An Analysis of an Extended Cavity TEM Coil

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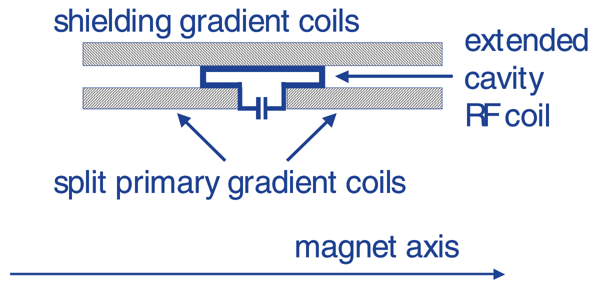
Concept



At last year's ISMRM Vester et al [1] presented an interesting RF body coil concept whereby the RF coil was integrated into the space between two halves of a split unshielded gradient coil, thereby freeing up bore space for the patient. In addition, by bulging the magnet warm bore an extended RF cavity was created which improves the RF efficiency (defined as B_1^+ / I).

More recently the same group has presented a more practical embodiment of this concept, using a shielded gradient set with split primary coils, and again an RF body coil embedded in the gap [2]. In this version the extended RF cavity is created within the space between the primary and shield gradient coil windings, as shown schematically in the top figure.

This RF concept, which is basically a TEM coil [3] with an extended cavity, was studied using numerical finite-difference time-domain simulations. A physical TEM coil without an extended cavity was built in order to calibrate the power calculations.

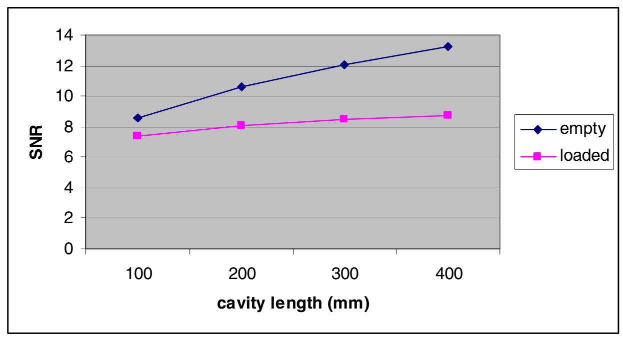
Methods

The physical coil was a very short 32-rung TEM coil with 100mm rungs spanning the "gradient gap", and a 700mm diameter. The exterior surface of the cavity had a 800mm diameter. The copper foil of the cavity was extended axially on a 700mm diameter in order to model an RF shield around the primary gradient coils. Empty and loaded Q measurements were made; and using a calibrated flux probe the empty power efficiency was calculated. From the Q and tuning capacitance, the coil resistance was estimated.

In the simulations the gap was kept at 100mm, while the cavity length was varied from 100mm to 400mm. The radial space in the extended part of the cavity was 25mm. The simulated load corresponded to that of a 104kg man

Coil resistance can be estimated from FDTD, but the values are typically much less than in practice, hence the obtained values were scaled using that of the physical coil.

As a function of cavity length, empty and loaded efficiency, B_1^+ uniformity, SNR, tuning capacitance, patient SAR, and power requirements were calculated; and the modal structure of the resonances determined.



Results

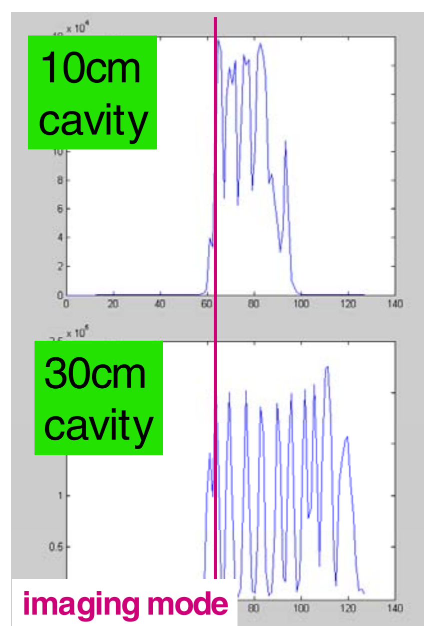
For the physical coil, the empty and loaded Q's were 310 and 140 respectively; and the power requirements were 11.5W at 1uT (empty).

While the coil's efficiency increased almost linearly with cavity length, the coil's inductance was also proportionally increased; resulting in an almost constant E field (normalized with respect to B_1^+) within the patient bore. Hence patient SAR was virtually independent of cavity length.

The cavity had virtually no effect on the peak B_1^+ uniformity error, which was about 40% over a 45cm diameter sphere.

The simulated empty and loaded SNR variations are shown in the middle figure. Increasing the cavity length from 100mm to 400mm increased the SNR by about 58% and 18%, for the empty and loaded cases respectively. These correspond to empty and loaded power reductions of 58% and 29% respectively.

The extended cavity also improves the mode spacing quite dramatically, as shown in the lower diagram.



Discussion

Provided the construction practicalities can be overcome, using an extended cavity is a very nice technique for improving the performance of a short TEM coil.

References

[1] Vester et al, ISMRM Proc., abstract 404 (2005)
[2] Heid et al, US Patent 6930482 B2 (2005)
[3] Vaughan et al, MRM 32:206-218 (1994)