A Computational Study of Image Shading due to Matching Circuitry, in Head Resonators at 3.0 T

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Image shading due to reactive perturbation has been studied in multi-mode resonators; and it is found that susceptibility to shading becomes worse as the frequency spacing decreases between adjacent resonant modes (*1*). We here begin to take up the related, but more complex question of shading due to the combined resistive and reactive perturbation from the impedance matching network. Given that the circuit theory of cylindrical resonators is sufficiently advanced to permit determination of the mode resistance from the element resistance (*2*), the perturbed current distributions are straightforwardly calculable. Also, efficient radiofrequency models now allow that such perturbed currents be used to supply the drive for shielded resonators, loaded with lossy dielectrics (3). We therefore start with a realistic circuit model, add dissipation, calculate the mode resistance, determine the matching network, reduce this to an equivalent series RC network, and solve the resonator circuit equations for the perturbed currents, which then become the inputs for the electromagnetic model, from which are obtained the magnetic fields and simulated images, for the resonator irradiating a lossy dielectric cylinder. We hasten to add that the resistive losses in the circuit model are introduced *deus ex machina*, and not derived from the dielectric losses, which are given only to provide a realistic imaging sample. As described below, our preliminary results are that a shielded bird cage head coil at 3.0 T will experience a shading effect of roughly 3% in image intensity, when run with conventional two port quadrature drive.

Our circuit model is based on an actual resonator: a shielded, end-capped, high pass, bird cage head coil for 3.0 T, for which the reactive circuit parameters (capacitances, self and mutual inductances) are already known (*1*). The reactive (lossless) circuit model is then modified by addition of a 2 Ω resistance to each mesh, plus the correct match capacitance (at the drive point) shunted with a 50 Ω load resistor. The net equivalent series resistance, 16 Ω, then corresponds closely to the resistance due to loading with a human head. Figure 1 shows the perturbed current distribution (red trace) compared with an ideal cosine distribution (green trace). The horizontal axis is the coil azimuth/2π; the driven leg is at zero azimuth. A small imbalance is observed (augmented currents at π/2 and 3 π/2, diminished at π). This imbalance is clearly manifest in the real part of the linearly driven vector potential (Fig. 2, left), where the flux is seen to be slightly concentrated about the element at 3 o'clock, which corresponds to the drive point. The imaginary vector potential (Fig. 2, right) does not show an obvious shading, nor does the simulated image (gradient recalled, small flip angle) of Fig. 3, which is calculated for two point quadrature drive using the perturbed currents in both channels. However, a profile of the image (Fig. 4) shows a slight but unmistakble asymmetry, with an intensity increase of about 3% in the uptick at the right periphery of the image, corresponding to the position of the drive point. While results with a phantom predict only approximately those with an actual human head, the indications here are that 4 point quadrature drive is not a necessity (or even a noticeable advantage) for imaging the head at 3.0 T with bird cage resonators.

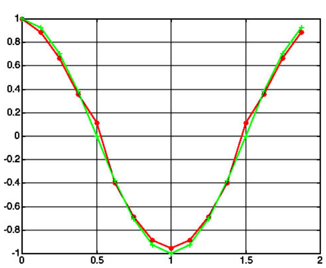

Figure 1: Perturbed currents (red) for linear excitation of lossy bird cage model with matching; also ideal cosine current distribution (green.) The horizontal axis is (azimuth/π); the drive point is at zero. See comments in text

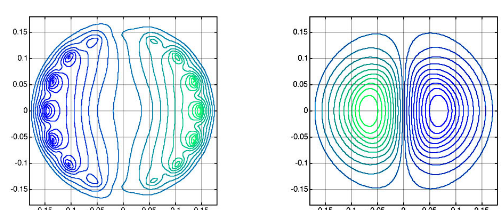

Figure 2: Plots of magnetic flux (iso-contours of vector potential) for linear excitation of shielded resonator with dielectric load (left, real component of vector potential, right, imaginary) shield radius 17.7 cm, resonator rods on 14.6 cm bolt circle, dielectric phantom radius 9.25 cm, relative dielectric constant ε = 80, conductivity σ = 0.5.

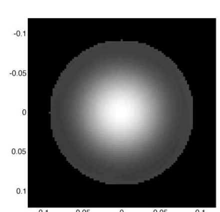

Figure 3: Simulated image of dielectric cylinder with quadrature excitation by perturbed currents

References:

1. J. Tropp, "Proceedings of the ISMRM" (2001) 1129.
2. J. Tropp, *Magn. Reson. Eng.* (2002)**15B** 177.
3. D. Spence & S. Wright, *Magn. Reson. Eng*. (2003)**18B** 15.

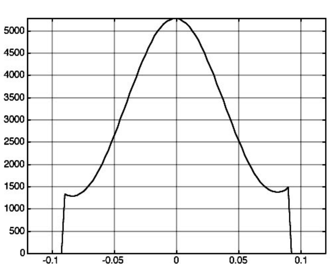

Figure 4: Profile of image (Fig. 3) showing slight asymmetry – enhanced uptick of intensity at right, corresponding to location of drive point (maximum current).