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Second order proton traps for multi-nuclear RF coils: Applied for 13C MRS in humans at 7T

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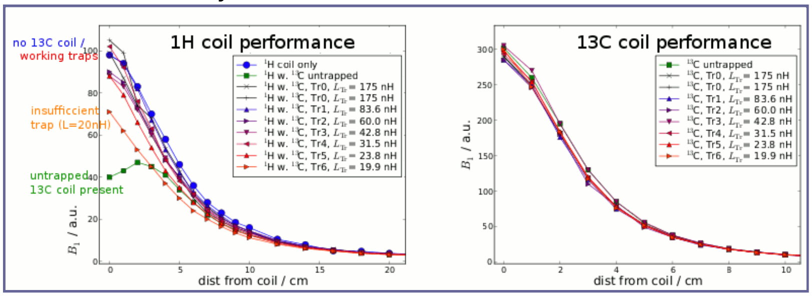
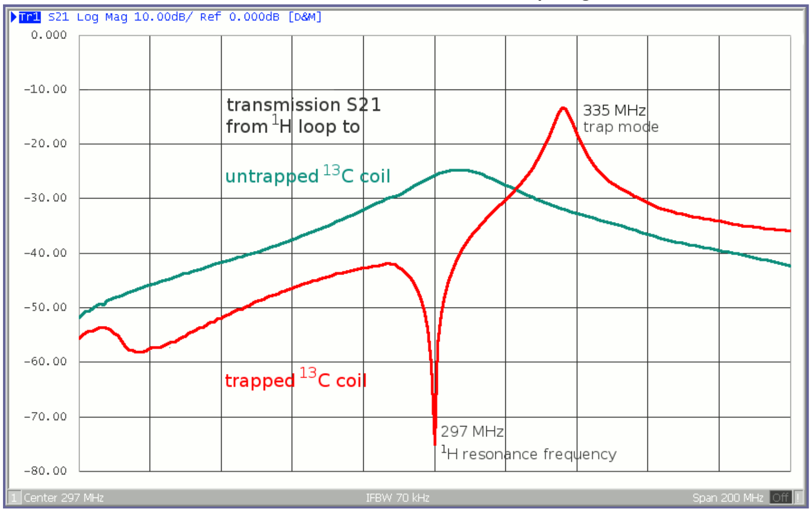
Abstract:
Purpose/Introduction:
Multi-nuclear coils typically consist of two sets of elements, tuned to operate at the proton and lower X-nuclear frequency. One technique to prevent coupling between the X and 1H elements at the 1H frequency is to insert traps into the non-proton elements. The simplest trap consists of a parallel inductor and capacitor tuned to block current at the proton frequency [1,2]. When adding an extra capacitor in series with the inductor [3], the trap can be designed to appear capacitive at low frequency which gives the freedom to replace one of the loop capacitors (C_{coil}) at the low frequency.
Methods:
Solving the conditions for the trap at 1H and X frequency

$$Z_{\mathrm{Tr}} = \left[\mathrm{j}\omega C_{\mathrm{p}} + \frac{1}{\frac{1}{\mathrm{j}\omega C_{\mathrm{s}}} + \mathrm{j}\omega L_{\mathrm{Tr}} + R_{\mathrm{Tr}}} \right]^{-1} \longrightarrow \begin{cases} \infty & \text{for } f_{\mathrm{HF}} = f_0(^1\mathrm{H}) \\ Z_{C_{\mathrm{coil}}} & \text{for } f_{\mathrm{LF}} = f_0(^{13}\mathrm{C}) \end{cases}$$

