

The Helical Resonator: A High Q RF Coil For MRI and MRS

M.E. Meyerand and J.F. Dunn

Biomedical NMR Lab, Department of Diagnostic Radiology, Dartmouth Medical School, Hanover, NH

Introduction

Solenoid RF coils have been used extensively in NMR to produce extremely uniform B_1 fields (1). However, conventional solenoids have a geometry that makes it difficult to obtain a high Q factor at high field strengths. The small current carrying cross section of the solenoid lowers the Q due to unavoidable resistive losses. The use of discrete capacitors utilizing materials that have a finite dielectric loss also lowers the Q. A variant of both the solenoid coil and the high Q coaxial resonator, is the helical resonator (Fig. 1) (2,3). The helical resonator can be considered a coaxial resonator with the center conductor formed into a helix. The helical resonator has never before been designed and constructed for use in MRI and MRS applications.

Theory

While similar to a solenoid, the helical resonator is not simply a solenoid inside a shield. It is a shielded, resonant section of a helical wound transmission line with low axial propagation velocity. The inner conductor of the resonator has a large diameter thereby reducing resistive losses. In addition, the resonating capacitance is provided by the air space between the helix and outer shield removing capacitive losses from consideration. It has been shown that Q factors of several thousand can be obtained with this design (2,3). The current in the helix is maximum at the point where it attaches to the shield and decreases from that point toward the open circuit end where it is zero. This reduction occurs because the current flowing in the helix gradually is replaced by displacement current flowing through the air space between the turns and the shield. Nevertheless, the fall off in the field is gradual enough not to degrade image quality and can be manipulated by changing the pitch of the windings of the helix.

Methods

A helical resonator was constructed for use at 7T on a SMIS operating system with a 12cm bore. Figure 1 shows a diagram of the resonator

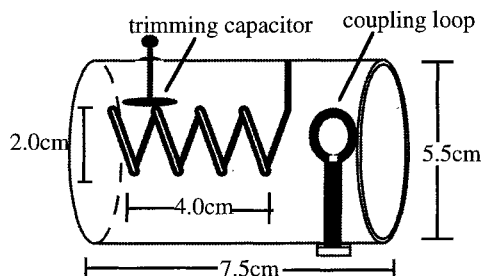


Fig. 1 - Diagram of helical resonator.

Hardware: The outer can was constructed from copper pipe with a 2mm wall thickness. The helix was constructed from 0.25 inch (0.635cm) copper tubing. The trimming capacitor consists of a brass disk 2cm in diameter soldered to a brass screw for adjustment through the outer can. An unloaded Q of 1150 and a loaded (saline phantom) Q of 460 was measured for the helical resonator using a HP 8753a network analyzer.

Pulse Sequence Parameters: A multi-slice gradient echo sequence was used for phantom studies. TR/TE=1,000/9ms, 90° pulse length=100μs, Matrix=128x128, field of view=30mm, slice thickness=1mm, 1 average.

Results and Discussion

Figure 2 is an axial image of a cylindrical saline phantom placed within the helix as a preliminary test of image quality. The SNR=170. The overall signal intensity is quite uniform over the field of view.

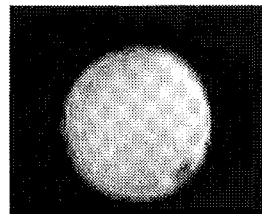


Fig. 2 - Image of water phantom using helical resonator. TR/TE=1,000/9ms, Matrix=128x128, field of view=30mm, slice thickness=1mm, 1 average.

The uniformity in signal intensity along the axis of the helix is shown in Fig. 3.

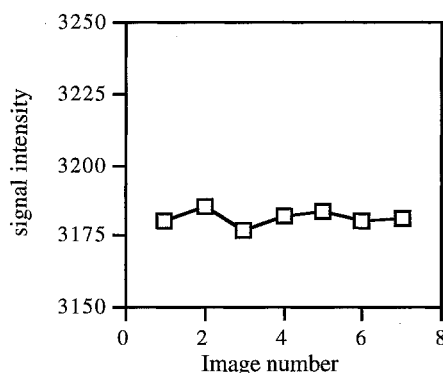


Fig 3 - Graph of signal intensity vs image slice number in a multi-slice gradient-echo imaging series along the axis of the coil. The average signal intensity was measured in 7 - 1mm slices separated by 3mm along the axis of the axis of the helix (a distance equal to 70% of the total length of the helix).

Conclusions

The feasibility of using a helical resonator as a high Q MRI RF coil has been demonstrated. Further studies are being conducted to investigate the behavior of eddy current production in the outer shield and to optimize the experimental design for high field microimaging applications.

This design will prove very useful in many low field and open systems where B_0 is lateral to the axis of the magnet. In addition, the outer shield provides excellent isolation, making additional tuning inside the magnet unnecessary.

References

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