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(54) Title: TRANSMIT/RECEIVE COIL FOR ULTRA-HIGH FIELD MRI
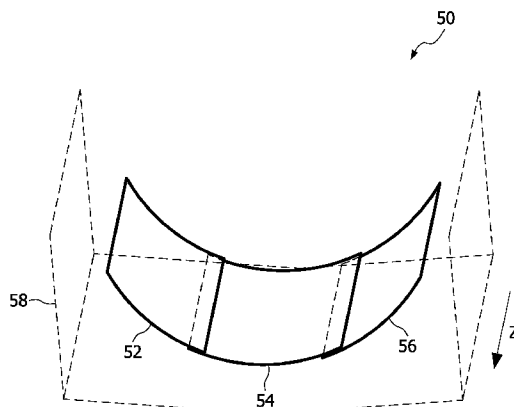
FIG. 4

(57) Abstract: A magnetic resonance coil comprises a first set of coil elements (54, 56, 80) operatively connectable with a transmit
channel (66, 74) to couple with a transmit region of sensitivity for a selected load at a magnetic field strength greater than 3 Tesla,
and a second set of coil elements (52, 54, 82) operatively connectable with a receive channel (66, 74) to couple with a receive region
of sensitivity for the selected load at the magnetic field strength greater than 3 Tesla. The first set of coil elements is arranged
proximate to but not surrounding the transmit region of sensitivity, and the second set of coil elements is arranged proximate to but
not surrounding the receive region of sensitivity. The first set of coil elements and the second set of coil elements having at least one
coil element (52, 56) not in common. The first and second sets of coil elements define transmit and receive regions of sensitivity for
the selected load at the magnetic field strength greater than 3 Tesla that are substantially similar.

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Transmit/Receive Coil for Ultra-High Field MRI

FIELD OF THE INVENTION

The following relates to the magnetic resonance arts. The following finds illustrative application to magnetic resonance imaging and spectroscopy, and is described with particular reference thereto. However, the following will find application in other magnetic resonance and radio frequency applications.

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BACKGROUND

At low magnetic field, for example at 1.5 Tesla, the magnetic resonance frequency is relatively low, resulting in a corresponding radio frequency (RF) wavelength that is relatively long compared to the size of the object. As a result, a low magnetic field tends to provide good spatial uniformity on the scale of a typical human anatomical region 10 of interest (e.g., head, torso, limb, or so forth). Accordingly, those skilled in the art have typically employed a volume coil such as a birdcage coil for magnetic resonance excitation, and have used a volume coil or a local coil (possibly comprising a plurality of coil elements) for magnetic resonance signal reception. The tendency toward good spatial uniformity for magnetic resonance at low magnetic field has led to substantial clinical and diagnostic 15 success with such systems. However, low magnetic field has certain disadvantages with acquisition time constraints in mind, such as relatively lower spatial resolution, lower signal strength and correspondingly lower signal-to-noise ratio (SNR), and so forth.

Accordingly, there has been continued interest in performing magnetic resonance imaging and spectroscopy at higher magnetic fields. At high magnetic field, for 20 example at 7 Tesla, the magnetic resonance frequency is substantially higher (in proportion to the main field), the corresponding radio frequency (RF) wavelength is substantially shorter, and tissue properties and object shape (load) can lead to substantial B_1 non-uniformity on the scale of a typical human head or extremity such as calf. As a result, at high magnetic field those skilled in the art have explored ways to improve B_1 uniformity for 25 head imaging and use local coils for other anatomical regions for both magnetic resonance excitation and reception.

At 1.5 Tesla, if the same surface coil (which, again, may be an array or other plurality of coil elements) is used for both excitation and reception, it has generally been accepted that the coil will excite and read from the same region of sensitivity of the proximate load. This is because the $|B_1^+|$ transmit field and the $|B_1^-|$ field sensed by the coil are both reasonably similar, having regions of sensitivity that substantially overlap. At higher fields like 7T, the region of sensitivity may exhibit substantial load-induced non-uniformity and asymmetry, even for a uniform object. Even worse, the transmit and receive sensitivity patterns are different spatially. Sensitivity in this context refers to the $|B_1^+|$ field that is generated at a spatial point per unit current and the $|B_1^-|$ spatial field intensity that can generate a unit of current in the receive antenna. Recognition of the erroneous presumption that the transmit and receive fields substantially overlap has led to certain improvements in the art as disclosed herein.

SUMMARY OF THE INVENTION

In accordance with certain illustrative embodiments shown and described as examples herein, a magnetic resonance coil is disclosed, comprising: a first set of coil elements operatively connectable with a transmit channel to couple with a transmit region of sensitivity for a selected load at a magnetic field strength, the first set of coil elements being arranged proximate to but not surrounding the transmit region of sensitivity; a second set of coil elements operatively connectable with a receive channel to couple with a receive region of sensitivity for the selected load at the magnetic field strength, the second set of coil elements being arranged proximate to but not surrounding the receive region of sensitivity; the first set of coil elements and the second set of coil elements having at least one coil element not in common; and the first and second sets of coil elements defining substantially similar transmit and receive regions of sensitivity for the selected load at the magnetic field strength.

In accordance with certain illustrative embodiments shown and described as examples herein, a magnetic resonance coil is disclosed, comprising: a first set of coil elements operatively connectable with a transmit channel to couple with a selected region of sensitivity of a selected load at a magnetic field strength; and a second set of coil elements operatively connectable with a receive channel to couple with the same selected region of sensitivity of the selected load at the magnetic field strength; the first set of coil elements and the second set of coil elements being spatially offset from each other and having at least one coil element not in common.

