DISCUSSION

INTRODUCTION

Since the start of magnetic resonance imaging, there has been a constant drive towards more powerful magnets and consequently higher operational frequencies. For head imaging, it is expected for the electromagnetic fields to be influenced by the presence of the tissue at these frequencies (field strength >7T). As a result, fundamental problems were anticipated regarding the presence of dielectric resonances [1] in the human head which would result in highly inhomogeneous images. In this paper, we study the effect of dielectric resonances at ultra high field MRI (>7T). This is done by examining the electromagnetic fields produced by a 16-strut TEM resonator loaded with an anatomically detailed human head model, and spherical phantoms of pure water, and 0.125 M NaCl. More importantly, we address the differences between these resonances and the inherent inhomogeneity in the RF coil.

RESULTS

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THEORY

As the operational frequency of the MRI scanner rises, the RF wavelength in tissue will be smaller than the dimensions of anatomical structures. As RF frequencies rise, magnetic and electric fields are tightly coupled and these fields interact strongly with the global structure of the body through wave propagation processes. This interaction, distinct from the spin-B1 interaction, gives rise to dielectric resonances within the sample.

Some essential characteristics of dielectric resonators in MR systems can be illustrated by a spherical phantom in the presence of a circularly polarized plane wave. Over the working region of the TEM resonator, a common high-field coil with quadrature drive, the fields approximate a circularly polarized standing plane wave with underlying propagation in the axial direction. The resonance frequencies and the modal field distributions are intrinsic properties of the object, unaffected by the source.

METHODS

The electromagnetic interaction between a homogeneous dielectric sphere and a linearly polarized plane wave can be described exactly [2] Using [2], the B1 field distribution for 18.5 spherical phantoms of pure water and 0.125 M NaCl. For the electromagnetic fields within the human head, a finite difference time domain model of the TEM resonator and of an anatomically detailed human head model has been developed. The coil and the head are modeled together. By this, the model accounts for the electromagnetic interactions between the coil, source, and the tissue. Three different excitations are considered: 2-port quadrature, 4-port, and phase/magnitude-optimized 4-port excitations. The 4-port drive is done by driving each port with the same current amplitude, but with progressive phase shifts of 90 degrees. The phase/magnitude-optimized 4-port excitation is done by optimizing the magnitude and the phase of each port to achieve a homogeneous field distribution in the human head.

RESULTS

Figure 1 shows a calculation of the image intensity for a low flip-angle pulse exciting pure water (a) and 0.125 M NaCl (b) spherical phantoms. Figure 2 gives an axial slice of the B1 field distribution inside the human head model for a case where no coil is present (four free excitation sources around the head) and for the aforementioned three excitations of a 16-strut TEM resonator at 340 MHz.

DISCUSSION

For distilled water (Figure 1 (a)), only the first TE and TM modes are significantly excited. The image shows a bright center which is a characteristic of these modes. When studying 0.125 M NaCl saline (Figure 2 (a)), the resonances are still evident, but they are reduced in intensity by more than an order of magnitude.

For the FDTD data where the interaction between the source and the object is considered, it is apparent that homogeneity of the fields significantly improves from no coil to quadrature to 4-port to optimized 4-port excitations. If dielectric resonance was the dominant factor on the electromagnetic fields in the sample, then the presence of the coil or if the coil is present, the way the excitation is done would have little effect on the field distribution. But as demonstrated, the B1 field distribution differed in all the four cases.

CONCLUSIONS

In summary, our study confirms the following facts. First, dielectric resonances are most strongly excited in objects comparable in size to the head when the conducting medium has a high dielectric constant and a low conductivity. When the conductivity of the medium approaches levels found in tissue, there is strong attenuation of dielectric resonances (the lossy spherical phantom and the human head). This fact leads to much more homogeneous images than found in the case of lossless materials. The principle determinants of homogeneity in high field MRI lie both in the nature of the RF coil and in the coupling between the head and the RF coil.

REFERENCES