Surface RF and Gradient Coil Set for Microscopic Skin MRI

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Abstract: For high resolution skin microscopic MR imaging, strong gradient fields of more than 10 Gauss/cm is required. In this paper we designed and implemented an integrated planar RF and gradient coils for skin microscopic imaging. By the coil system we were able to get high resolution skin images less than 50 µm resolution.

Introduction: MR imaging of human skin has been of little diagnostic value as yet because most skin abnormalities can be investigated visually. Nevertheless, a noninvasive visualization of the skin may have an important role in some cases, such as preoperative staging of skin tumors. But MR skin imaging has some technical problems to be solved. One of them is design and implementation of strong gradient coil which can distinguish each skin layer in image. The aim of this study is to design and implement planar-type strong gradient coil and integrate it with optimized surface RF coils for skin microscopic MRI.

Methods and material: In this paper, design scheme using current-loop elements is proposed and applied to the design of skin gradient coils. In this study, the distribution of discrete current elements calculated from the mesh distribution is optimized for the minimum power consumption. To provide the spatial information of MR images, Gx, Gy, Gz are constant within the volume of interest.

$$G_x = \partial B_z / \partial x,\ G_y = \partial B_z / \partial y,\ G_z = \partial B_z / \partial z$$

To find the desired currents, we obtain a set of linear equations. $[Const.][Desired\ Current] = [Desired\ B_z]$,which can be solved for the currents. Current matrix are computed for the minimum power by using the Lagrange multiplier. $c = W^{-1} G^{T} [GW^{-1} GT]^{-1} l$ (c: loop current element, i: line current element, G: field at target position, l: target field of target position k: conversion matrix) We have used the target field method to obtain the current distribution. Choosing various target positions, the simpler current pattern has been obtained with reasonable power consumption. Target positions and the algorithm proposed are shown in Figs.1 and 2.

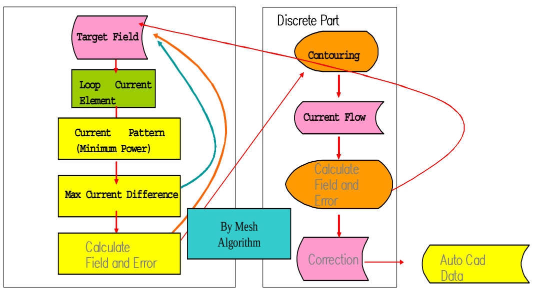

Figure 1. The optimization algorithm

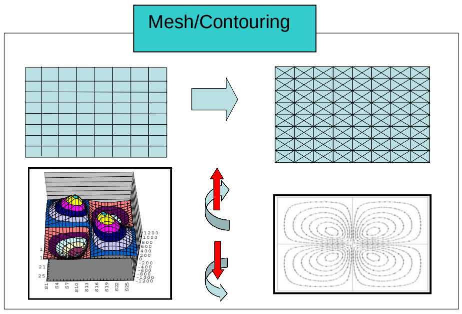

Figure 2. The mesh algorithm

Results: A surface gradient coil has been designed using the proposed algorithm. With a constraint of target field, we can get a current pattern by using matrix equation as shown in Fig. 3 and the field linearity are around 5% errors in the 5mm region of interest.

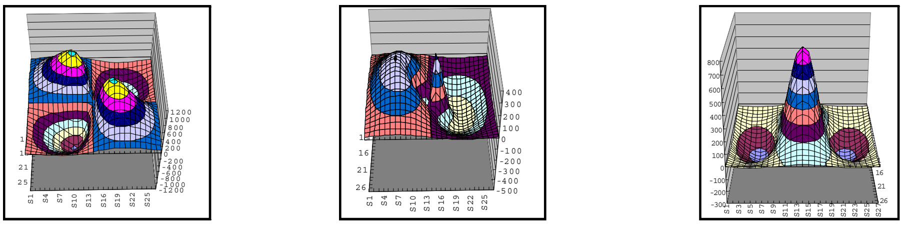

Figure 3. The current pattern (X-Gradient, Y-Gradient, Z-Gradient)

According to the simulation results, we can achieve 10 Gauss/cm gradient strength in the region of interest for all 3 gradients x, y, z.. Surface, TX, RX, and RF coils are also being constructed to incorporate with the gradient coil. Figure 4 shows a skin image obtained before with 2.5 Gauss/cm gradient strength. The Z-gradient coil is shown in Fig. 5. We make the TX coil of planar type which is shown in Fig. 7. and the high-SNR surface RX coil which is proper to skin MRI. The diameter of the coil is 8mm. The RX coil is shown in Fig. 6.

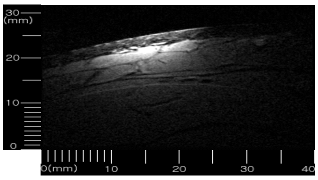

Figure 4. A skin image

Figure 5. The Z-gradient

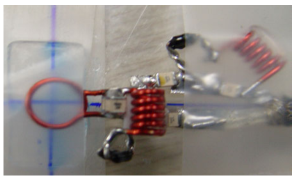

Figure 6. RX coil

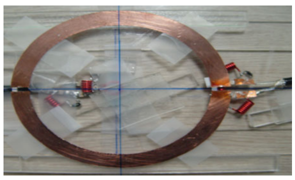

Figure 7. TX coil

Conclusions: The designed gradient coil used loop current elements and minimum-power method has been implemented and used for imaging. Experimental results show the effectiveness and utility for human skin imaging.

Reference:

C.H. Oh, D.R. Lee, “Minimum-Power and/or Minimum Inductance Gradient Coil Design Scheme of Arbitrarily-Selected Shape Using Loop-Current Element”, Proc. ISMRM Vol. 3, pp.1468, 1997

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