In accordance with certain illustrative embodiments shown and described as examples herein, a magnetic resonance method is disclosed, comprising: positioning a first set of coil elements asymmetrically respective to a selected region of sensitivity of a selected load at a magnetic field strength; positioning a second set of coil elements asymmetrically respective to the selected region of sensitivity of the selected load at the magnetic field strength, the asymmetric position of the second set of coil elements respective to the selected region of sensitivity being different from the asymmetric position of the first set of coil elements respective to the selected region of sensitivity; generating magnetic resonance in the selected region of sensitivity of the selected load at the magnetic field strength using the asymmetrically positioned first set of coil elements; and receiving a magnetic resonance signal from the selected region of sensitivity of the selected load at the magnetic field strength using the differently asymmetrically positioned second set of coil elements.

One advantage resides in improved correspondence between the transmit and receive sensitivity regions.

Another advantage resides in improved magnetic resonance at high magnetic field.

Another advantage resides in magnetic resonance coils with improved performance at high magnetic field.

Another advantage resides in better targeting of magnetic resonance excitation and signal reception.

Still further advantages of the present invention will be appreciated by those of ordinary skill in the art upon reading and understand the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects will be described in detail hereinafter, by way of example, on the basis of the following embodiments, with reference to the accompanying drawings, wherein:

FIGURE 1 diagrammatically shows a magnetic resonance scanner system;

FIGURE 2 diagrammatically shows a magnetic resonance coil including two surface coil elements used in the system of FIGURE 1. The coil aligns along the direction of main magnetic field B_0 (z-axis);

FIGURE 3 plots finite difference time domain (FDTD) modeling results of the quadrature transmit $|B_1^+|$ field (lefthand side) and quadrature receive $|B_1^-|$ field (righthand

side) in the center transverse slice for the coil of FIGURE 2 loaded with a uniform cylindrical object. Higher B_1 field strengths are plotted relatively brighter than lower B_1 field strengths;

FIGURE 4 diagrammatically shows a magnetic resonance coil including three surface coil elements. The coil aligns along the direction of main magnetic field B_0 (z-axis);

FIGURE 5 diagrammatically shows a transmit/receive selection box for use in operating the three-element coil of FIGURE 4 using different coil elements (loops) for the transmit and receive phases;

FIGURE 6 plots FDTD modeling results of the transmit $|B_1^+|$ field (lefthand side) and receive $|B_1^-|$ field (righthand side) in the center transverse slice for the coil of FIGURE 4 loaded with the load of FIGURE 2 and operated by the selection box of FIGURE 5. Higher B_1 field strengths are plotted relatively brighter than lower B_1 field strengths; and

FIGURE 7 diagrammatically shows a magnetic resonance coil and a single transmit/receive channel for operating the coil, with an interposed transmit/receive switch box configured to operate the coil using a first sub-set of coil elements for the transmit phase and a second subset of coil elements for the receive phase.

DETAILED DESCRIPTION OF EMBODIMENTS

With reference to FIGURE 1, a magnetic resonance scanner 10 includes a main magnet 12 generating a static (B_0) magnetic field having a field direction oriented parallel or anti-parallel with an axial or "z" direction (indicated in FIGURE 1) in an examination region 14 in which is disposed a subject 16 (shown in dashed line in FIGURE 1). The illustrated magnetic resonance scanner 10 is a horizontal bore-type scanner shown in cross-section to reveal selected components; however, other types of magnetic resonance scanners can be used. The magnetic resonance scanner 10 is a high-field scanner in which the main magnet 12 produces the static main magnetic field (also known as B_0 magnetic field) in the examination region 14 at a magnetic field strength greater than 3 Tesla, and in some embodiments greater than or about 5 Tesla. In some embodiments, the main magnet 12 produces a static (B_0) magnetic field in the examination region 14 at a magnetic field strength of 7 Tesla. Higher magnetic field strengths are also contemplated.

The magnetic resonance scanner 10 also includes magnetic field gradient coils 18 that superimpose selected magnetic field gradients on the static (B_0) magnetic field to perform various tasks such as spatially restricting magnetic resonance excitation, spatially encoding magnetic resonance frequency and/or phase, spoiling magnetic resonance, or so

forth. Optionally, the magnetic resonance scanner may include other elements not shown in FIGURE 1, such as a bore liner, active coil or passive ferromagnetic shims, or so forth. The subject 16 is suitably prepared by being placed on a movable subject support 20 which is then inserted along with the supported subject 16 into the illustrated position for magnetic resonance acquisition. For example, the subject support 20 may be a pallet or table that is initially disposed on a couch 22 adjacent the magnetic resonance scanner 10, the subject 16 placed onto the support 20 and then slidably transferred from the couch 22 into the bore of the magnetic resonance scanner 10.

With continuing reference to FIGURE 1 and with further reference to FIGURE 2, a magnetic resonance coil 30 is disposed on or with the subject 16 in the examination region 14. As seen in FIGURE 2, the magnetic resonance coil 30 includes two surface coil elements 32, 34 disposed on the subject 16, and a distally located radio frequency screen or shield 36 which can have beneficial effects such as reducing stray radio frequency interference, enhancing coupling with the subject at the magnetic resonance frequency, or so forth. The illustrated coil elements 32, 34 laterally overlap slightly; however, in other embodiments the coils may be spaced apart or precisely adjoining with no overlap. In FIGURE 2, a region of sensitivity 40 with which the radio frequency coil 30 is intended to couple is diagrammatically indicated in dotted line. In the illustrated example, the region of sensitivity 40 is cylindrical and comports approximately with a curvature of the surface coil elements 32, 34; however, otherwise-shaped or oriented regions of interest are also contemplated. The example shown reasonably simulates an adult human lower extremity.

