulenwindungen (61, 62) in der Weise überlappt, dass ein Schenkel (61A) der einen Spulenwindung angrenzend an einen Schenkel (62A) der anderen Spulenwindung liegt, wobei sich zwei Abschnitte (61 B, 61 C) an gegenüberliegenden Enden des Schenkels der einen Spulenwindung mit zwei entsprechenden Abschnitten (62B, 62C) an gegenüberliegenden Enden des Schenkels der anderen Spulenwindung schneiden; **dadurch gekennzeichnet, dass**

(i) jeder der sich schneidenden Abschnitte (61 B, 61 C) und jeder der einander entsprechenden Abschnitte (62B, 62C) in einer Richtung rechtwinklig zu dem Halter (60) eine Dicke (T2) aufweist, die kleiner als die (T1) der Schenkel ist; und
(ii) der Halter (60) aus einem nichtleitenden Material gebildet ist, das eine Dicke aufweist, die so gewählt ist, dass eine Dämpfung der durchdringenden elektromagnetischen Strahlung an Orten an dem Halter (60), die von den Leiterbahnen beabstandet sind, im Wesentlichen gleich der Dämpfung an Orten an dem Halter bei den Leiterbahnen ist;

so dass eine Dämpfung der durchdringenden elektromagnetischen Strahlung, die durch die HF-Spule innerhalb des Strahlungsbilds verursacht wird, über ein gesamtes Blickfeld (35) des Strahlungsbildgebungssystems im Wesentlichen konstant ist, wenn die Spule der phasengesteuerten HF-Antennengruppe während der Strahlungsbildgebung innerhalb des Blickfelds an ihrer Stelle gehalten wird, um einen durch die

Anwesenheit der Spule (32) der phasengesteuerten HF-Antennengruppe verursachten sichtbaren Artefakt innerhalb des Strahlungsbilds zu vermeiden.

2. Vorrichtung nach Anspruch 1, wobei jeder der sich schneidenden Abschnitte (61 B, 61 C) und jeder der entsprechenden Abschnitte (62B, 62C) eine Dicke (T2) in einer Richtung rechtwinkelig zu dem Halter aufweist, die gleich der Hälfte derjenigen (T1) der Schenkel ist.

3. Vorrichtung nach Anspruch 1 oder 2, wobei jede der Spulenwindungen (61, 62) mit Ausnahme der sich schneidenden Abschnitte und der entsprechenden Abschnitte entlang ihrer vollen Länge eine Dicke (T1) aufweist, die konstant ist.

4. Vorrichtung nach einem der Ansprüche 1 bis 3, wobei die eine der Spulenwindungen (61, 62) auf einer ersten Oberfläche der Substratlage (S1) angeordnet ist und die andere der einzelnen Spulenwindungen (61, 62) auf einer zweiten, gegenüberliegenden Oberfläche der Substratlage (S1) angeordnet ist.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, wobei der Halter eine erste und eine zweite, darüber liegende Schichtsubstratlage (S1, S2) umfasst und wobei die eine der Spulenwindungen (61, 62) auf einer ersten Oberfläche der ersten Substratlage (S1) angeordnet ist und die andere der einzelnen Spulenwindungen auf einer zweiten, gegenüberliegenden Oberfläche der ersten Substratlage (S1) angeordnet ist, so dass sie sich zwischen der ersten und der zweiten Substratlage (S1, S2) befindet.

6. Vorrichtung nach Anspruch 5, wo eine dritte der Spulenwindungen vorgesehen ist, die sich auf einer zweiten, gegenüberliegenden Oberfläche der zweiten Substratlage (S2) befindet, und wobei die dritte Spulenwindung mit der einen und mit der anderen (62) der Spulenwindungen überlappt ist.

7. Vorrichtung nach Anspruch 1, wobei der Halter aus einem gemeinsamen Material gebildet ist.

8. Vorrichtung nach Anspruch 1, wobei der Halter aus einem Grundmaterial (33A) und aus einem Zusatzmaterial (33B), das von dem Grundmaterial verschieden ist und das zu dem Grundmaterial (33A) hinzugefügt ist, gebildet ist.