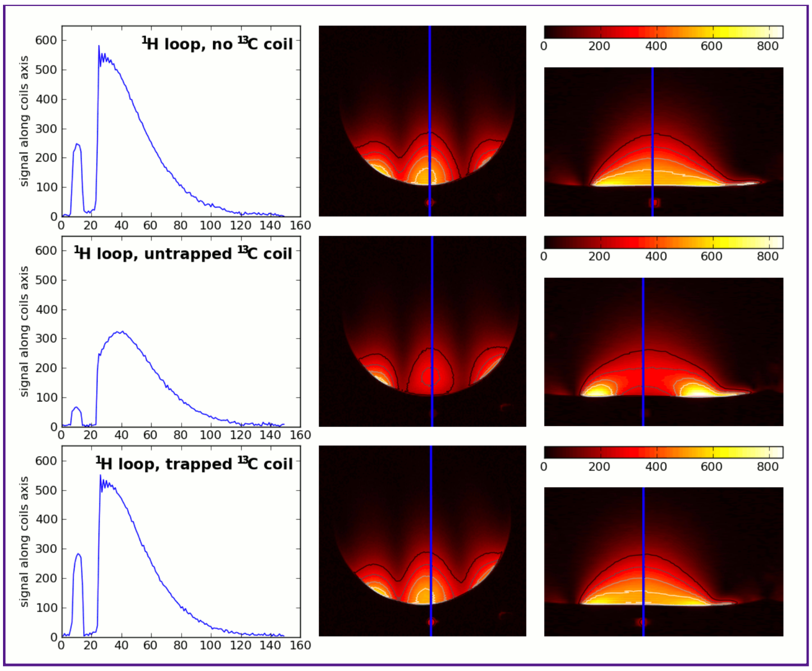
results in a pair of capacitors for an arbitrarily chosen trap inductance. Based on these calculations a series of second order traps was constructed L_{Tr}=20-175nH for use in a 7cm 13C-coil. For tests in the MR scanner, L_{Tr}=40nH was chosen. Performance was assessed on the bench using a single sniffer loop to measure B1 with and without traps in the presence of a single 1H loop.
Results:
Above a threshold of ca. 25nH, the trap effectively blocks interactions between the coils at the 1H frequency (Fig. 4a), while the sensitivity reduction of the 13C coil remains below 10%, even for very large trap inductances (L_{Tr}>L_{coil}).



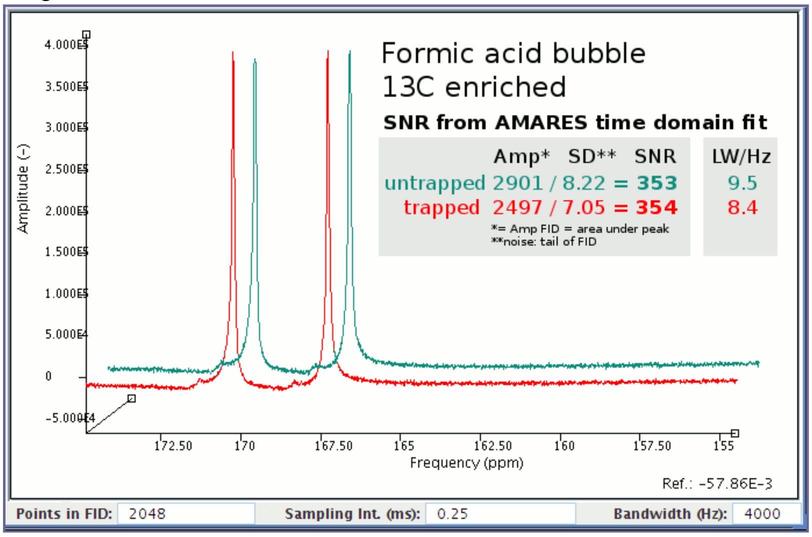
An S21 measurement shows excellent decoupling of 1H and X-coil:



1H GRE images clearly show signal drop out when adding an untrapped 13C loop to the system, and how this effect is alleviated by a second order trap.



Adding the second order trap has only minor impact on 13C SNR (<5% as line width corrected comparison of peak height/noise, and <1% when SNR is determined from an AMARES fit.)



Discussion/Conclusion:

The concept of second order proton traps (consisting of an inductor and two capacitors) in coils for non-proton NMR allows control over the resonance frequency, the blocking frequency and the trap mode frequency. Effective proton traps with relatively high L_{Tr}, and thus very effective blocking, can be constructed, which impose only small degradation of the non-1H coil sensitivity.

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References:

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