INVERSE RF ARRAY HEAD COIL DESIGN FOR MRI-LINAC SYSTEM

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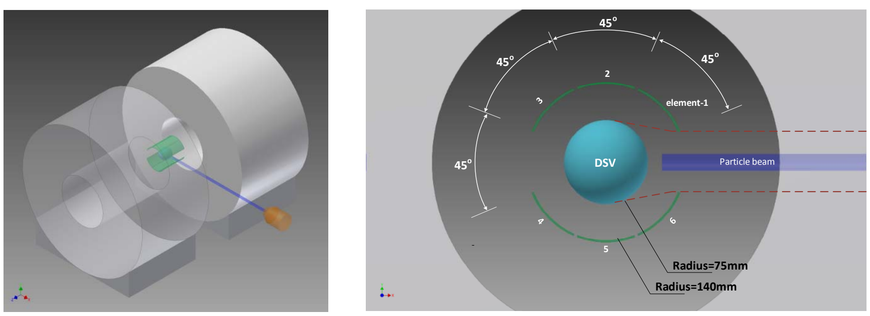
Introduction In this work, we use the inverse method to design RF array coil for human head imaging in a hybrid Magnetic Resonance Imaging-Linear accelerator (MRI-LINAC) system. A MRI-LINAC system [1] combines cancer detection functionality with therapy delivery and image guided radiotherapy. For optimal and precise radiotherapy application, an unobstructed pathway from the LINAC to the patient is essential. This must be considered in the design process of the RF-coils. An inverse RF array coil design method [2, 3] is proposed to produce a homogeneous magnetic field within a predefined region of interest (ROI) of 150mm in diameter and to detect a radio frequency (RF) signal emitted by excited hydrogen atoms in the sample. The inverse method has been demonstrated to be a practical tool in the RF array coils design [2, 3]. This paper focuses on the theoretical inverse design of a cylindrical head RF array coil with gaps applied in the MRI-LINAC system and investigates the feasibility of the method to produce a homogeneous circularly polarized magnetic field within a given ROI.

Method The MRI-LINAC system is illustrated in Fig 1(a). The grey cylinder depicts the MRI scanner, and the accelerator gun (the yellow component) rotates around the scanner body along the gap to generate particle beams for radiotherapy. The RF array coil is positioned in the green region. The cylindrical former has a diameter of 280 mm and is 300 mm long. The MRI-LINAC system comprises a split magnet with a magnetic field strength of 1Tesla (T), corresponding to a *Larmor Frequency* of 42.5MHz. The six-element array coil is designed to produce a circular-polarized field to achieve a high signal to noise ratio (SNR) and high transmit efficiency while providing a gap of 45°for the access of the accelerator beam, as illustrated in Fig 1(b).

In the design, the DSV (diameter spherical volume) size is 75mm in radius, and sampled points over the DSV surface are shown in Fig 4(a). By minimizing the error between induced circularly polarized field and target field, we can first find the continuous current density over the coil surface. Using a stream function method, we can then find the discrete current density distribution. We extracted the contour lines from the plot of stream function for the coil windings. Each coil unit is individually pre-tuned to 42.5 MHz. By using the obtained coil windings, we were able to calculate the B_1 fields to test the performance of the designed phased array coils. In the B_1 field calculation, the phases of the array coil were offset at 0° (1st and 4th element), 45° (2nd and 5th element) and 90° (3rd and 6th element).

Results and discussion The concept coil pattern is shown in Fig.2, black and red color indicate reverse directions of current flow. The results of the B_1 fields of the XY-plane and the YZ-plane are displayed in Fig 3(a) and (b) respectively. From these field plots, it can be seen that homogenous fields were achieved. It is noted that the homogeneity of the field may not be able to be achieved using conventional coil design schemes which are array coils with single-loop elements. The inhomogeneity (peak to mean) of fields produced by our inverse design and traditional ones were 40.35% and 81.36%, respectively (as shown in Fig 4(b)). More importantly, the designed RF phased array coils were tailored for optimal system integration.



(a) (b)

Fig. 1 Illustration of a MRI-LINAC system (a); and transverse view of the 6-element phased-array coil (b).

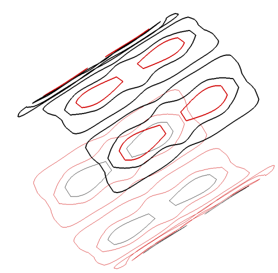
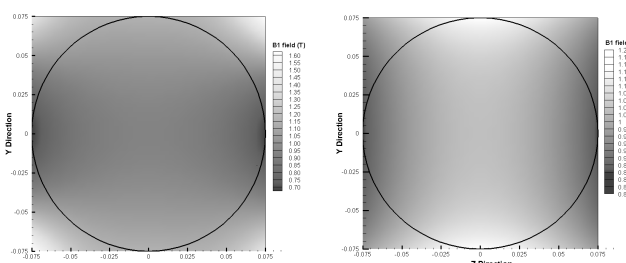
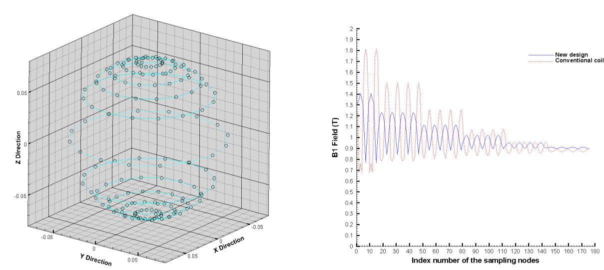


Fig. 2 RF array coil winding pattern.



(a) (b)

Fig. 3 B_1 field induced by the 6-element array: Axial-plane (a); Sagittal-plane (b).



(a) (b)

Fig. 4 Sampled points over the DSV (a); B_1 fields induced by conventional coil (red) and new design (blue) (b).

Conclusions In this work, a set of RF phased array coils for a MRI-LINAC system were designed and simulated. The coil winding pattern was obtained using an inverse field method, and the numerical results clearly indicate that a homogenous circularly polarized B_1 field can theoretically be achieved by the proposed coil structure.

References

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