A new RF-coil for UHF MRI based on a slotted microstrip line

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Abstract. We propose to use an antenna based on a microstrip line with a slotted ground plane, as a transcieve RF-coil for ultra-high field (UHF) human body MRI at 7 Tesla. In this work we show by numerical simulations, that while being loaded with a homogeneous dielectric phantom, this slotted line supports fast-wave propagation and radiation of power into the phantom. As a result, it produces high RF magnetic field at a deeply located region of interest, which is the same as one produced by the well-known fractionated dipole.

1. Introduction

Transmission-line antennas can be waveguiding structures periodically modulated to convert a non-radiative propagating mode into radiation. Typical examples are substrate-integrated waveguides with transverse slots in the wide wall [1]. This antenna radiates the beam at the angle θ angle with respect to the direction of wave propagation in the guiding structure, which depends on the propagation constant and frequency. Such antennas are popular at microwave frequencies because of their capability to create a relative narrow beam without using a complex feeding network, typically required for phased array antennas [2].

MRI of a human body at ultrahigh fields (UHF) (7 T and higher) is difficult due to wave effects such as interference caused by the reduced wavelength of electromagnetic wave propagating in human body tissues when the wavelength becomes comparable to the dimensions of a human body. To solve this issue the parallel transmit (pTx) approach is widely used [3]. This approach allows for the manipulation of the transmit field distribution by the use of individual antennas surrounding the body and driven with customized phases and/or magnitudes of signals. One of the most efficient antenna types used for transceiving array coils for body imaging at 7 T are dipoles. One of the best configurations for prostate imaging was the fractionated dipole [4] that reaches high transmit efficiency in the prostate, while keeping relatively low SAR for the same transmit power. A dipole coil usually creates the maximum magnetic field right under its center, while the distribution of the RF magnetic field B_1^+ is symmetric in the axial direction and is determined by the distribution of current along the antenna. In this work we propose an alternative design of a radiative antenna that reaches the same transmit efficiency a the dipole, but allows to create an axially-asymmetric RF-field pattern due to a phase-non-uniform

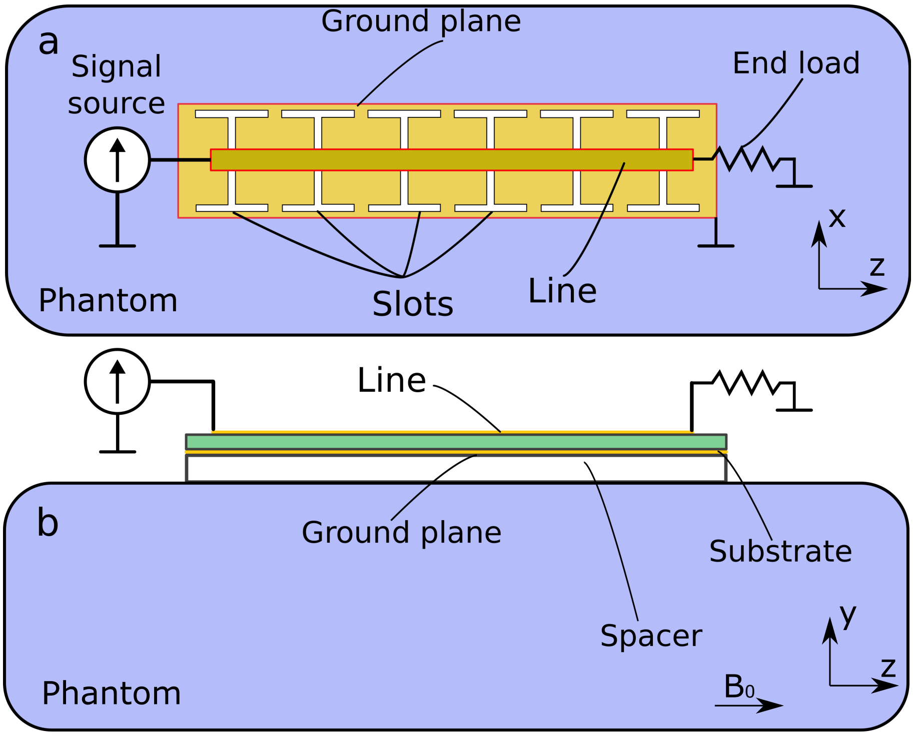

Figure 1. Schematic layout of the proposed RF-coil: (a) top view; (b) side view

distribution of currents. Namely, we propose to use transmission-line antenna, based on a slotted ground microstrip line, that can radiate electromagnetic waves into the object(so called phantom) having the same properties with the averaged ones properties of human body tissues (ε=34, ς=0.45 S/m) [4].