In the illustrative example of FIGURE 2, the coil 30 is a half-volume or partial-volume surface coil of a type sometimes used at 1.5T or 3T, typically as a receive only coil, or at 4T as a transmit/receive coil. The coil is made of the two curved loop coil elements 32, 34 suitable for human calf imaging or spectroscopy. The nucleus of interest is ^{1}H (64 MHz at 1.5T, 128 MHz at 3T and 298 MHz at 7T). To simulate coil performance at high magnetic field, the coil 30 was simulated using a finite difference time domain (FDTD) modeling method, with the coil loaded with a uniform 11.4 cm-diameter cylindrical phantom ($\sigma = 0.855$S/m, $\varepsilon_r = 80$) to represent portion of a leg in a 7 Tesla B_0 field. The left loop 32 and right loop 34 are both used during transmit and receive through a 90° quadrature transmit/receive switch box (not shown). At 1.5T or 3T the coil array is expected to generate relatively uniform and symmetrical B_1 in the bottom region of the phantom with some regular gradation from top to bottom.

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With reference to FIGURE 3, however, at 7 Tesla the transmit $|B_1^+|$-field (left-hand side of FIGURE 3) and receive $|B_1^-|$-field (right-hand side of FIGURE 3) show substantial asymmetric inhomogeneity. The regions of maximum sensitivity for transmit and receive do not overlap. As seen in FIGURE 3, both the transmit and receive B_1 intensity distributions are off-centered toward the bottom region of the phantom. More generally, the non-uniformity is a function of the shape and properties of the selected load at the selected magnetic field of 7 Tesla, and is expected to be exhibited for most coils at high magnetic field (e.g., greater than 3 Tesla). The observed difference in the transmit and receive field simulations (left-hand and right-hand sides of FIGURE 3, respectively) is a behavior that generally worsens with increased frequency of operation. It has been observed at 3 Tesla in the body, but the trend to address it at 3 Tesla has generally been to use multi-channel transmit or B_1 shimming. Multi-channel transmit solutions tend to be more expensive and complex.

With the recognition of this heretofore generally uncorrected effect, it becomes feasible to design the coil and/or the coil excitation to reduce the effect without substantial hardware and software cost. For example, review of FIGURE 3 indicates that the transmit region of sensitivity is rotated relatively to the left while the receive region of sensitivity is rotated relatively to the right. Accordingly, improved overlap of the transmit regions of sensitivity in the bottom region of the phantom is expected by physically rotating the coil element 32 and 34 some degree counter clockwise for transmitting the B_1 excitation field. Similarly, improved matching or overlap of the receive region of sensitivity in the bottom region of the phantom is expected by physically rotating coil element 32 and 34 some degree clockwise for receiving the magnetic resonance. In practice, physically rotating coil element 32 and 34 during the MR imaging time is not practical. However, with one more coil element added to the coil 30, the equivalence of physically rotating coil elements for transmitting and for receiving can be accomplished by selectively using two of the three coil elements (or another selected subset of an array of coils) for each function.

More generally, the non-uniform B_1-field demonstrated by the FDTD modelling of the half-volume quadrature array coil 30 loaded with the uniform phantom 40, leads to the concept of a spatially selective transmit and spatially selective receive scheme with an array of coil elements. The elements of a transmit/receive (T/R) array coil are selected/detuned with a suitable T/R switch box, which selects some or all of the coil elements for use during the transmit phase and selects (a generally different) some or all of the coil elements for use during the receive phase. A conventional linear or quadrature T/R

switch box can be used with additional diode switch circuitry in order to selectively tune/detune selected elements of the array coil during transmit and receive. In some embodiments, the selective excitation and receive configurations are selected based on the object and surface coil geometry with fixed radio frequency (RF) amplitude and 90° quadrature phase. In other embodiments, a phase difference other than 90° is contemplated, depending on coil geometry and B_1-field optimization. Optionally, transmission line lengths in the coil array can be adjusted to provide a phase difference of 90° or another selected phase difference.

With reference to FIGURES 4 and 5, a magnetic resonance coil 50 is a partial-volume surface coil made of the three curved loop coil elements 52, 54, 56 shielded by a radio frequency shield or screen 58, and is driven by a transmit/receive switch box 60 diagrammatically shown in FIGURE 5. In this embodiment, the rightmost two coil elements 54, 56 of the array are used in quadrature mode for the transmit phase, while the leftmost two coil elements 52, 54 of the array are used in quadrature mode for the receive phase. The circuitry of FIGURE 5 accomplishes this operation using a -90° phase shifter 62 and switching diodes 64. When all the switching diodes 64 are ON (i.e., conducting), coil elements 54, 56 are driven in quadrature while coil element 52 is disconnected or operatively isolated. This is the configuration for the transmit phase. To ensure that the coil element 52 is disconnected or operatively isolated, connecting transmission line lengths 65, 67 should be quarter-wavelength transmission lines which present a high impedance when the diodes are on. When all the switching diodes 64 are OFF (i.e., non-conducting), coil elements 52, 54 are driven in quadrature while coil element 56 is disconnected or operatively isolated. This is the configuration for the receive phase. The effect of transmitting in quadrature using the two coil elements 54, 56 without the coil element 52 is to transmit with a two-element array rotated to the right. The effect of receiving in quadrature using the two coil elements 52, 54 without the coil element 56 is to receive with a two-element array rotated to the left. Referring back to FIGURE 3, it can be seen that the effect of these rotations is to improve the relative alignment or overlap of the transmit and receive regions of sensitivity.

