開発レポート

Shield for Decoupling rf and Gradient Coils in an NMR Apparatus

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キーワード
rf shield, decoupling shield, rf coil, gradient coil

The author has developed a shield for decoupling rf and gradient coils in an NMR apparatus. The shield comprises a plurality of copper foil strips overlapped each other via Teflon sheet, and chip capacitors to enhance the capacitance formed by the Teflon layer and widen the operating frequency range. The shield performance has been experimentally tested, showing that the decoupling shield maintains high Q of the rf coil and practically dose not affect pulsed magnetic field gradients.

INTRODUCTION

In an NMR apparatus, it has been reported that the gradient coils cause losses to the rf coil(1). These losses lower the quality factor Q of the rf coil, resulting in a lower signal-to-noise ratio of the NMR image. The interaction between the rf and gradient coils can be eliminated by an rf shield, a conducting cylinder placed between the gradient and rf coil forms. The conducting cylinder, however, may degrade the transient response of pulsed magnetic gradient fields, which results from the eddy currents induced in the continuous conductive layer. A decoupling shield disposed between rf and gradient coils has been proposed to minimize the degradation (2); nevertheless, details such as the operating frequency range and the rf coil sensitivity with this shield have not been shown. Besides, the previous decoupling shield cannot be constructed easily due to its complex structure. I have developed a different and simple decoupling shield; comprising copper foil strips overlapped each other through Teflon sheet, and chip capacitors to enchance the capacitance formed by the Teflon layer and widen the operating frequency range.

SHIELD DESIGN

It is well known that the current distribution in the inner shield surface replicates the current in the rf coil elements; consequently, paralleling the conductive paths to the current flow directions of the rf coil elements serves to maintain high Q of the coil (2). I have developped an alternative decoupling rf shield based on this principle. The diagram of the proposed rf shield is shown in Fig. 1. The basic structure of the shield (Fig. 1-a) comprises a plurality of 80 mm width copper foil strips slightly overlapped each other through Teflon sheet, each having a silicon adhesive layer for easy construction. The copper foil thickness is chosen to be 18 μm which almost equals the skin depth of the operating fre-

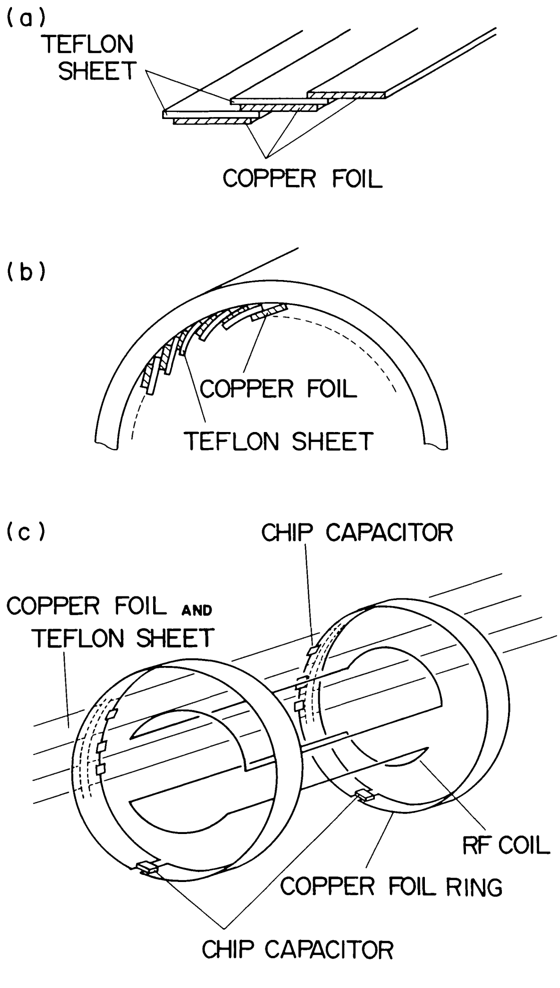

Fig. 1 Diagram of the constructed decoupling rf shield. (a) The shield is made of copper foil strips (width 80 mm, copper thickness 18 μm, and silicon adhesive thickness 35 μm), which are 10 mm overlapped each other and separated by Teflon sheet (width 90 mm, Teflon thickness 20 μm, and silicon adhesive thickness 20 μm). (b) The shield is cylindrically placed on the inner wall of the gradient coil assembly (shown partially). The Teflon sheets substantially overlay the copper foil strips. (c) Copper foil rings (same foil as above) further overlaying the Teflon surface are placed at both ends of the rf coil, thus helping to maintain high Q of the rf coil. Chip capacitors (0.01-0.1 μF) connected between the rings and each horizontal copper strip (not totally shown) enhance the capacitance formed by the Teflon layer in the overlap region. At each connecting point, the Teflon layer is partially removed for the capacitor soldering. Capacitors on the rings prevent circumferential gradient-induced eddy currents, while providing low rf impedance. Under the rings, the horizontal copper foil strips have a few millimeter gaps to further cut the eddy current loops.

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quency, thus minimizing the eddy current effects at audio frequencies induced by the pulsed magnetic field gradients, while possibly maintaining high Q of the rf coil. The shield is cylindrically placed on the inner wall of the gradient coil assembly (Fig. 1-b). The Teflon sheets substantially overlay the copper strips. As shown in Fig. 1-c, copper foil rings further overlaying the Teflon surface are placed at both ends of the rf coil. Chip capacitors arranged between the rings and each horizontal copper strip enhance the capacitance formed by the Teflon layer in the overlap region, thereby acting essentially as electrical short circuits at radio frequencies. Capacitors on the rings prevent circumferential gradient-induced eddy currents and provide low rf impedance.

Under the rings, the copper strips have gaps to further cut the eddy current loops. In operation, at radio frequencies, the shield appears to be a single continuous conductor which is opaque to the rf magnetic fields generated by the rf coil. The effect of capacitive coupling via the Teflon sheet and chip capacitors is negligible at audio frequencies associated with the magnetic field gradient pulses, thus eliminating large gradient-induced eddy current loops.

PERFORMANCE TEST

After constructing the decoupling rf shield, a slotted tube body coil(3), having a major axis dimension of 550 mm and a minor axis dimension of 450 mm with a length of 400 mm, was positioned inside the shield. Using two small loop coils(4), the unloaded Q's of the body coil were measured within a frequency range of 18 to 57 MHz. A conventional cylindrical shield, a single continuous copper foil, was also used and compared with the decoupling shield, each having a diameter of 710 mm. On the other hand, using a small solenoidal coil and a computer system, pulsed magnetic gradient fields were observed without the shields and with the decoupling shield. The gradient rise time was approximately one millisecond.

RESULTS AND DISCUSSION

The body coil Q's are shown for a variety of operating frequencies (18-57 MHz) in Table 1, indicating substantially no Q degradation when using the proposed rf decoupling shield. In addition, it was also observed that the gradient pulse response practically did not change after installing the decoupling

TABLE 1 Measured body coil unloaded Q's

Frequency (MHz)	Q	
	Decoupling shield	Conventional shield
18.3	420	424
25.6	604	626
57.4	766	838

shield. The previous article mentioned that the shield conductor must be several rf skin depths thick (2). However, this experiment shows that commercially available 18 μm copper foil, the thickness of which almost equals the skin depth at the above frequencies, can still maintain the rf coil performance, while helps to further reduce the gradient-induced eddy currents due to its thin structure.

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