Multi-tuned transmission line (TXL) probes for solid state NMR have been in use for two decades now and have been described in detail in [1] and [2]. The TXL probe consists of a single sample coil, low RF loss transmission line, and a matching network mounted outside the magnet. TXL probes generally have the advantage of a very efficient observe channel. In physically long, high field magnets, however, it comes at the price of high loss in the high frequency $^1$H channel. To make TXL probes more useful in high field magnets, we have modified their design in two ways. First, we have reduced loss at high frequency by locating tuning and matching capacitors within the bore of the magnet. Second, we have provided for higher $B_1$ homogeneity by electrically balancing the sample coil at the $^1$H frequency. With these two modifications, the transmission line approach can be efficiently used in long, high field magnets such as the NHMFL 900 UWB.

We have designed and tested a balanced, double tuned $^{15}$N {$^1$H} TXL probe for a 600 MHz spectrometer. Figure 1 shows a schematic diagram of the probe. Because of their low RF loss, 75 Ω air coaxial cables were used throughout. The lengths of three coaxial cables from point 'b' to points 'a', 'c', and 'd' are critical for proper functioning of the probe: to transfer maximum power to the sample coil and to create the maximum $B_1$ field [2]. Optimal lengths of the cables depend on the impedance of the RF coil and the frequency of operation. The probe shield, which is grounded a quarter-wavelength away from point 'a', acts as “sleeve balun” and electrically balances the sample coil at the $^1$H frequency. The coaxial cable from 'a' to 'b' is used to create a voltage node at 'b', while the cable length between 'b' and 'c' aids in $^1$H tuning. For proper isolation between two channels, a cable is added from point 'b' to point 'd'. The latter cable is nearly a quarter-wavelength long, thus producing a high impedance at point 'b' and reducing the transfer of power at the $^1$H frequency to the $^{15}$N port. At the 61 MHz $^{15}$N frequency, The low AC resistance of the large diameter (.375") center conductor in the transmission line between points 'd' and 'a' ensures that most of $^{15}$N power dissipates in the sample coil and not in the matching network.

A TXL probe using above concept was built for the 600 MHz wide bore spectrometer at the NHMFL. The sample coil for the probe was a 5.5 x 7.5 x 12 mm rectangular solenoid with four turns. Performance of the TXL probe was compared with that of a double tuned $^{14}$N {$^1$H} probe with a similar sample coil based on a balanced version of the Cross-Hester-Waugh (CHW) network [3,4]. For 66 W of input power at 600 MHz, the 90° pulse widths ($\tau_{90}$) were measured with a reference sample of 100% neutral parafinic oil. $^{15}$N pulse lengths were measured with a sample of 84 mg of (NH$_4$)$_2$SO$_4$. The results, as shown in Table 1, demonstrate that a properly designed, multi-tuned TXL probe for a high field magnet can improve the efficiency of lower frequency observe channel, while retaining the same high performance in the $^1$H channel.

<table>
<thead>
<tr>
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<th>$^1$H $\tau_{90}$ (μs)</th>
<th>$^{15}$N $\tau_{90}$ (μs)</th>
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</thead>
<tbody>
<tr>
<td>CHW</td>
<td>4.9</td>
<td>7.8</td>
</tr>
<tr>
<td>TXL</td>
<td>4.7</td>
<td>6.3</td>
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</tbody>
</table>

Table 1. Measured pulse lengths for Cross-Hester-Waugh (CHW) and Transmission Line (TXL) probes.

Acknowledgements

The authors would like to thank Dr. E. Y. Chekmenev for his assistance in testing the probe.

References