Design of a Strip Transmit Coil/Array for Low Field Open MR

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Introduction

RF coils with microstrip transmission line structure have shown the advantages for high and ultrahigh field MRI [1-3] due to the excellent high frequency performance. In this work, we explore the feasibility of transmit body coil or coil array design using microstrip design technique for low-field open MR applications. Simulation result shows that the proposed microstrip transmit (Tx) coil or parallel transmit array appears to be more compact and efficient than the conventional saddle-type transmit coils.

Method

The discontinuity structure of open MR systems makes it difficult to obtain a high degree of homogeneous B_0 fields within the imaging volume. To achieve uniform transmit B_1 field (i.e. B_1^+), the current transmit (Tx) coil design uses disk-like conductors which are placed in parallel. The currents passing through those conductors have the same directions. In GE Ovation 0.35T Tx coil, for instance, there are two sets of such conductors (which are orthogonal to each other) in order to generate circularly polarized B_1 fields for efficient excitation. However, additional conductors have to be placed at the peripheral of the disk-like conductors to provide the current return path [4]. Two disadvantages are: (1) the B_1 field generated by currents in this return path is in the B_0 direction. This B_1 field is therefore nonproductive for NMR excitation. In addition, it can become a source of ohmic loss and also induce conduction currents in the tissue which increases SAR potentially; (2) the return conductors are relatively long and crossed each other, which are not easy for fabrication and result in larger coil dimension. To overcome these problems, we propose a new Tx coil using microstrip technique for open MRI at low fields. The design is depicted in Fig 1. To adapt to open MR structure, the proposed body Tx coil is composed of radial placed straight-strip elements. The current return path is through the ground plane of the microstrips, thus avoiding the use of the long return conductors. This microstrip body Tx coil contains two disk-like pieces, which are placed at the top and bottom of the magnet. There are *n* elements in each piece of body coil. Each microstrip element is a resonator. Two shunt capacitors are connected between the strip conductors and the ground planes at both ends of the microstrip (Fig. 1). One or more tuning capacitors may be distributed along the top strip for frequency tuning. Based on the microstrip design, the following two Tx coil configurations are investigated.

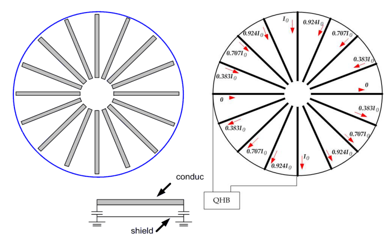

Fig.1. Schematic of microstrip Tx coil for open MRI.

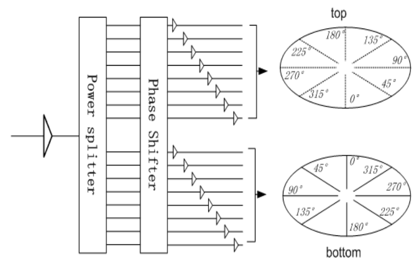

Fig.2. Schematic of microstrip Tx array for open MRI.

1. Tx coil with coupled strips

For this body coil, sufficient inductive coupling between microstrip elements is necessary. The first mode (homogeneous mode) is selected. Larger mutual coupling can make all mode-frequencies more separated and distinct. Several steps can be taken to achieve enough mutual coupling.

(1). Increase the number of elements

(2). Increase gap between the strip conductors and ground planes.

2. Tx coil with decoupled strips

If all the elements are decoupled, it is a transmit array which is essential for parallel transmission. Fig 2 shows the schematic of a microstrip transmit array with eight elements in each piece. To achieve better element decoupling, capacitors or inductors may be connected between each element neighbors to minimize their mutual inductance. Each transmit channel may contain a T/R switch and preamplifier to allow the array to operate for both transmission and reception.

Simulation has been performed with xFDTD (Remcom Inc, ver. 5.3) to calculate field distribution on this microstrip transmit array. Parameters of this array include: eight elements; strip length = 29.0cm, height of bottom and top pieces=43.0cm, RF shield diameter = 80.0cm, frequency = 14.85MHz, gap of strip conductor and ground plane = 2.0cm.

Result Coil structure is shown in Fig 3a, in which RF shield is specifically designed to achieve homogeneous B_1 field. Figure 3b and 3c show the B_1 field in axial and coronal plane passing through iso-center of the coil. Within 38-diameter sphere, the B_1 variation is less than 3dB.

Conclusion and discussion In open MRI system, the RF shield plane, which is usually 1.8~2.2 cm apart from the transmit coil, is naturally used as a part of microstrip Tx coil. The absence of long return path increases the efficiency of this body Tx coil. The diameter of the conventional dual-saddle type Tx coil, which is about 980 mm for human scan, can be reduced to 650 mm with the microstrip design. At the center of coil disks, smaller coil-to-shield plane is selected to achieve -3dB field homogeneity within 380mm sphere. Although the return conductors in conventional saddle coil design can provide fast field drop-off, thus to prevent annefact when scan phantom or patient with larger size, the microstrip Tx coil which is more compact, can also provide enough field dropping outside 380 cm sphere. With the microstrip body coil array, parallel imaging techniques, such as parallel excitation and/or reception can be readily used for low field open MR applications.

References [1] G. Adriany, et al. MRM. 53 (2005) 434-445. [2] X. Zhang, et al. MRM. 46 (2001) 443-450. [3] B. Wu. et al JMR 182 (2006) 126-132. [4].E. B. Boskamp, IEEE 22nd EMBS, (2000) 2387-2389.

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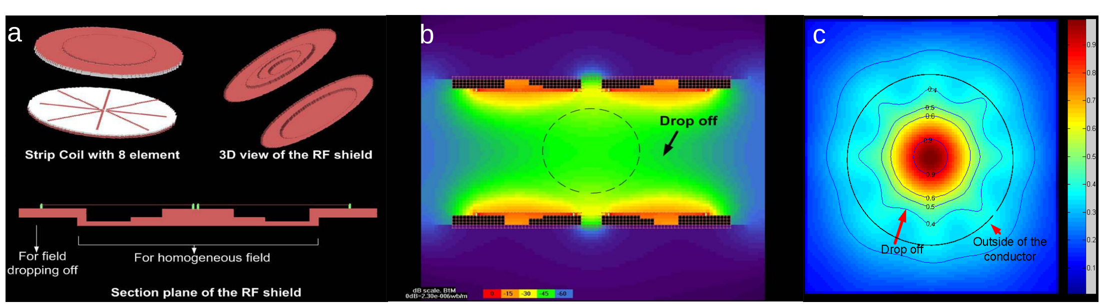
Fig.3. Simulation results of 16-element microstrip array for open MRI. There are 45 deg phase difference between adjacent elements, while 180 deg phase difference between top and bottom pieces. Figure 3a shows the schemetic of microstrip Tx array. Figure 3b is the B_1 field distribution at axial plane. Figure 3c is B_1 distribution at coronal plane.



Patent pending.