Magnetic Field of RF Coil Measurement by NMR Method

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Abstract: *A spectroscopic imaging technique with high spatial resolution was used for the measurement of the static magnetic field homogeneity of RF coils. Measured magnetic fields of optimised and not optimised saddle-shaped coils were compared with the theoretical calculations. Results are in good qualitative agreement between calculated and measured magnetic field distributions. Quantitative disagreements however appeared in some experiments. We suppose that the method is suitable for magnetic field measurement of RF coils operating at frequencies where RF magnetic field may be replaced by the static magnetic field.*

1. Introduction

The magnetic field homogeneity of RF coil is an important parameter with direct influence to measured image quality [1, 2]. The verification of the calculated (optimised) magnetic field distributions can be performed in more ways. The simplest method is scanning point-by-point with a small pick-up coil or small water sample [3, 4]. Such measurements are however time consuming and precision is usually poor, particularly if the measured coil is small. Another method of magnetic field visualisation derives the B_1 distribution from the position of local extrema in the spectra obtained in a static magnetic field gradient at various pulse length [5]. More recently a further magnetic resonance imaging method for magnetic field measurement of RF coils appeared [6]. This method is based on measurement of images by a standard spin and a stimulated echo. It should be noted that mentioned methods enable measuring of the magnetic field components with some difficulties or not at all.

The main objective of this paper is to present a nuclear magnetic resonance method to quantify and display the static magnetic fields of RF coils caused by DC current flowing through the measured coil. The method is tested on standard and optimised saddle-shaped RF coils.

2. Materials and Methods

Two four-turn saddle-shaped coils were used for the measurements. The first coil was optimised for the best B_{xy} magnetic field homogeneity in the whole volume of the coil, straight conductors of the second coil were placed along the tube perimeter evenly. The optimisation was performed by a randomised gradient optimisation method to find the global optimum. The both coils were made of copper wire on a plastic tube with diameter of 75 mm. Each coil was immersed into a cylindrical plastic vessel filled with tap water. The static magnetic field in the considered planes has been measured by a spectroscopic imaging technique based on an RF spoiled gradient-echo sequence (TR = 50 ms, $\alpha = 25^{o}$) [7]. This method enables fast and precise measurements of the static magnetic field inhomogeneities. Spectroscopic imaging method is inherently robust against many artifacts because magnetic field deviations are calculated from the shift of voxel water spectral lines. Therefore all effects that influence the amplitude but not the position of the spectral lines are unimportant. Such effects are spatial RF inhomogeneity of the receiver/transmitter coil of the scanner, steady state effects, movement (vibration of the measured samples), flow artifacts, etc. The measurements were performed using a 1.5 T MR imaging system (Gyroscan NT, Philips, Best, The Netherlands). The spectral frequency offsets were encoded by incrementing the echo time (TE) of subsequent 24 image records. The slice thickness was chosen to be 3 mm. The in-plane resolution was 0.625 mm and the matrix size (256,256). Incrementing the TE by 1.3 ms led to a spectral bandwidth of 12 ppm (768 Hz). The spectral resolution was 0.5 ppm (32 Hz). The net measurement time was 3 minutes 50 seconds (1 acquisition). Measured RF coil was placed at the centre of the magnet with selected magnetic field component along the static magnetic field B_0. The magnetic field distributions of the phantoms were measured with and without DC electric current. The DC current of ~50 mA created in the centre of the measured coil magnetic field deviation of ~2.5 ppm. By subtraction of the background magnetic field (measurement without DC current) from the magnetic field distribution measured with DC current, magnetic field deviation caused by the electric current was obtained. The components B_x and B_y (related to the measured coil magnetic field) of the magnetic fields of the measured coils were measured in central transversal, coronal and sagittal planes.

3. Results and Discussion

B_y components of magnetic field distribution possess relatively low values at the most of the planes. From this reason they are not optimal for the method demonstration. The more suitable examples are the x components in plane (y, z). Fig.1 shows the both magnetic fields B_x (y, z) of the optimised coil, the calculated and the measured. The three selected points were compared with the calculated magnetic induction. Table 1. shows differences between the calculated and the measured values.