With reference to FIGURE 6, FDTD simulations of the three-element coil 50 support this conclusion, and show that the three-element coil 50 operated using the single transmit/receive channel 66 via the transmit/receive switch box 60 provides transmit and receive regions of sensitivity with good relative alignment, especially in the lower region closest to the three-element coil 50.

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With reference to FIGURE 7, in a general arrangement a magnetic resonance coil 70 comprising an array of two or more coil elements 72 (four coil elements 72 in the diagrammatic illustrative example of FIGURE 7) are selectively operatively connectable with a single transmit/receive channel 74 by a transmit/receive switch box 76 which is configured 5   to operatively connect a first sub-set 80 of coil elements 72 during the transmit phase and to operatively connect a different (but possibly overlapping) second sub-set 82 of the coil elements 72 during the receive phase. A coil elements selection signal 84 is suitably input to the switch box 76 to change the configuration between the transmit configuration and the receive configuration. For example, the signal 84 can be a binary signal (e.g., "1" for the 10   transmit configuration and "0" for the receive configuration or vice versa) or can be a set of signals individually selecting and deselecting each coil element 72. The transmit sub-set 80 of coil elements is generally positioned asymmetrically respective to the transmit region of sensitivity, and similarly the receive sub-set 82 of coil elements is generally positioned asymmetrically respective to the receive region of sensitivity. The sub-sets 80, 82 are 15   selected such that the transmit and receive regions of sensitivity are substantially similar. For example, "substantial similarity" may be satisfied by having at least the region of maximum sensitivity for transmit and receive overlap in space. This is accomplished by recognizing and accommodating the asymmetries between the coil elements used for excitation or reception and their respective transmit and receive regions of sensitivity. The result is that the first 20   sub-set of coil elements used for transmit and the second sub-set of coil elements used for receive are positioned asymmetrically respective to each other so as to provide substantially similar transmit and receive regions of interest. In some embodiments, the effect of this accommodation is that the transmit region of sensitivity and the substantially similar receive region of sensitivity are each positioned substantially symmetrically respective to a union of 25   the first and second sub-sets 80, 82 of coil elements. Similarly, in some embodiments in which there are some common coils that are members of both the first and second sub-sets 80, 82 of coil elements, the set of one or more common coil elements is positioned substantially symmetrically respective to the substantially similar transmit and receive regions of sensitivity. For example, in the three-element coil 50 of FIGURE 4, the common 30   coil element 54 is positioned substantially symmetrically respective to the substantially similar transmit and receive regions of sensitivity as indicated by the FDTD simulations of FIGURE 6.

In accommodating the asymmetries, the first set 80 of coil elements and the second set 82 of coil elements are spatially offset from each other and have at least one coil

element not in common. In some embodiments, such as the illustrative embodiment of FIGURE 4 where the first sub-set of coil elements includes the coil elements 54, 56 and the second sub-set of coil elements includes the coil elements 52, 54, the two sub-sets have one or more coil elements in common (namely coil element 54 in the example of FIGURE 4). In other embodiments, the two sub-sets may have no coil elements in common.

At a magnetic field strength greater than 3 Tesla, or more predominantly greater than 5 Tesla, or still more predominantly at greater than 7 Tesla, the transmit $|B_1^+|$ and receive $|B_1^-|$ distribution patterns are substantially influenced by the load imposed by the imaged object or subject. As a result, the transmit and receive B_1 distributions are generally not uniform or symmetric, and (as shown herein) are generally different for the transmit and receive phases when the same coil elements are used for both phases. Accordingly, it is disclosed herein to use a non-symmetric selection of coil elements for the transmit and receive phases, respectively, with the surprising result that the transmit and receive regions of sensitivity can be made substantially similar for a given load at a particular magnetic field strength by suitable selection of the different transmit and receive coil element sub-sets. For a specific array coil designed for specific anatomy imaging, the selection of transmit and receive coil element sub-sets can be made based on B_1-map measurements or numerical calculations to determine which elements to use for transmit and which elements to use for receive. Additionally, such mapping or numerical calculation can be used to adjust or optimize positions of individual coil elements to further enhance the substantial similarity of the transmit and receive regions of sensitivity. Similarly, the phase shift of the nominally quadrature operation can be adjusted for this purpose in embodiments that employ quadrature excitation and reception.

In the illustrated embodiments, the coil elements have been shown as single loop surface coil elements. More generally, the coil elements can be single-loop surface coil elements, multiple-loop surface coil elements, tuned axial stripline surface coil elements, other types of coil elements, or various combinations thereof. In addition the array of coils may consist of adjacent groups of coils in the axial direction to increase coverage of the selected anatomy. For example, the coil illustrated in Figure 4 may be duplicated in the axial direction to create two such coils that are selectively chosen based on the region of interest. In this way greater anatomical coverage can be obtained. While the illustrated embodiments employ surface coils, other non-volumetric arrays of coil elements are similarly expected to exhibit asymmetry in the transmit and receive regions of sensitivity when operated as a unit, and can similarly be improved upon by addition of a transmit/receive switch box that selects

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different sub-sets of coil elements for use in transmission and reception so as to provide substantially similar transmit and receive regions of sensitivity. In the illustrated embodiments, the single transmit/receive channel has been operatively connected to the coils for transmit or receive in quadrature. However, a linear operative connection or other

5   electrical connection is also contemplated, or the transmit and receive channels can be arranged separately.