9. Vorrichtung nach Anspruch 8, wobei das Grundmaterial (33A) und das Zusatzmaterial (33B) zum Bilden einer gemeinsamen Struktur geschichtet sind.

10. Vorrichtung nach einem vorhergehenden Anspruch, wobei der Halter biegsam ist.

Revendications

1. Bobine de réseau phasé RF (32) destinée à être utilisée dans un système d'imagerie RM pour générer une image RM d'un sujet et destinée à être employée dans un système d'imagerie par rayonnements pour générer une image par rayonnements dudit sujet en utilisant un rayonnement électromagnétique pénétrant, la bobine de réseau phasé comprenant :

des traces conductrices ;
un support (60) défini par au moins une feuille de substrat (S1) ;
et une pluralité de boucles de bobine (61, 62) formées par lesdites traces conductrices montées sur ledit support (60) ;
une desdites boucles de bobine (61, 62) chevauchant une autre des boucles de bobine (61, 62) de façon à ce qu'une patte (61A) de ladite une boucle de bobine soit adjacente à une patte (62A) de l'autre boucle de bobine avec deux sections (61 B, 61 C) à des extrémités opposées de la patte de ladite une boucle de bobine traversant deux sections correspondantes (62B, 62C) à des extrémités opposées de la patte de ladite autre boucle de bobine ;
caractérisée en ce que

(i) chacune des sections transversales (61 B, 61 C) et chacune des sections (62B, 62C) correspondantes présente une épaisseur (T2) dans une direction en angle droit par rapport au support (60) qui est inférieure à celle (T1) des pattes ; et
(ii) le support (60) est formé d'un matériau non-conducteur qui présente une épaisseur sélectionnée de telle sorte qu'une atténuation du rayonnement électromagnétique pénétrant à des emplacements sur le support (60) espacés des traces, est essentiellement égale à l'atténuation à des emplacements sur le support sur les traces conductrices ;

de telle sorte qu'une atténuation du rayonnement électromagnétique pénétrant provoquée par la bobine RF à l'intérieur de ladite image de rayonnement est essentiellement constante sur tout le champ de visualisation (35) du système d'imagerie par rayonnements, lorsque la bobine de réseau phasé RF est maintenue en place pendant l'imagerie par rayonnements à l'intérieur dudit champ de visualisation pour éviter un artefact visible à l'intérieur de ladite image par rayonnements provoqué par la présence de la bobine de réseau phasé RF (32).

2. Appareil selon la revendication 1, dans lequel chacune des sections transversales (61 B, 61 C) et chacune des sections (62B, 62C) correspondantes présente une épaisseur (T2) dans une direction en angle droit par rapport au support qui est égale à une moitié de celle (T1) des pattes.

3. Appareil selon la revendication 1 ou 2, dans lequel chacune des boucles de bobine (61, 62) présente une épaisseur (T1) sur toute la longueur de celle-ci, à l'exception des sections transversales et des sections correspondantes, qui est constante.

4. Appareil selon l'une quelconque des revendications 1 à 3, dans lequel ladite une desdites boucles de bobine (61, 62) est agencée sur une première surface de la feuille de substrat (S1) et ladite autre des boucles de bobine (61, 62) individuelles est agencée sur une deuxième surface opposée de la feuille de substrat (S1).

5. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel le support comprend des première et deuxième feuilles de substrat stratifiées (S1, S2) et dans lequel ladite une desdites boucles de bobine (61, 62) est agencée sur une première surface de la première feuille de substrat (S1) et ladite autre des boucles de bobine individuelles est agencée sur une deuxième surface opposée de la première feuille de substrat (S1) de façon à être située entre les première et deuxième feuilles de substrat (S1, S2).