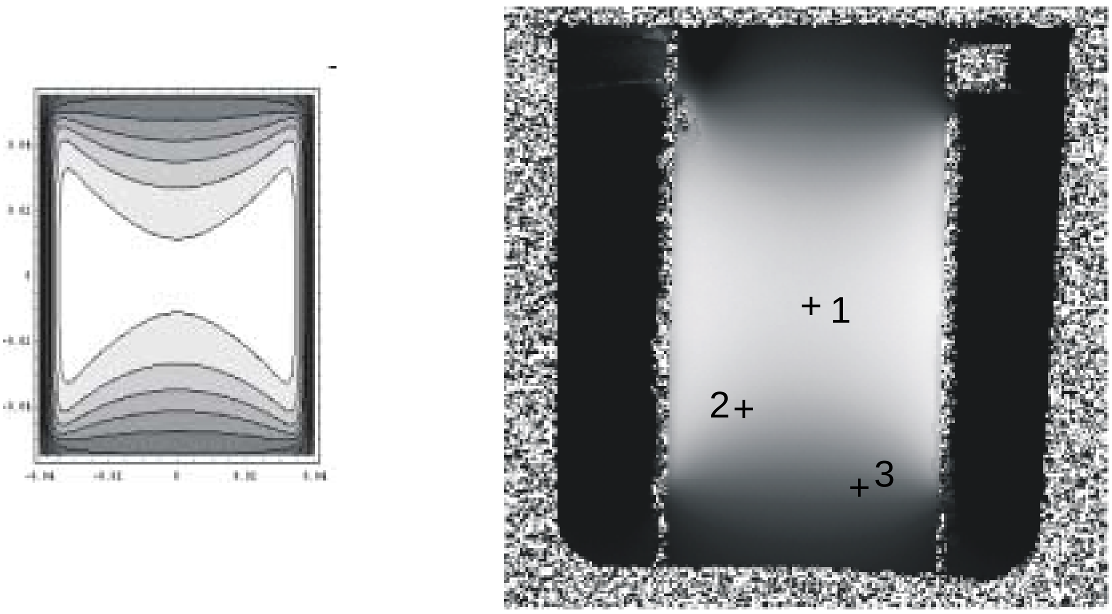

Fig. 1. The calculated and measured magnetic field distributions B_x (y, z) of the optimised coil. The coil was optimised for the best homogeneity of the magnetic field component B_{xy} in the coil volume.

Tab. 1.

	Calculated B_x [μT]	Measured B_x [μT]	Error [%]
1	0.0	0.0	0.0
2	-0.62794	-0.7506255	19.54
3	-2.50843	-2.70173	7.7

Similar results have been obtained with not optimised coil as shown in Fig. 2. The qualitative agreement between the calculated and the measured magnetic fields is excellent. The quantitative differences of the magnetic induction in selected points are acceptable (Tab. 2). Quantitative differences can be explained by the fact that measured magnetic field in each voxel corresponds to the average magnetic induction of the measured voxel (0.625x0.625x3 mm^3). We note that the coils were supplied from a battery through a resistor without any stabilisation during experiments. Using an appropriate stabiliser the errors could be probably significantly reduced. Not negligible source of quantitative errors is mechanical construction.

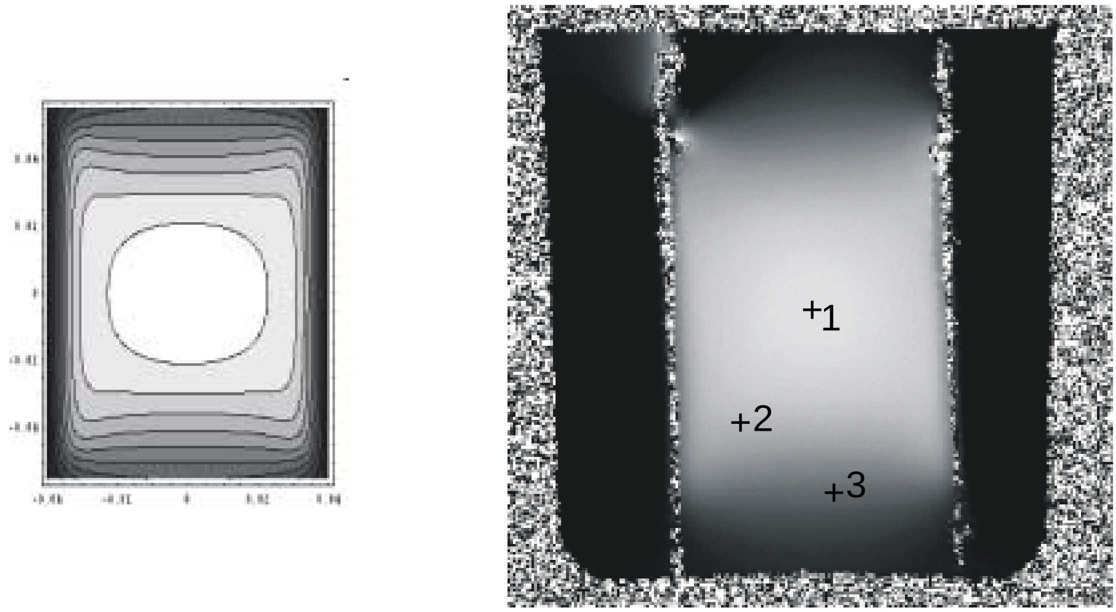

Fig. 2. The calculated and measured magnetic field distributions B_x (y, z) of the not optimised coil.

Tab. 2.

	Calculated B_x [μT]	Measured B_x [μT]	Error [%]
1	0.0	0.0	0.0
2	-0.55632	-0.579187	4.1
3	-1.786	-1.907447	6.8

Some parts of the coils could not be realised precisely according to the calculations. RF coil is element able to change magnetic fields into electric signals and vice versa. Its magnetic field due to DC current could be therefore influenced by transmitter RF pulse or by gradient pulses necessary for NMR experiments.

4. Conclusion

The static magnetic field of RF coil placed into high homogeneous magnetic field of NMR imager can be considered as its inhomogeneity and with a relative high precision measured by spectroscopic imaging method with high spatial resolution. We conclude that the described method is promising. The main task for the future is study of the reasons of quantitative disagreements and improvement of experimental arrangements.

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