The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be

10   construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a

15   plurality of such elements. The disclosed method can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the system claims enumerating several means, several of these means can be embodied by one and the same item of computer readable software or hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a

20   combination of these measures cannot be used to advantage.

CLAIMS:

Having thus described the preferred embodiments, the invention is now claimed to be:

1.   A magnetic resonance coil comprising:

a first set of coil elements (54, 56, 80) operatively connectable with a transmit channel (66, 74) to couple with a transmit region of sensitivity for a selected load at a magnetic field strength, the first set of coil elements being arranged proximate to but not surrounding the transmit region of sensitivity;

a second set of coil elements (52, 54, 82) operatively connectable with a receive channel (66, 74) to couple with a receive region of sensitivity for the selected load at the magnetic field strength, the second set of coil elements being arranged proximate to but not surrounding the receive region of sensitivity;

the first set of coil elements and the second set of coil elements having at least one coil element (52, 56) not in common; and

the first and second sets of coil elements defining substantially similar transmit and receive regions of sensitivity for the selected load at the magnetic field strength.

2.   The magnetic resonance coil as set forth in claim 1, wherein the first set of coil elements (54, 56, 80) and the second set of coil elements (52, 54, 82) have at least one coil element (54) in common.

3.   The magnetic resonance coil as set forth in claim 1, wherein the first set of coil elements (54, 56, 80) includes:

a first sub-set of one or more coil elements (56) connectable with the transmit channel (66) at a first phase, and

a second sub-set of one or more coil elements (54) connectable with the transmit channel (66) at a second phase in 90° quadrature respective to the first phase; and the second set of coil elements (52, 54, 82) includes:

a first sub-set of one or more coil elements (54) connectable with the receive channel (66) at a first phase, and

a second sub-set of one or more coil elements (52) connectable with the receive channel (66) at a second phase in 90° quadrature respective to the first phase.

4.   The magnetic resonance coil as set forth in claim 1, wherein the first set of coil elements (54, 56, 80) includes:

a first sub-set of one or more coil elements (56) connectable with the transmit channel (66) at a first phase, and

a second sub-set of one or more coil elements (54) connectable with the transmit channel (66) at a second phase different from the first phase;
and the second set of coil elements (52, 54, 82) includes:

a first sub-set of one or more coil elements (54) connectable with the receive channel (66) at a third phase, and

a second sub-set of one or more coil elements (52) connectable with the receive channel (66) at a fourth phase different from the third phase.

5.   The magnetic resonance coil as set forth in claim 4, wherein the phase difference between the first and second phases and the phase difference between the third and fourth phases is selected by adjustment of transmission line lengths in the corresponding coil elements.

6.   The magnetic resonance coil as set forth in claim 1, wherein each coil element of the first set of coil elements (54, 56, 80) and of the second set of coil elements (52, 54, 82) is a surface coil element disposed on or proximate to the selected load.

7.   The magnetic resonance coil as set forth in claim 6, wherein each surface coil element of the first set of coil elements (54, 56, 80) and of the second set of coil elements (52, 54, 82) is selected from a group consisting of (i) a single-loop surface coil element, (ii) a multiple-loop surface coil element, and (iii) a tuned axial stripline surface coil element.

8.   The magnetic resonance coil as set forth in claim 1, wherein the transmit region of sensitivity is positioned asymmetrically respective to the first set of coil elements (54, 56, 80) and the substantially similar receive region of sensitivity is positioned asymmetrically respective to the second set of coil elements (52, 54, 82).

9.   The magnetic resonance coil as set forth in claim 8, wherein the transmit region of sensitivity and the substantially similar receive region of sensitivity are each positioned substantially symmetrically respective to a union (52, 54, 56, 80, 82) of the first and second sets of coil elements.

10.   The magnetic resonance coil as set forth in claim 1, wherein:

the first set of coil elements (54, 56, 80) and the second set of coil elements (52, 54, 82) are positioned asymmetrically respective to each other; and

the transmit region of sensitivity and the substantially similar receive region of sensitivity are each positioned substantially symmetrically respective to a union (52, 54, 56, 80, 82) of the first and second sets of coil elements.

11.   The magnetic resonance coil as set forth in claim 1, wherein:

the second set of coil elements (52, 54, 82) is spatially offset from the first set of coil elements (54, 56, 80); and

the transmit region of sensitivity and the substantially similar receive region of sensitivity are each positioned substantially centered respective to a union (52, 54, 56, 80, 82) of the first and second sets of coil elements.

12.   A magnetic resonance method comprising:

positioning a first set of coil elements (54, 56, 80) asymmetrically respective to a selected region of sensitivity of a selected load at a magnetic field strength;

positioning a second set of coil elements (52, 54, 82) asymmetrically respective to the selected region of sensitivity of the selected load at the magnetic field strength, the asymmetric position of the second set of coil elements respective to the selected region of sensitivity being different from the asymmetric position of the first set of coil elements respective to the selected region of sensitivity;

generating magnetic resonance in the selected region of sensitivity of the selected load at the magnetic field strength using the asymmetrically positioned first set of coil elements (54, 56, 80); and

receiving a magnetic resonance signal from the selected region of sensitivity of the selected load at the magnetic field strength using the differently asymmetrically positioned second set of coil elements (52, 54, 82).

13.   The magnetic resonance method as set forth in claim 12, wherein a union (52, 54, 56, 80, 82) of the first set of coil elements and the second set of coil elements is positioned substantially symmetrically respective to the selected region of sensitivity.

