Quadruple-Tuned (23Na, 7Li, 31P, 1H) Band/Low Pass Birdcage Coil at 3.0 T

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Introduction

Most designs of multiply-tuned coils have lower efficiency than single-tuned coils due to the inherent coupling between channels [1-4]. We have designed a high efficiency, switchable, double-layer, quadruple-nuclear, 7Li, 31P, 19F and 1H, birdcage brain coil with EPI capability. Because all nuclei are operated independently, the optimal performance can be attained for each nucleus. This design should provide a powerful tool for studying the neurochemical basis of bipolar disorder.

Methods

Band/Low Pass Configuration

To optimize the performance at 3.0 T for all four resonant frequencies, the nuclei: 7Li, 31P, 19Fand 1H can be divided into two groups: high resonant frequencies, 1H (128 MHz), 19F (120 MHz) and low resonant frequencies, 7Li (48 MHz) and 31P (52 MHz). For the low resonant frequencies, a low-pass configuration will be used. Based on the available experimental and theoretical data this configuration is expected to yield high performance at these low frequencies. For the high resonant frequencies, 19F, 1H, a band-pass birdcage configuration is better because it minimizes the electrical field loss and maximizes the loading factor.

Double-layer Design

In order to obtain spatial co-registration and identical B1 field for all nuclei, the coil geometry and current distribution for all frequencies should be identical. To keep the same geometry for all four nuclei, we use an etched thin, double-sided, flexible circuit on both sides of a double-sided circuit board.

Electronic Switch

The four nuclei can be changed using two steps. First, the coil is switched to high (1H, 19F) or low (7Li, 31P) frequency operating modes. These operating modes correspond to band-pass (1H, 19F) or low-pass (7Li, 31P) birdcage modes. Once the operating mode is chosen, each pair of nuclei is switched within its own frequency group.

The coil configurations can be switched between band-pass and low-pass through DC biased pin diodes and RF chokers by selecting positive or negative DC voltage source. In Fig. 1, two birdcage configurations, band-pass and low-pass share the same rods. These end rings are etched on both sides of a double-sided circuit board. Inside end rings are actually disconnected, therefore, the outside end rings function as part of a band-pass birdcage coil. The RF chokers (RFC) are used to block RF signal from the ground. Cr is a RF pass capacitor that is normally 0.1 PF or higher to keep the impedance of the capacitor negligible at the operating resonant frequencies (48 - 50 MHz) while blocking the eddy current caused by fast EPI gradient switching.

Fig. 1. Band-pass and low-pass share the same rods. Dash lines indicate these end rings are in the same position, but etched on the separate sides of a double-sided circuit board.

Fig. 2. Demonstrating the switching mechanism between band-pass and low-pass configurations.

The principle of switching nuclei in their own frequency group is simple. Because in either the high frequency group (1H, 19F) or the low frequency group (7Li, 31P), the frequency differences are only about 5% of their resonant frequencies, therefore, these small frequency differences can be easily adjusted through the use of tuning circuits.

Results and Discussion:

A prototype of the quadruple-tuned birdcage coil was implemented and tested in our electronic lab. Each nuclear resonant circuit could be independently tuned and matched. When the switching circuits were connected to their resonant circuits, their resonant frequencies were shifted slightly and 50 Ω matching was degraded; these effects were compensated by adjusting both parameters. All four channels were tuned and matched to more than 20 dB, Sll, with normal load (500 ml, 4” diameter bottle with 100 mM saline). The quality factors, Q for all the channels were greater than 150 and 55 on unloaded and loaded Q, respectively.

<table>
<thead>
<tr>
<th>1H</th>
<th>19F</th>
<th>31P</th>
<th>7Li</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loaded</td>
<td>55</td>
<td>75</td>
<td>95</td>
</tr>
<tr>
<td>Unloaded</td>
<td>245</td>
<td>185</td>
<td>165</td>
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</tbody>
</table>

Table 1. Comparison of loaded and unloaded Q for four different nuclei

Conclusion:

A prototype quadruple-tuned RF probe was designed and implemented. This Band/Low-pass coil will have applications in high resolution MRS and may help future application in clinical MRI/MRS.

Reference:


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