6. Appareil selon la revendication 5, dans lequel il est prévu une troisième des boucles de bobine qui est située sur une deuxième face opposée de la deuxième feuille de substrat (S2) et dans lequel ladite troisième boucle de bobine est chevauchée par ladite une et ladite autre (62) des boucles de bobine.

7. Appareil selon la revendication 1, dans lequel le support est formé d'un matériau commun.

8. Appareil selon la revendication 1, dans lequel le support est formé d'un matériau de base (33A) et d'un matériau supplémentaire (33B) différent du matériau de base et ajouté au matériau de base (33A).

9. Appareil selon la revendication 8, dans lequel le matériau de base (33A) et le matériau supplémentaire (33B) sont stratifiés pour former une structure commune.

10. Appareil selon l'une quelconque revendication précédente, dans lequel le support est flexible.

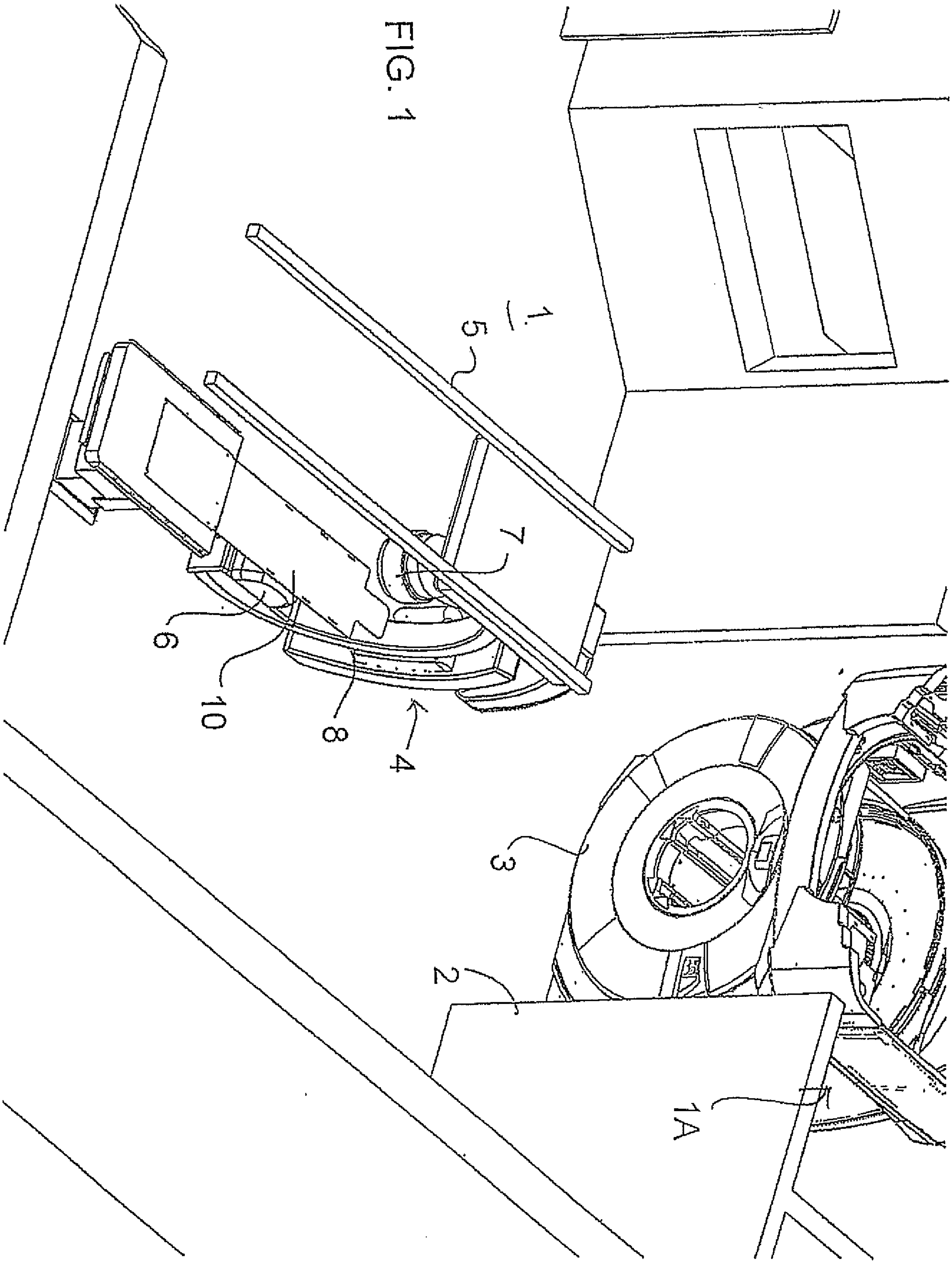


FIG. 1

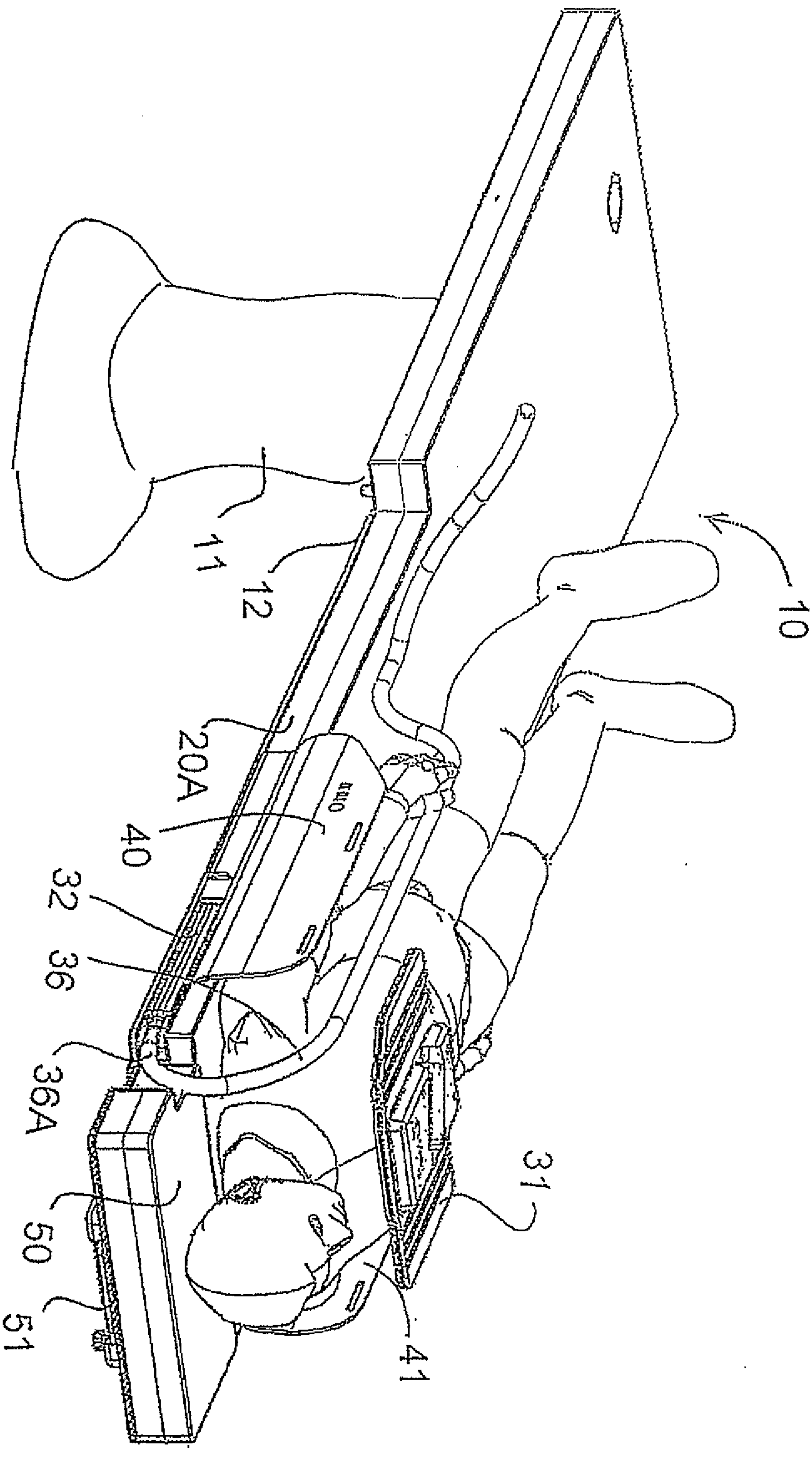
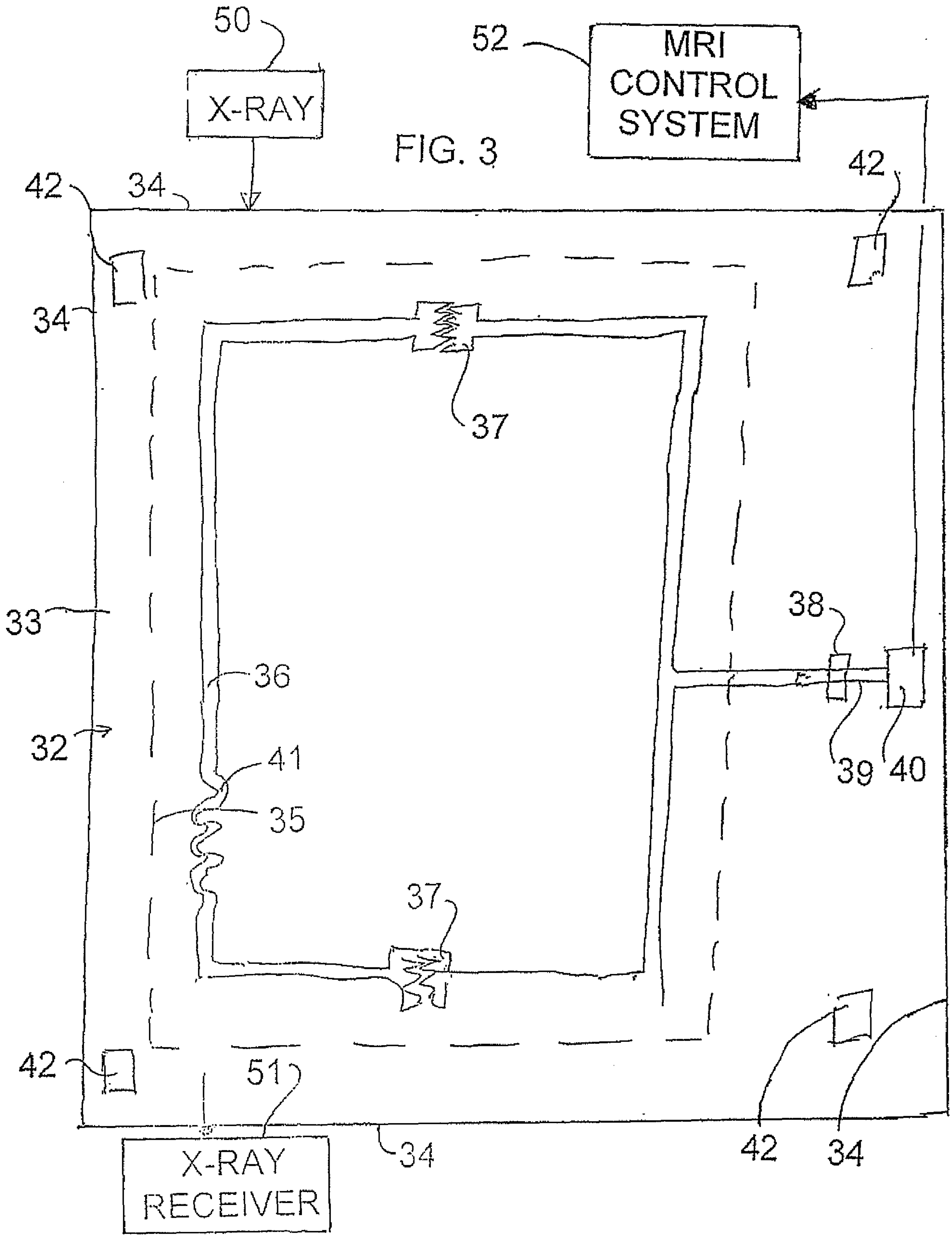