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14.   The magnetic resonance method as set forth in claim 12, wherein the generating comprises:

energizing a first sub-set (56) of one or more coil elements of the first set of coil elements at a first phase; and

5   energizing a second sub-set (54) of one or more coil elements of the first set of coil elements at a second phase in quadrature respective to the first phase.
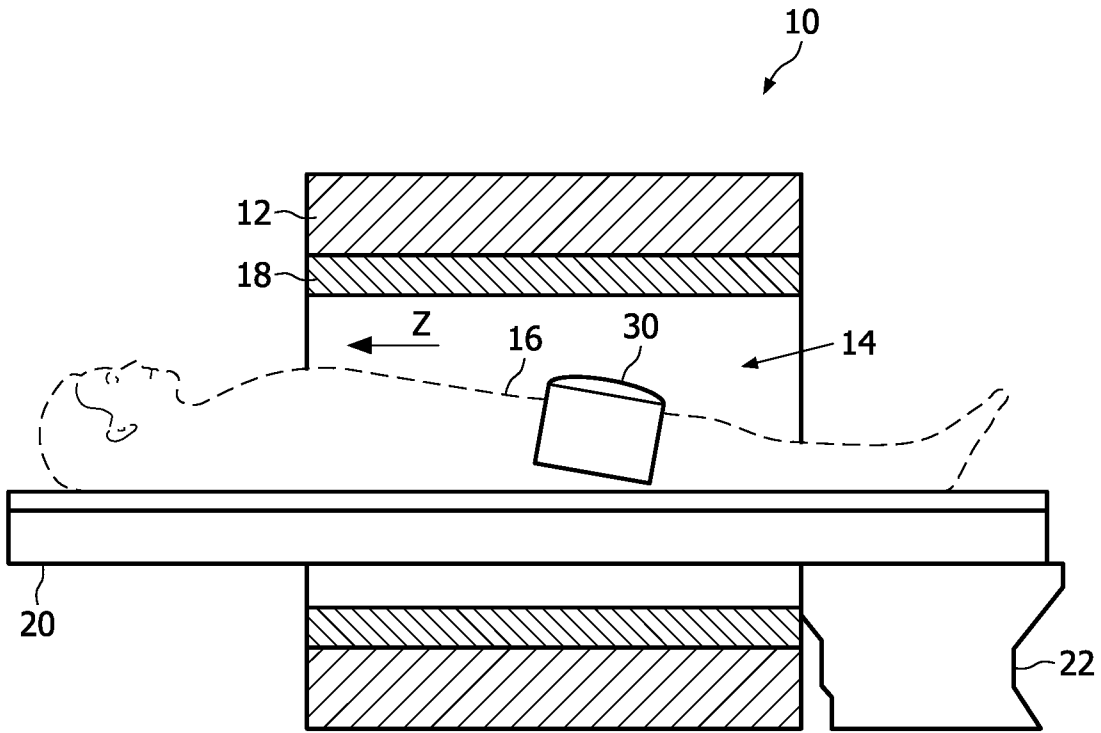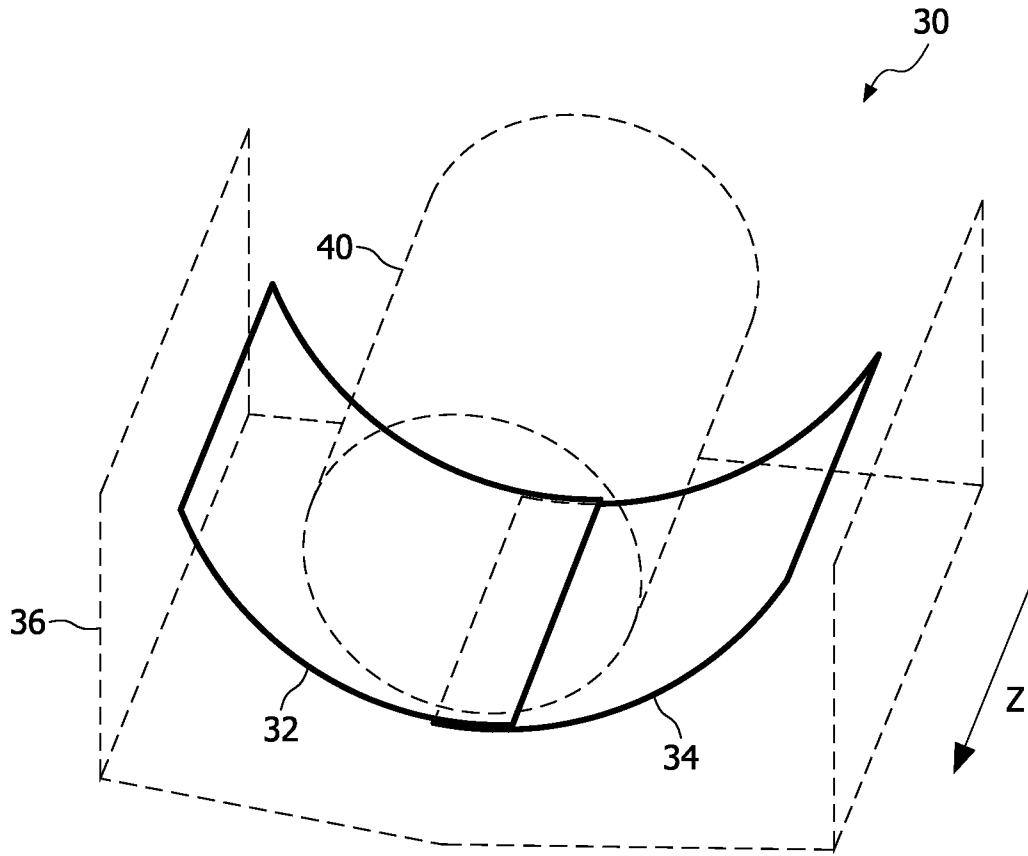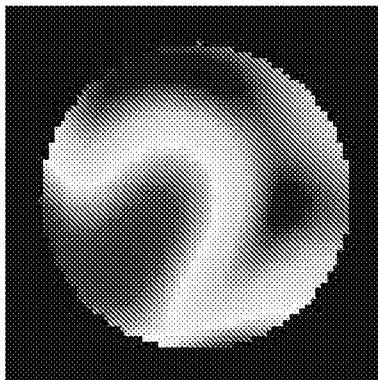
1/5

