B1+ uniformity in Birdcage Body coils versus the alignment and shape of the RF shield

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Introduction:

Birdcage resonators [1] are widely used in MRI as a body coil for transmitting RF energy into the object being scanned. In order to make an image without shading, it is critical for the body coil to produce uniform B_1^+ field distribution inside the imaging volume. A balanced current distribution is one of the requirements for producing such a uniform B_1^+ field distribution. In order to shield the RF fields from the lossy gradient environment, a mesh RF shield is present between the body coil and the gradient coil. For a balanced current distribution inside the body coil , both the body coil and the RF shield have to be perfect cylinders, and they have to be concentric. Any variation in the shape or the orientation of either the body coil or the RF shield can lead to an unbalanced current distribution inside the body coil, which impacts the B_1^+ field homogeneity, and hence the image quality. In this work the impact on B_1^+ field homogeneity using numerical simulations is studied under various non-ideal conditions.

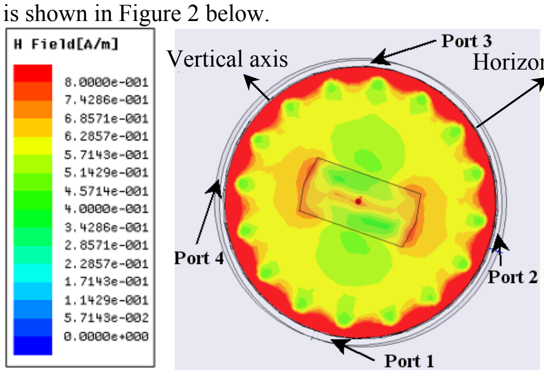
Materials and Methods:

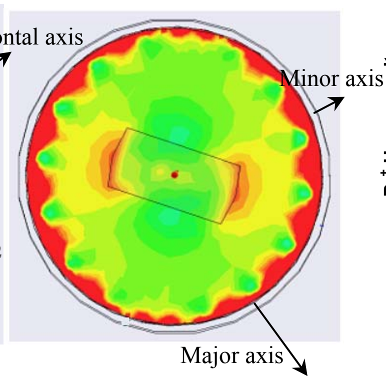
HFSS (Ansys corporation) was used to perform the numerical simulations. A 3T high pass birdcage body coil with 16 rungs was modeled. The distance between the coil elements and the 4 feet long RF shield is 20 mm, coil length was 590mm, rung width was 70mm, and the end-ring width was 60mm. Each endring segment capacitor had a value of 37.9pF, for a coil resonance frequency of 127.8MHz. The coil design had a 4 port drive scheme where the 4 input ports are 90 degrees apart in space and in phase. All 4 ports were on the same endring. The body coil was loaded with a phantom that was approximately 288mm long, 280mm wide, and 144mm high. The phantom was filled with a material having a conductivity of 0.7S/m, and the relative permittivity of 60. The impact on B_1^+ field homogeneity was studied under the following scenarios: **1)** The body coil was concentric with the RF shield (Ideal case). **2)** The RF shield was elliptical, 2mm longer in the diameter along the major axis, and 2mm shorter in the diameter along the minor axis. **3)** The body coil axis was shifted 1mm up with respect to the RF shield axis. **4)** The body coil axis was shifted 1mm down with respect to the RF shield axis. **5)** The body coil axis was shifted 1mm right with respect to the RF shield axis. **6)** The body coil axis was shifted 1mm diagonal at 45 degrees with respect to the RF shield axis. B_1^+ field homogeneity was calculated using the following equation:

$$B_1^+ Homogeneity = 100 * \left(1 - \frac{MaxROI - MinROI}{MaxROI + MinROI}\right) \qquad (1)$$

Results and Discussions:

The B_1^+ field distribution at the center of the body coil for the ideal case (Scenario #1) is shown in Figure 1, and for the elliptical case (Scenario #2) is shown in Figure 2 below.





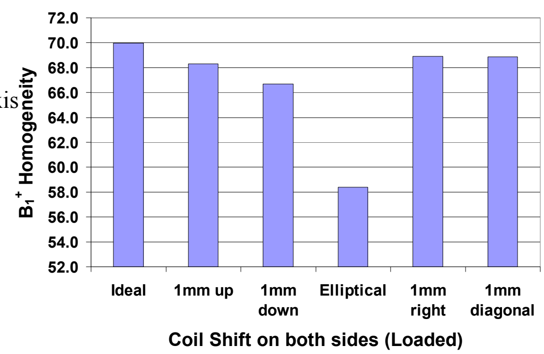


Figure 1: B_1^+ field for scenario # 1* Figure 2: B_1^+ field for scenario # 2 * Figure 3: B_1^+ field homogeneity for all scenario

*Figure 1 and Figure 2 in fact are the plots of the complex magnitude of the H field. However, since B field is directly related to H field by the equation B=μH, H field also has the same field distribution as that of B field and hence can be used for B_1^+ field homogeneity calculations. The color scale in Figure 1 and Figure 2 ranges from 0 to 0.8A/m.

Figure 3 shows the calculated B_1^+ field homogeneity using Equation (1) mentioned above. It is clear from Figure 3 that the imperfection in the centering of the high pass body coil inside the RF shield has less impact on the B_1^+ field homogeneity (Max reduction of ~5% in B_1^+ field homogeneity for a 1mm down scenario) as compared to imperfections in the shape coherence of the RF shield and RF coil (Reduction of ~16.5% in B_1^+ field homogeneity for the elliptical RF shield scenario.).

Conclusion:

A similar cylindrical shape of the body coil and the RF shield, and the centering of the body coil inside the RF shield is critical for the balanced current distribution in the body coil and hence for the B_1^+ field homogeneity and image quality. Impact on the B_1^+ field homogeneity is less significant for the high pass body coil when the imperfection is only in the centering. However, when the shape of RF shield or the RF Body coil is made slightly elliptical a significant impact on the B_1^+ field homogeneity was observed. These distortions in the field uniformity are on top of any non uniformities caused by wavelength effects (i.e. when the wavelength in the object is smaller than the object). It is important to note that such imperfections in the shape of the RF shield and the body coil are normal for a typical manufacturing process, i.e. one can expect a 1 mm tolerance on a 700 mm diameter tube.

Reference:

[1] C. E. Hayes, W. A. Edelstein, J. F. Schenck, O. M. Mueller, and M. Eash, An efficient, highly homogenous radiofrequency coil for whole-body NMR imaging at 1.5 T, *J. Magn. Reson.* **63,** 622–628 (1985).