FIG. 2


50
X-RAY
52
MRI
CONTROL
SYSTEM
FIG. 3
42
34
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34
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41
35
37
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51
X-RAY
RECEIVER
34
42
34

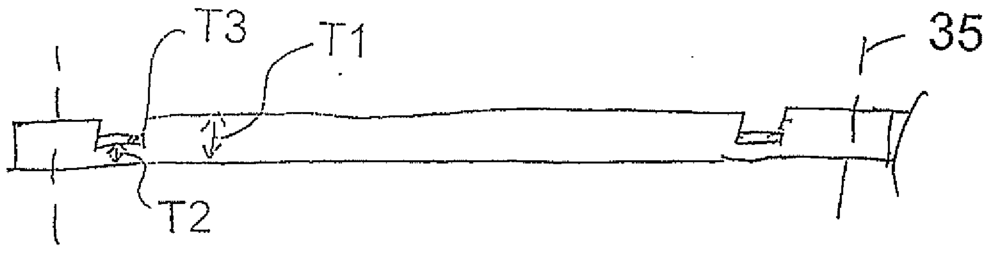

FIG. 4

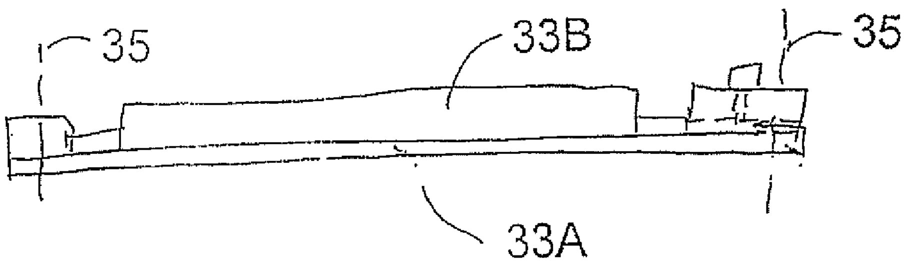

FIG. 5

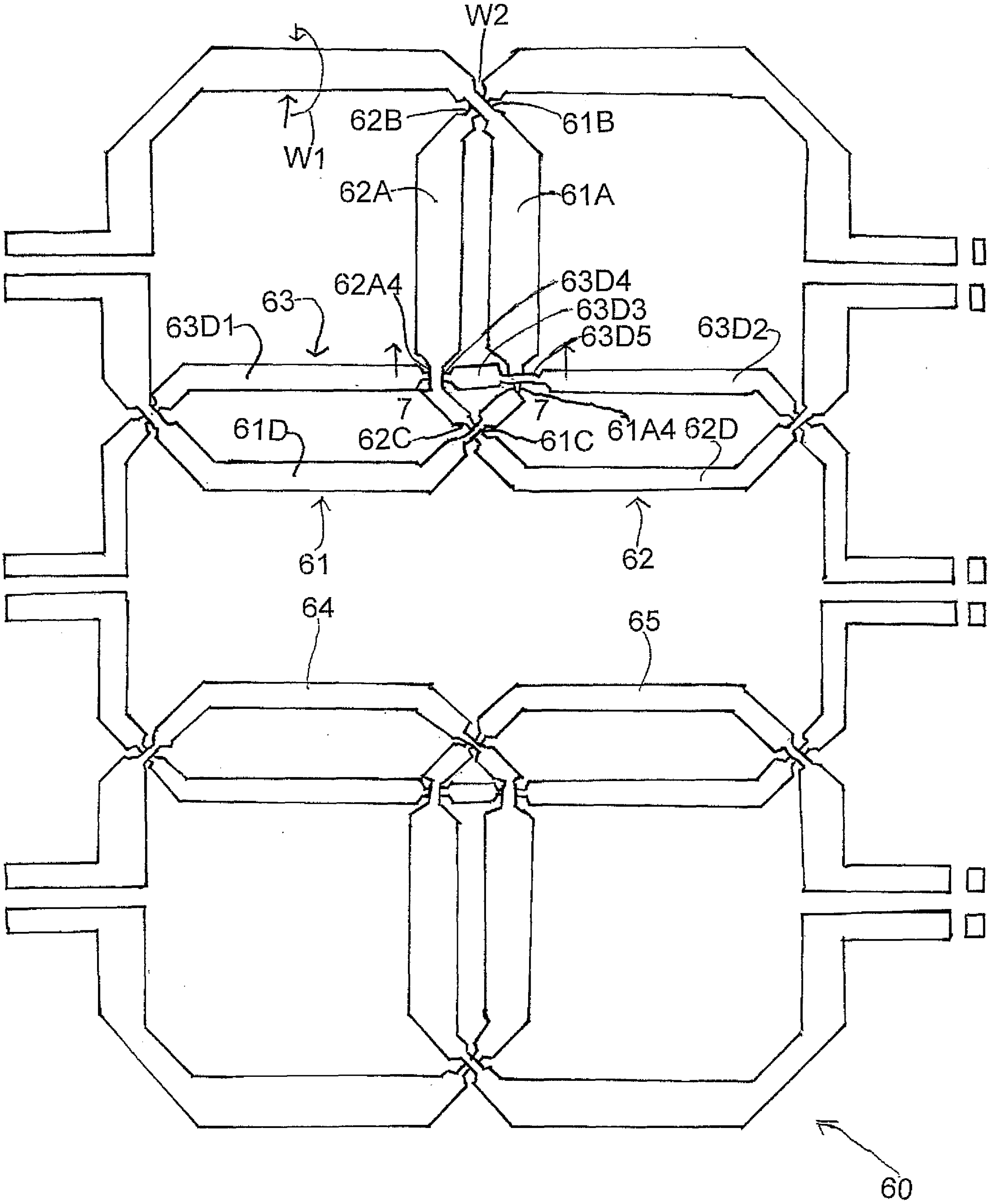
W2
W1
62B
61B
62A
61A
62A4
63D4
63D3
63D5
63
63D1
63D2
7
7
61D
62C
61C
61A4
62D
61
62
64
65
60