FIG. 1

FIG. 2

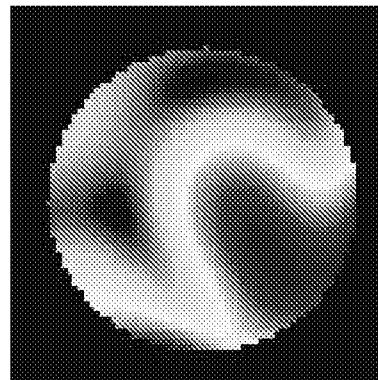Transmit $|B_1^+|$-field   Receive $|B_1^-|$-field
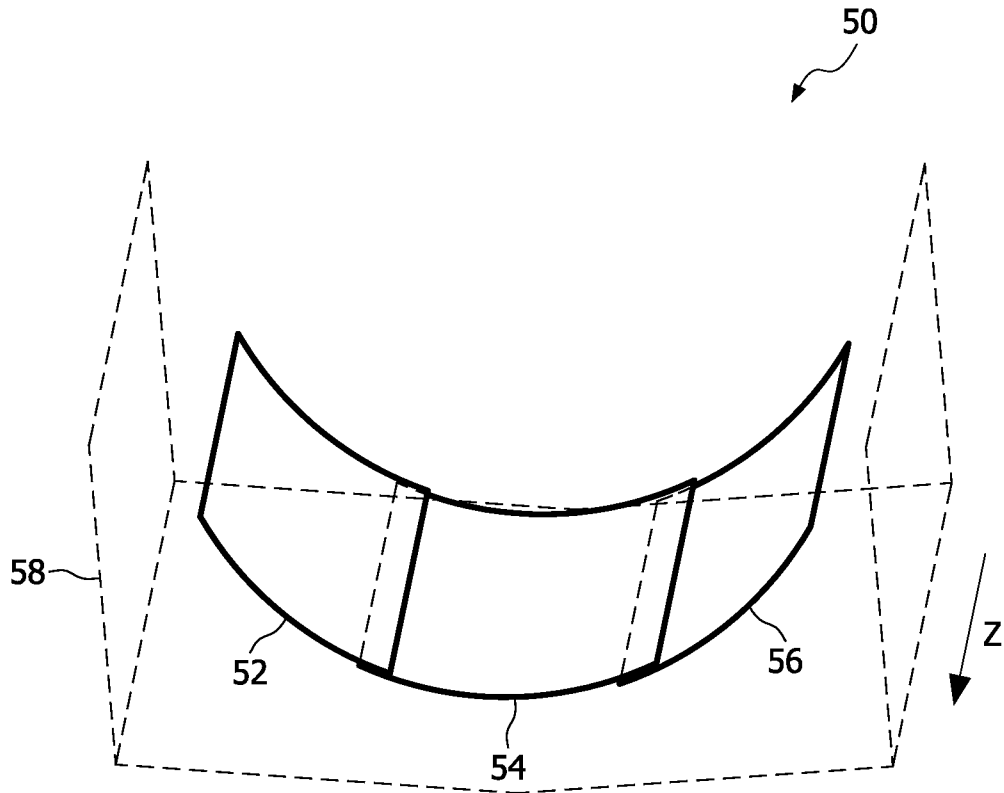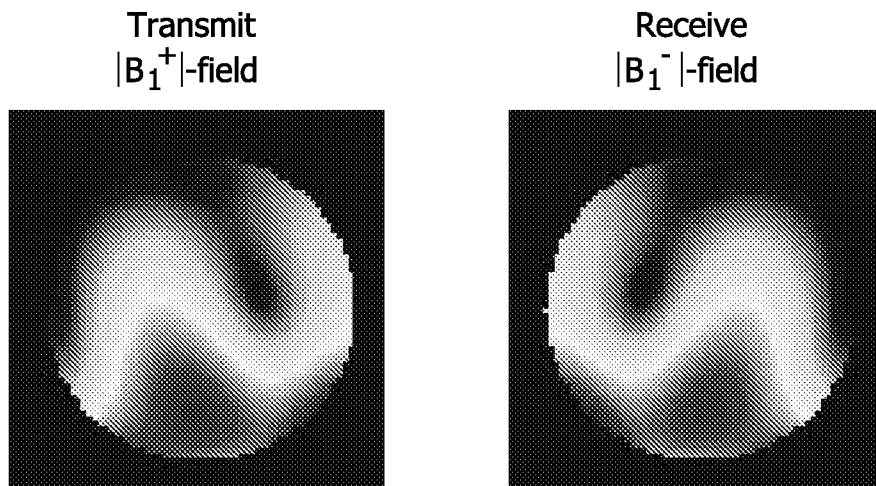
FIG. 3

