High-Field Double-Tuned TEM/Birdcage Hybrid Volume Coil for Human Brain Imaging.

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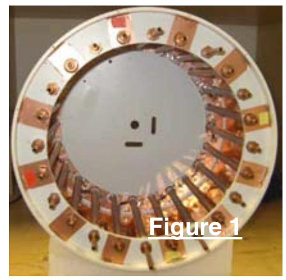
Introduction: ^{31}P and ^{13}C spectroscopic imaging of the human brain is ideally performed using double-tuned coils, so as to avoid repositioning artifacts arising from changing the ^{1}H imaging coil and ^{31}P spectroscopic coil during the study**.** Also running experiments at high fields (>3 T) yields superior SNR, which is often a limiting factor at X nuclei (^{13}C and ^{31}P) frequencies. TEM (1) designs have been reported for the fields up to 7 T for body (2) and up to 9.4 T for head (3) MRI. Double-tuned TEM coils are commonly constructed by placing elements needed for the high frequency (^{1}H) operation in between those for the lower frequency X nuclei in an alternating fashion (1). However, this causes a substantial decrease (from ~10-15 MHz to ~2-3 MHz at 4 T) in the mode splitting at ^{1}H frequency, due to residual coupling between the ^{1}H and X nuclei elements (1). This makes the TEM coils susceptible to a shading artifact produced by mode mixing due to the interaction of the RF B_1 field with imaged tissue (1,4). In this work we report a novel design of a ^{1}H/^{31}P double-tuned 4T hybrid volume head coil, in which a TEM-type ^{1}H coil (170 MHz) is combined with a high-pass BC ^{31}P coil (69 MHz).

Methods: A double-tuned quadrature 24-element (12 for each frequency) TEM/BC head coil was built using tunable capacitive coaxial elements (1) for both TEM and BC coil's components (Fig.1). The volume coil was shielded and end-caped. The TEM part of the coil was constructed as described in Ref. (1) with the central rods of the adjustable coaxial elements connected to the shield by sliding contact. High-pass BC's elements, located between the TEM elements, were attached to the same plastic former, but were electrically isolated from the shield. To decrease the resonance frequency of the ^{31}P BC coil, 100 pF capacitors were soldered across each of the BC coaxial element. The RF cavity (shield) id was 34.5 cm; the coil length was 20 cm with all 24 elements positioned at a diameter of 28.5 cm. Both coils (TEM and BC) were driven in quadrature using two-port drives (1) and capacitive matching (Fig.2). For simplicity, only one of the two driving points for each coil is shown. All variable capacitors shown in the figure are coaxial capacitive elements of the TEM (C_{TEM}) and the BC (C_{BC}), except the two matching capacitors. Isolation between the quadrature channels of each coil as well as between the ^{1}H and ^{31}P coils themselves was better than -20dB.



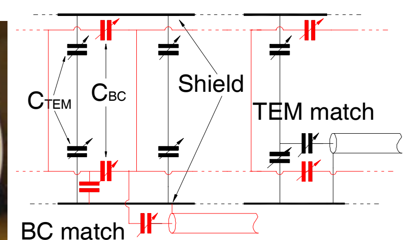


Figure 1 Schematic of the TEM/BC.

Results and Discussion: Fig. 2 shows the resonance modes of the ^{1}H/^{31}P hybrid TEM/BC coil as well as those of a similar sized common ^{1}H/^{31}P TEM coil, as in Ref. (1). The separation between the modes of the ^{1}H channel of the hybrid coil was 17 MHz (Fig.2A), while for the ^{1}H/^{31}P TEM it was only ~2.5-3 MHz (Fig.2B). Since meshes of the BC and the inductive "windows" of the TEM in the hybrid coil are positioned at 90° relative to each other, the coupling between them is substantially reduced, thereby restoring the mode separation of the ^{1}H TEM part of the coil. The mode separation for the ^{31}P part was also improved (Figs 2B and D) due to the intrinsically stronger coupling between the elements of the BC coil. Using variable coaxial capacitors for both the TEM and the BC provided an easy way of tuning and adjusting the RF current in the elements of both coils to mimic a sinusoidal distribution, using the procedure previously described (5). Performance of the hybrid TEM/BC and the TEM coils at both frequencies (measured as power required to produce a 90° pulse) was the same within an error of 1dB. However, the volume of the hybrid BC/TEM coil was about 15-20% larger.

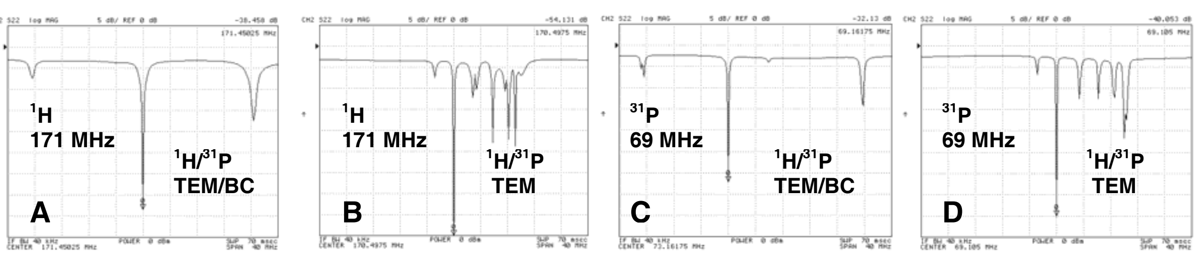


Figure 2 Resonance modes of the ^{1}H/^{31}P TEM and the new TEM/BC coils. Frequency span is 40 MHz.

Conclusion: A new type of double-tuned coil for human brain imaging and spectroscopy was designed and constructed. Combination of TEM and BC designs allows substantial increase in resonance mode separation at ^{1}H frequency (TEM part), thereby removing shading artifact and preserving the associated high-field advantages of the TEM technology.

References: 1) Vaughan JT et al, MRM 1994;32:206-218. 2) Vaughan JT et al, Proc ISMRM 14, 2006, p 213. 3) Vaughan JT et al, Proc ISMRM 14, 2006, p 529. 4) Tropp J, Proc ISMRM 9, 2001, p 1129. 5) Avdievich NI et al, MRM 2003;50:13-18.