B1 Homogeneity of Re-entrant Cavity Resonator

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Introduction

The re-entrant cavity resonator has been proposed as an effective form of multimode RF resonator with potential advantages over conventional birdcage and TEM volume coils [1]. This resonator has two inner cylinders and an outer cylinder, with the outer and inner cylinders in a coaxial configuration. Rungs and capacitors, similar to a low pass birdcage resonator, connect the two inner cylinders. The two inner cylinders are connected to the outer cylinder at each end, similar to co-axial sections that are shorted at each end. A variation of this type of resonator has also been considered for integrated gradient and RF resonator structures, in order to increase the patient bore size in full body imaging [2].

In this work, we evaluate the field homogeneity of the re-entrant cavity resonator using experimental data and numerical analysis. The results indicate that the re-entrant cavity resonator has a limited field of view in the sagittal plane, comparable to approximately half the field of view of a similar size birdcage resonator.

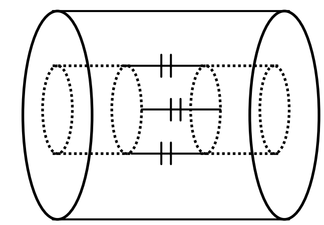

Fig. 1. Re-entrant cavity resonator

Methods

Using two Plexiglas cylinders, we constructed a re-entrant cavity resonator suitable for head imaging. The cylinders were attached together at each end by Plexiglas sections to form the co-axial configuration. At the center of inner cylinder, we used copper tape to create eight rungs. Each rung was 100mm long and was split at the center to accommodate capacitors. The surfaces outside the rung area were covered with copper tape to create the two inner cylinders and outer cylinder. The final dimensions of the resonator were ID=257mm, OD=367mm and height=367mm (Fig. 1).

In order to evaluate the field in-homogeneity experimentally, we used the method proposed in [3]. This method uses standard spin echo pulse sequence and is based on in-vivo or phantom image data collected at multiple transmit power levels. With spin echo pulse sequence, the image intensity S at a given location $\underline{r}$ and at a power level p_i is given by

$$S_i(\underline{r}, p_i) = \left| kPD(\underline{r})R(\underline{r})\sin^3\left(\frac{\pi}{2}\frac{b(p_i)}{b(p_{\pi/2,0})}T(\underline{r})\right)\right| \quad i = 1\ldots N \qquad (1)$$

where $T(\underline{r})$ is our desired transmit uniformity, k is a proportionality constant, $PD(\underline{r})$ is the proton density, $R(\underline{r})$ is the receive uniformity, $b(p_i)$ is a function of transmit power and $b(p_{\pi/2})$ is a function of transmit power for $\pi/2$ flip angle. Placing the re-entrant cavity resonator in a 1.5 Tesla GE Signa scanner, we obtained images of a phantom load (plastic jug filled with 2% copper sulphate solution) at several transmit power levels by varying the TG parameter. The data were fitted to equation (1) to obtain the transmit uniformity in the sagittal plane.

The field in-homogeneity was also evaluated using numerical analysis methods. Using the finite difference time domain method (xFDTD 6.4, Remcom(USA), State College, PA) we obtained the steady state field magnitude and phase within the re-entrant cavity resonator for circularly polarized excitation. Using these steady state values, B1+ in the rotating frame was calculated [4].

In order to compare the results, we have looked at the in-homogeneity of the well-known birdcage resonator. We considered a similar size birdcage resonator, which would have 8 rungs at ID=257mm and a shield at OD=367mm. This resonator was modeled in FDTD and the B1+ values were calculated for comparison.

Results

In Fig. 2, we show the in-homogeneity of the cavity resonator in the sagittal plane. The magnitude of B1+ is normalized to the iso-center value and the contours shown correspond to –3dB (brown line) and –6dB (blue line) values. The thin lines show the results of numerical analysis, whereas the thick lines show the results of measurement. The measured data do not fill up the entire volume of the imaging area as the plastic jug was only 18cm in diameter. Overall, we see good agreement between the measurement and the numerical analysis.

In Fig. 3, we show the normalized B1+ magnitude in the re-entrant cavity resonator and the birdcage resonator. The results are along the z-axis at the center of resonator. Defining the field of view as the –3dB region, we find that the re-entrant cavity resonator has 15cm field of view, whereas the similar size birdcage resonator has 29cm field of view in the sagittal plane.

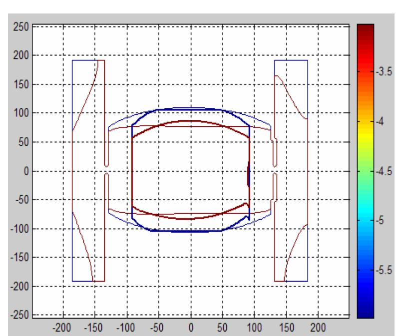

Fig. 2. Contours of constant B1+ in the sagittal plane (-3dB brown, -6dB blue)

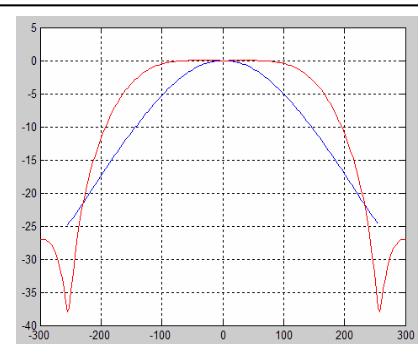

Fig. 3. Normalized |B1+| along z-axis (mm) cavity resonator (blue) and birdcage (red)

Conclusions

The re-entrant cavity resonator has been proposed as an alternative to TEM resonator. A variation of the resonator has also been considered for full body imaging. However, the re-entrant cavity resonator has a limited field of view in the sagittal plane, compared to a similar size birdcage resonator.

References:

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