FIG. 4

FIG. 5

Transmit
$|B_1^+|$-field

Receive
$|B_1^-|$-field
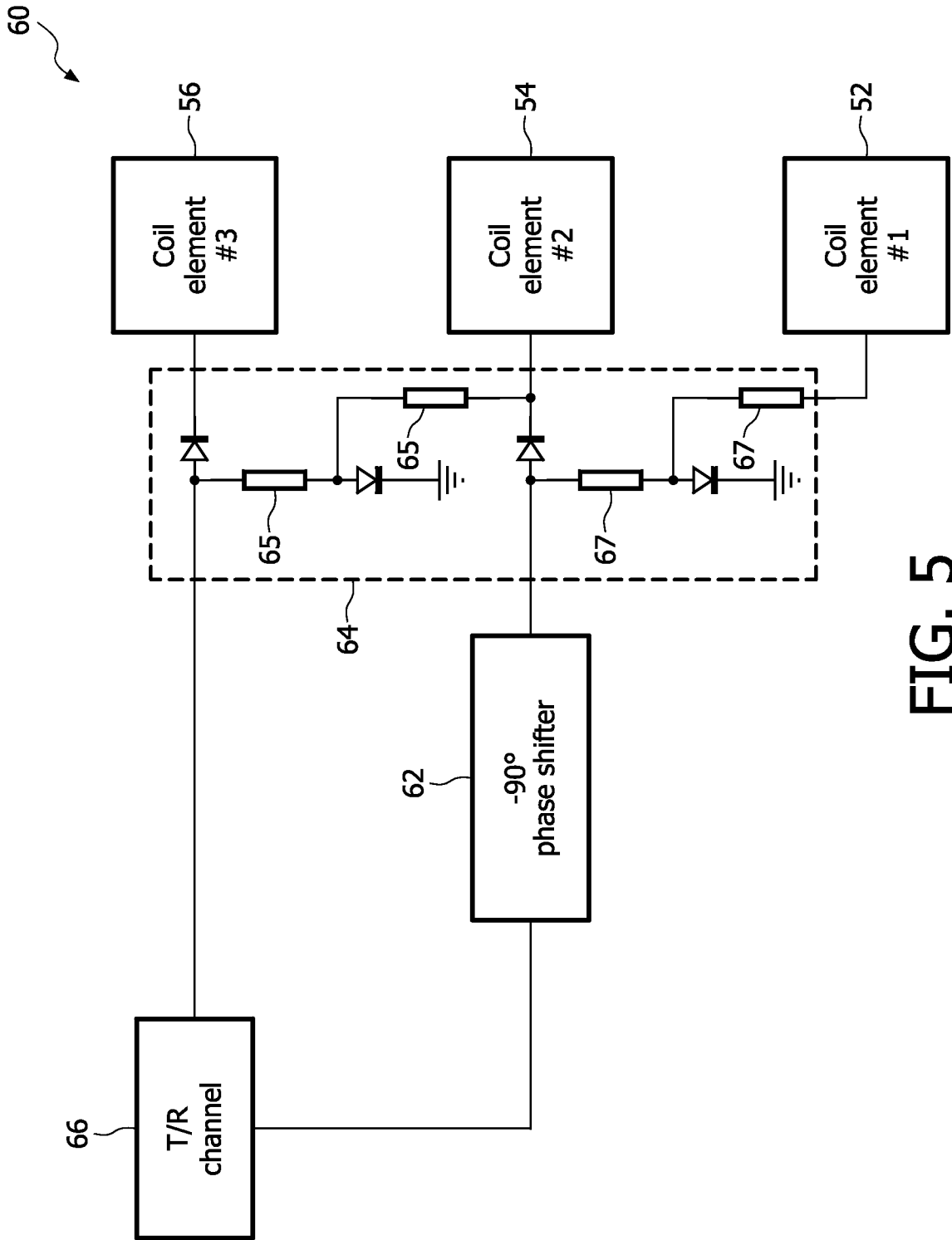
FIG. 6

FIG. 7

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R33/3415

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01R

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

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

EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/122546 A1 (LEUSSLER CHRISTOPH GUENTHER [DE]) 3 July 2003 (2003-07-03) paragraphs [0047] – [0078]; figures 1-13	1-14
A	WO 2006/114749 A (KONINKL PHILIPS ELECTRONICS NV [NL]; PHILIPS INTELLECTUAL PROPERTY [DE]) 2 November 2006 (2006-11-02) page 2, line 30 – page 7, line 27; figure 1	1-14
X	US 2007/241753 A1 (SODICKSON DANIEL K [US] ET AL) 18 October 2007 (2007-10-18) paragraphs [0012], [0038] – [0041], [0044] – [0050], [0053], [0054], [0058] – [0060], [0118] – [0120]; figure 1	1-8,11, 12,14

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[X] Further documents are listed in the continuation of Box C.	[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 May 2009	20/05/2009

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Lersch, Wilhelm

INTERNATIONAL SEARCH REPORT

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	J.WANG ET AL.: "Polarization of the RF Field in a Human Head at High Field: A Study With a Quadrature Surface Coil at 7.0 T" MAGNETIC RESONANCE IN MEDICINE, vol. 48, 2002, pages 362-369, XP002527082 the whole document	1-14
A	S.JUNGE ET AL.: "Six Channel Transmit-Receive Coil Array for Whole Body Imaging at 4T" PROC.INTL.SOC.MAG.RESON.MED. 14, 2006, page 124, XP002527083 the whole document	1-14
A	DE 10 2005 039686 B3 (SIEMENS AG [DE]) 10 May 2007 (2007-05-10) paragraphs [0024], [0025], [0078] - [0113]; claims 1,20	1-14
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C(Continuation).

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