Open Volume TEM Quadrature Coil for High Field Imaging

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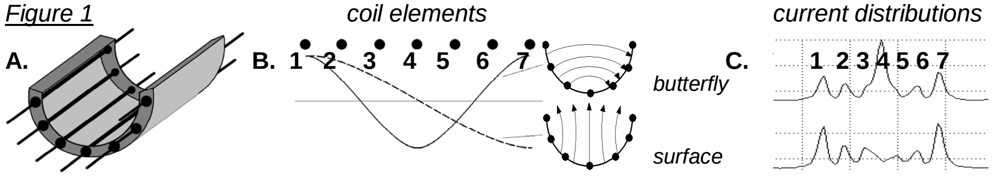
Introduction TEM volume coils are a well-established alternative to conventional birdcage designs for imaging at high fields due to a number of advantages including; easier size scaling, absence of the end ring currents and better sensitivity (1). A number of imaging applications can benefit by the use of "open" volume coils, which would improve patient comfort and accessibility, increase the transmission efficiency and detection sensitivity, and minimize power deposition (by restricting the field of view to the region of interest). While open quadrature birdcage coils have been constructed in the past (2), successful development of similar TEM devices has not been reported, although some attempts have been made (3). In this presentation, we describe our design of the first quadrature open TEM coil and show the results of its operation at 4T.

Theory A TEM coil consists of a number of coupled resonant elements producing several modes that resonate at different frequencies. The number of modes in a chain of coupled elements is equal to the number of elements. In a typical closed TEM coil (1), some of the modes are degenerate and the number of distinct resonant frequencies is reduced. The second lowest resonance frequency of this coil corresponds to a degenerate pair of modes with currents flowing in the elements such that their amplitudes are modulated sinusoidaly around the coil, fitting one period for the 360^0 revolution. Quadrature coil operation is easily achieved in a closed TEM coil by simultaneously driving these two degenerate modes. The situation is different for an open TEM coil, in which no frequency-degenerate modes naturally exist. To achieve quadrature operation, two orthogonal modes have to be selected, explicitly made degenerate and independently driven. These modes have been identified and utilized in our design.

Methods The geometry of our open, seven-element TEM coil (20 cm id, 20 cm length, 26 cm shield diameter) is presented in Figure 1A. Coaxial elements similar to those described by Vaughan et. al. (1) were used. The boundary conditions require that an integer number of current amplitude modulation sinusoid's half-periods exists in the elements going from element one to element seven. The current distributions and B_1 field patterns for the "surface mode" (vertical B_1 field) and "butterfly mode" (horizontal B_1 field), corresponding to the second and the third lowest resonant frequencies, are illustrated in Figure 1B. Surface mode was driven by using symmetrized matching network connected to the elements one and seven. To ensure 180^o phase shift between the currents in these elements, virtual ground was created at the center point between the connections by using a balancing unit. Butterfly mode was driven at the center leg. No currents in this leg exist for the surface mode, which made it possible to achieve high degree of isolation (better than 23 dB) as well as independent tuning of the butterfly mode.

Figure 1

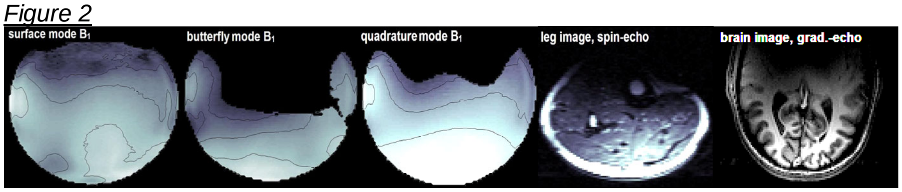


A. Coil geometry. **B.** Theoretical currents for the chosen modes and the corresponding B1 field patterns.
C. Currents in the elements for the butterfly (top) and surface (bottom) modes, made degenerate.

The frequency of the butterfly mode was reduced to match the frequency of the surface mode by increasing capacitance in the center element. The frequency of the surface mode was also affected by the placement and values of the matching capacitors. The current distribution pattern became somewhat perturbed (Figure 1C) because of these adjustments, which did not significantly distort the field patterns. When the modes were made degenerate, quadrature coil operation became possible. The absolute values of currents in each element are presented for both modes in the coil's final configuration in Figure 1C using a device described by Avdievich (5).

Results B_1 maps for the surface, butterfly and quadrature modes, as well as images of a volunteer's leg and brain are presented in Figure 2. The B_1 maps for the two linear modes of the coil are distorted due to the RF penetration artifact, which is observed in conducting objects imaged at high frequencies (4). The distortions are roughly complementary to each other, which leads to an effective self-compensation of the artifact when the coil is operated in quadrature. Sensitivity comparison with a full-volume TEM coil (27 cm id, 20 cm length, 33 cm shield diameter), based on the human brain image, yielded peripheral SNR enhancement by a factor of approximately 3 with a gradual decrease in the direction away from the surface, until the SNR values for both coils became equal at the depth of approximately 7 cm. Additionally, power calibration performed over the central axialslice led to the optimal power level roughly 7 dB lower for the open TEM coil. The homogeneous region of the device is sufficiently large that it can be used as an efficient volume coil. Constructing high-frequency body coils accommodating receive arrays, therefore, becomes possible using this technology, since it provides easier access and lower power deposition than conventional volume coils.

Figure 2



.**References**

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