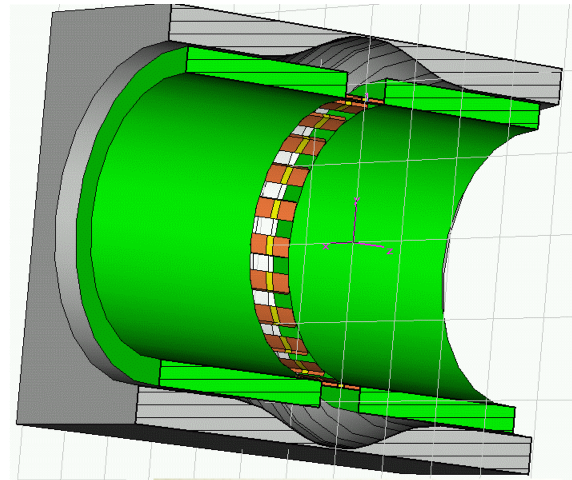
A Novel Concept for RF Coil and Gradient Coil Integration

M. Vester[1], O. Heid[1], L. Eberler[1], J. Nistler[1]
[1]Siemens Medical Solutions, Erlangen, Germany



Concept: The thickness of the RF body coil is usually selected as a compromise between maximizing RF efficiency, governing transmit power requirement and receive SNR, and minimizing radial space to increase gradient coil efficiency or maximize patient bore size. Therefore it would be attractive to integrate the RF functions into the gradient coil system. However, attempts to lead RF flux through parts of the gradient coil are difficult due to excessive RF absorption around the gradient conductors, which show a broad spectrum of self-resonances at MHz frequencies.

The concept of a barrel-shaped, bulged magnet bore enclosing a passively shielded gradient coil [1] offers a new opportunity to combine RF and gradient generation. Driven by gradient linearity considerations, both longitudinal and transverse coils tend to have low current densities near the central plane (z=0). With a neglegible performance penalty, it is possible to create a 10 cm wide gap which is completely free of conductors. Thus the gradient coil can be split longitudinally into two halves that can separately be enclosed by RF shields. These halves can then be connected by short rungs containing series resonance capacitors, creating a lowpass birdcage resonator with very wide endrings.

In this arrangement, the gradient return flux and the RF return flux make use of the same space behind the coils. This gives rise to two important benefits:

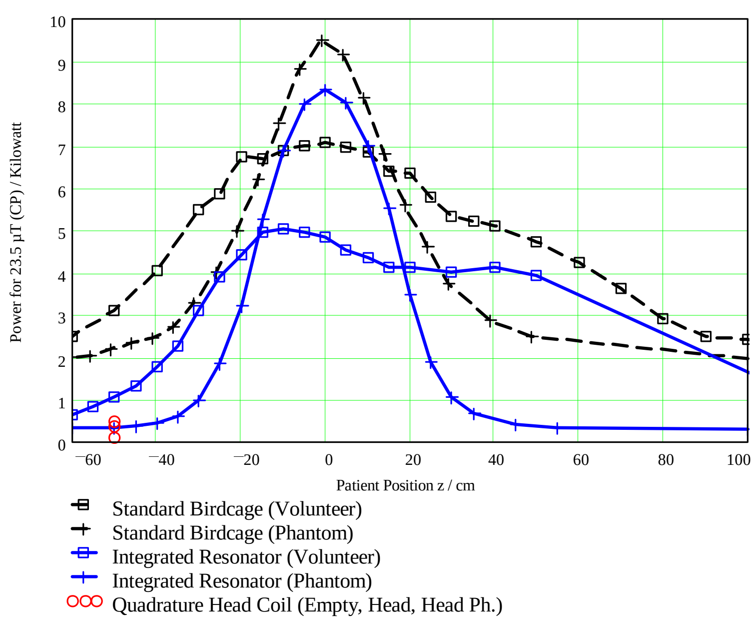
1. The RF body coil function consumes no extra radial space. This allows either an increased gradient coil performance, or a smaller magnet warm bore enabling a shorter magnet design, or a wider patient bore.

2. The cross sectional area of the RF return flux can be made quite large, resulting in less stored RF field energy and stronger magnetic coupling to the load. At a given practical value of unloaded coil Q, this results in significantly lower coil loss and higher SNR, especially with light patient loading.

The outer ends of the gradient halfs can simply be RF-shorted to the magnet bore. Alternatively, employing chokes in the gradient leads, they can be left open or connected by capacitive impedances, allowing a controlled amount of flux leakage from the ends to reduce B_1 near the regions of gradient ambiguity. However the options of B_1 profile shaping are more restricted than in a conventional birdcage design.

Measurements and results: To demonstrate the feasibility of the concept, we built an outer shield with a barrel-shaped central section, containing mock-ups of the gradient halves with continuous copper surfaces and 24 rungs. Unloaded resonator Q_o at 64 MHz was ~540, decreasing to ~21 when loaded by a 80 kg person. B_1 efficiency was measured as a function of volunteer z-position and plotted as total input power required to generate a 23.5 µT circular polarized central B_1 field. This was compared to a standard highpass-type birdcage coil of 3 cm thickness (Q_o~350).

The effective magnetic volume $V_{mag} = 2\ \mu_o\ W_{mag} / B_{1\,(center)}$ was 3.9 m^3 for the birdcage and 1.0 m^3 for the new resonator, resulting in approx. six times lower intrinsic coil loss. The power absorbed by the patient is similar for maximum loading, but decreases more rapidly as thorax and shoulders are moved outwards from the central gap. In a position for head imaging (-50 cm), receive SNR of the integrated resonator is about 4.9 dB better than the standard birdcage and only 4.3 dB less than a quadrature head coil.



Reference: [1] Heid O. et al, A Novel Concept for Gradient Coil and Magnet Integration (submitted to ISMRM 2005)