A Complete Modeling System with Experimental Validation for Calculating the Transmit and Receive Fields, Total Power Deposition, Input Impedance, and Coupling between Coil Elements

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Introduction: Multichannel RF coils are getting significantly popular because of their capability of parallel imaging methods such as transmit SENSE and B_1 shimming. In this work, we demonstrate a simulation method that provides a complete modeling of all the RF coil characteristics that are extremely important for parallel imaging including coupling between coil elements, input impedance, transmit/receive fields, and total RF power deposition.

Method: ***(I)****Simulation:* The in-house EM simulation software based on Finite-Difference Time-Domain (FDTD) method is used to study a coupled TEM coil. Fig 1 illustrates the cross section of the FDTD model and the rear end of the TEM resonator. The spatial step uses 1/635 wavelength to avoid stair-step error. The resonator is placed within the perfectly matched layer (PML) to simulate the radiation condition [1]. To incorporate coupling accurately, transmission line scheme [2] was incorporated into the model. A phantom with conductivity measured at 0.46S/m was used as the load. The tuning of the resonator is done by setting different length of the copper rods (equal length for each rod) within the struts in different simulations run. After the tuning is achieved, the frequency components of the magnetic/electric fields are computed using the model. To generate the gradient echo (GRE) images, equation given in [3] is used.

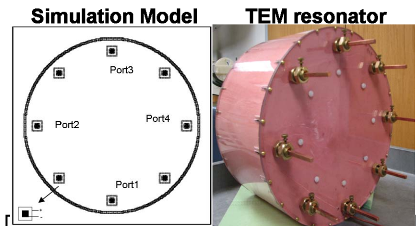

Fig 1 shows TEM coil uses 8 equally spaced struts and is capped at the rear end. The outer and inner dimension of the resonator is 13.5in/10in. The length is 7in. A half-wavelength semi-rigid coaxial transmission line is connected to the excitation port.

(II)*Experiment:* The diameter of the spherical phantoms was set at 17cm in diameter. It was doped with sulfate to shorten the longitudinal relaxation times T_1 which was measured at 117ms (obtained inversion recovery method). The tuning is done to have all the copper rods at the same length. This guarantees the symmetric excitation of the field. We collect all of our images using GRE with TR>=700ms and TE=3ms on a Siemens Tim Trio 7T system. Long TR is used to avoid ghosting due to eddy current effect. The FOV is 190mm and the slide thickness is 1.5mm. In addition, we also measure the B_1^+ map using the curve fitting method. The flip angle points are collected using a GRE sequence with matrix size=64x64.

Results and Discussions: The results of the single, two, four ports resonator are presented. To demonstrate RF power calculations, low/high flip angles of the images are collected for comparison (Fig. 2). The calculated and measured input impedances of the resonator with the phantom in the center are 125+j39/147+j41Ω, respectively (Fig. 3). The coupling for 2-port coil is also provided in Fig. 3. Fig 4 shows the measured and calculated $|B_1^+|$ map for each channel for a 4-port resonator. For the measured map, the SNR at the null points is very low because the curve fitting around those points are not accurately done since 90o flip isn't achievable. However, the overall images between the calculated and measured $|B_1^+|$ map still agree very well.

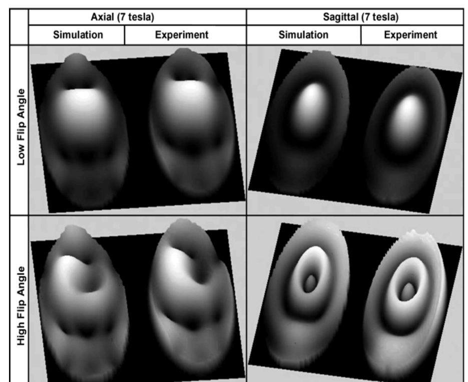

Fig 2 shows the single port TEM resonator images of the axial/sagittal slice at the center of the phantom. The images are symmetric at low flip angle and asymmetric at high flip angle.

Conclusion: With the validation of experiment results, our model has accurately described the electromagnetic characteristics of TEM resonator. With this model, the operation of the TEM resonator within the magnet can be predicted in advance and prior to imaging.

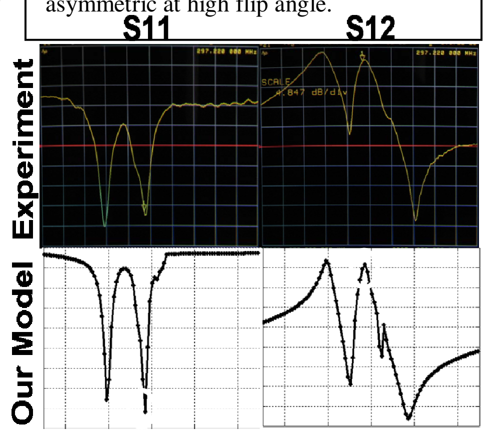

Fig 3 shows only the S_{11} and S_{12} for the two-port TEM resonator. The calculated values at 297.2 MHz are -8.2/-9.3 dB and the measured values are -6.3/-9.3dB, respectively.

References

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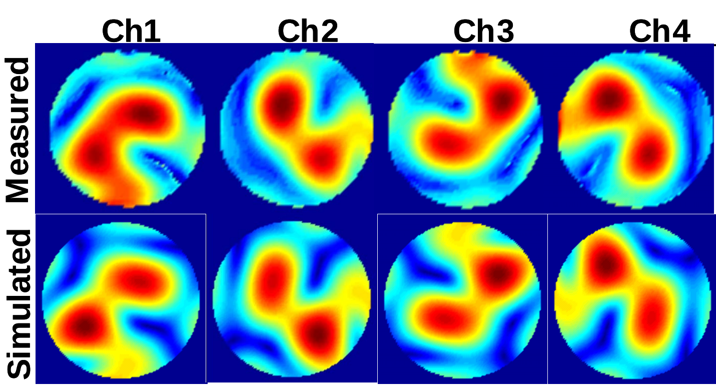

Fig 4 shows measured and calculated $|B_1^+|$ map. Ten flip angle points are collected using GRE sequence with the parameters: FOV=190mm, TR=1000ms, TE=3.5ms, BW=350 and FOV=190mm.