2. Design and simulation

The proposed coil is based on a microstip line with a strip width of 15 mm placed on a 1-mm thick foam substrate.In the ground plane of the microstrip line six parallel I-shaped slots are etched periodically in the direction z parallel to the static field B_0. Transmission line was designed to have wave impedance 50 Ohm. The slots have the period of 6 mm and the total length 16 mm. The input of the transmission line is connected to the signal generator, while it's output was loaded with 50 Ohm load. The antenna was placed over the polycarbonate spacer, that required to reduce SAR at the object [4]. Width of antenna was chosen to fit eight-channel array size. The length and period of slots were optimized to achieve the maximum power accepted in the phantom. Numerical simulation software CST Studio Suite (CST, Darmstadt, Germany) was used for calculation of RF magnetic field B_1^+ of an antenna and a fractionated dipole taken as a reference coil. Adaptive meshing was performed at the Larmor frequency of 297.2 MHz using Frequency Domain Solver. Antenna was matched with -15 dB level of the reflection coefficient at the input port when placed over the phantom with no matching circuit. Simulation showed, that for this coil 70 % of the stimulated power was dissipated in the phantom. The fractionated dipole was matched with an L-network of lumped elements.

3. Results

The simulation has shown that the transmission line supports slow waves as compared to the light velocity in vacuum, while having fast waves with respect to the media with the properties

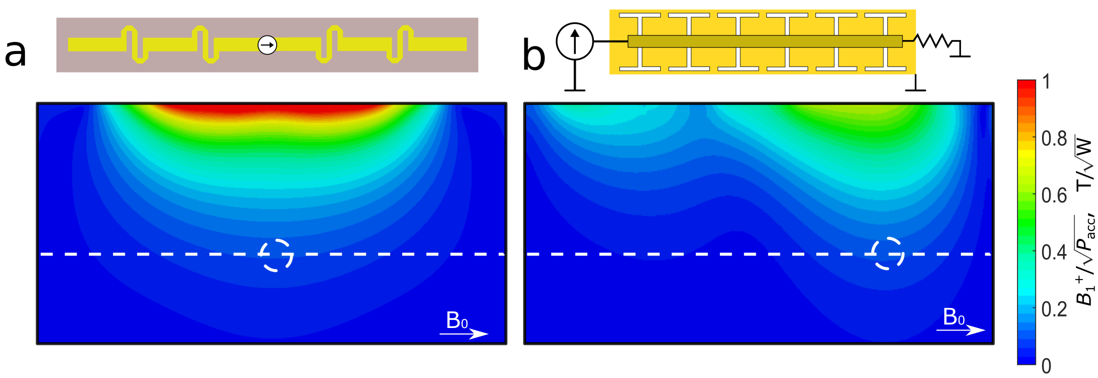

Figure 2. Simulated B_1^+ magnitude distributions normalized by square root of accepted power: (a) - fractionated dipole, (b) - proposed antenna antenna.

of the phantom. The distribution of the right-hand circularly-polarized component of RF-magnetic field (so called B_1^+-field), that interacts with spins during transmission of the MRI signal, normalized by the square root of the accepted power $\sqrt{P_{acc}}$ in the central coronal slice plane in the center of the phantom is presented in Fig. 2 both for the fractionated dipole and the proposed antenna. B_1^+-field magnitude at the 10 cm depth was equal 0.152 μT for the proposed antenna and 0.149 for the fractionated dipole antenna. From the comparison of the field patterns it is clearly seen that the antenna produces the maximum magnetic field at the angle of approximately 30 degrees from the center of the coil, while the dipole has a symmetric field pattern. This can be explained by an inhomogeneous distribution of the current phase along z-axis for the proposed coil.

4. Conclusion
In this work, we propose a new radiative coil for 7 Tesla MRI based on a slotted microstrip line. The results have shown that it can create RF-magnetic field comparable with one of a fractionated dipole, the well known coil for UHF body imaging. In contrast to the dipole coil, the proposed one is capable to create an asymmetric magnetic field pattern with respect to z-axis and does not require a matching network.

5. Acknowledgment
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