Shielded Surface Coils and Halfvolume Cavity Resonators for Imaging and Spectroscopy Applications at 7 Tesla

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Introduction:
At very high frequency such as 300 MHz, radiation losses contribute significantly to the coil losses for coils that approach wavelength dimensions. For that reason efficient human head volume and body coils are built with an RF shield incorporated into the resonance structure and with distributed capacitors that compensate for coil current phase errors [1]. Similar large very high frequency surface coils for human applications incorporate an RF shield into the coil resonance structure for optimal performance [2,3]. We have investigated the performance of various shielded surface coil combinations as well as cavity resonator type designs [4].

Methods:
We built shielded transmit/receive surface coils with dimensions ranging from 6 cm to 18 cm. For coils >12 cm we used 6 mm copper tubing and up to 10 distributed capacitors. Smaller coils were built from copper tape and up to 6 distributed capacitors. For the cavity resonator based coils we used split coaxial elements in various lengths [4]. The coils were capacitively coupled using a balanced output circuitry. The shield was connected to the RF coil ground. For multinuclear applications we built a shielded design comparable to a previously described 4 Tesla coil [5]. We compared the coil performances on the bench using a cylindrical phantom filled with 1.5 l saline solution. The experimental measurements were performed on a 7 Tesla/ 90 cm magnet with a 38 cm i.d. head gradient coil (Magnex Scientific, UK) interfaced to a Varian INOVA console (Palo Alto, CA).

Results and Discussion:
RF shielding improved the $B_1$ sensitivity in the coil center for surface coils by 1 dB to 1.8 dB (12 cm, 18 cm) at 300 MHz. Small surface coils (<7 cm) displayed negligible performance improvements when shielded. A distance between RF shield and coil of 4.5 cm was found best suited for surface coil sizes of 10 cm to 18 cm. For applications requiring larger FOV’s we found the halfvolume cavity resonator design optimal. On the bench we measured a 4 dB higher peak $B_1$ for a 9 element, 15cm length, halfvolume cavity resonator (Fig.1c) when compared to a shielded butterfly type surface coil of similar dimensions. However driving such cavity resonators in quadrature without loss in transmit efficiency was difficult. A shielded quadrature surface coil with 10 cm x 12 cm oval shaped coil loops (Fig. 1b) was found to achieve highest $B_1$ sensitivity and SNR, good penetration and sufficient FOV for most occipital lobe fMRI and spectroscopy applications (see Figure 2). We use this coil also in conjunction with a linear $^1$C coil (75 MHz) as a proton decoupling coil. Coil decoupling of at least 18dB between the proton coils and the carbon coil was routinely achieved with a human head as a load. Typically 40 Watts of RF peak power was required to achieve a 90° flip angle using a 2 ms Gaussian pulse with this coil.

Fig. 2 Sagittal and axial RARE [6] images acquired with a shielded 10 cm x 12 cm quadrature surface coil. TR = 4 s, echo train length 8, echo spacing 15ms, matrix size: 256 x 256.

Conclusions:
Shielded surface coil designs are required for human applications at very high frequencies of 300 MHz for highest $B_1$ sensitivity. The performance of shielded circular surface coils up to 12 cm-loop diameter is comparable to resonance cavity designs of similar dimensions.

Fig. 1 a) The coil former is shown with an adjustable bite-bar and patient controlled release mechanism. The drawings illustrate: b) a shielded quadrature surface coil design, c) a 9 element halfvolume cavity resonator design and d) a shielded surface coil combination for multinuclear and active decoupling applications.

References:

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