FIG.6

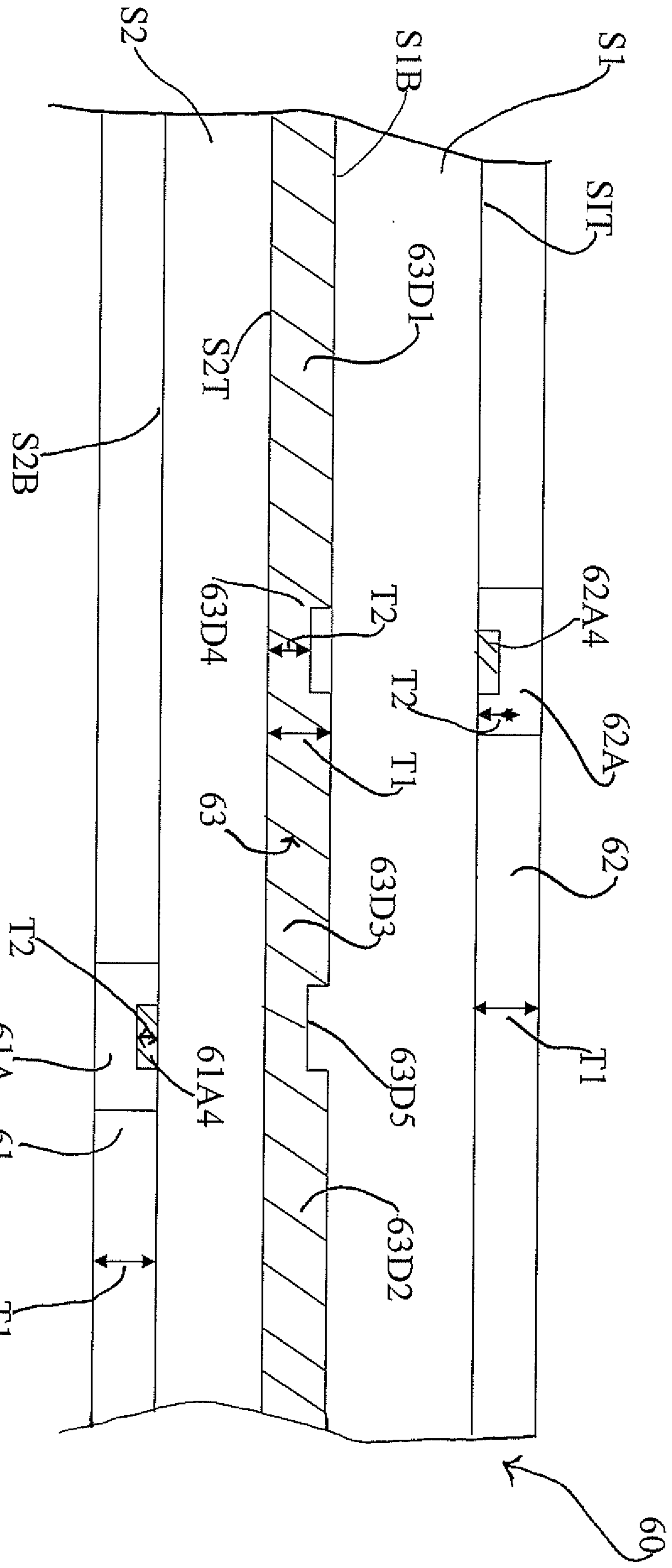
S2
S1B
S1
S1T
63D1
S2T
S2B
62A4
T2
63D4
T2
62A
T1
63
62
63D3
T2
T1
61A
61A4
63D5
61
63D2
T1
60

FIG.7

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	相控阵MR射频线圈在X射线图像中不可见		
公开(公告)号	EP2523011B1	公开(公告)日	2017-04-19
申请号	EP2012167077	申请日	2012-05-08
[标]申请(专利权)人(译)	IMRIS		
申请(专利权)人(译)	IMRIS INC.		
当前申请(专利权)人(译)	IMRIS INC.		
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发明人	SCHELLEKENS, WAYNE PETROPOULOS, LABROS CHAMPAGNE, KIRK FALLAH-RAD, MEHRAN ZHU, HAOQIN		
IPC分类号	G01R33/3415 A61B6/04 A61B6/00 G01R33/48 A61B5/055 G01R33/36 A61N5/10 A61B5/00		
CPC分类号	G01R33/3415 A61B5/0035 A61B5/0555 A61B6/0407 A61B6/4417 A61B6/5247 A61N2005/1055 G01R33/365 G01R33/4812		
代理机构(译)	JOSTARNDT PATENTANWALTS-AG		
优先权	61/484058 2011-05-09 US		
其他公开文献	EP2523011A1		
外部链接	Espacenet		

摘要(译)

用于MR成像的相控阵RF线圈（32）被设计成使其在X射线成像系统的视场中保持就位并且包括支撑板（33），在该支撑板上承载铜或铝导电迹线。由迹线（36）引起的X射线的衰减在辐射图像中是可见的，但是这通过布置支撑板的非导电材料使得衰减基本恒定来补偿。相控阵包括单独的线圈环，其与迹线（36）重叠，在迹线的交叉位置处具有半厚度，并且在一侧具有一个环（61,62）而在第二侧具有另一个环。基板。