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HIGH RESOLUTION *IN VIVO* IMAGING AT HIGH FREQUENCIES WITH IMPROVED SURFACE COILS

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Abstract — **The enhancement of the spatial resolution with an optimised surface coil design for MR imaging of small structures at high frequencies is presented. Surface coils provide high signal-to-noise ratios (SNR) which allow to improve the spatial resolution. However, their sensitivity is limited to the region adjacent to the coil where the B_1 field distribution is more homogeneous. We present an inductively coupled series-tuned circular coil prototype, optimised for ^{1}H MR imaging at 200 MHz. The inductively coupled scheme provides a good SNR by reducing the different losses mechanisms. Preliminary images, acquired on a Bruker BIOSPEC-BMT 47/40 working at 4.7 T, have been realised over rabbit knee. Images depict a high spatial resolution, an excellent B_1 field homogeneity and no 'hot spots'.**

I. INTRODUCTION

Dedicated surface coils are used to detect NMR signals with high sensitivity from the region adjacent to the coil. As they present a high SNR, it is possible to improve the spatial resolution to visualise small structures [1,2]. However, that high sensitivity is limited to the region where the B_1 field is homogeneous. For that reason, the position of the surface coil must be chosen carefully to really enhance the image quality.

The goal of this work is to design a probe for MR *in-vivo* imaging applications adapted to the shape of the sample, with good SNR and B_1 homogeneity. We present an inductively coupled probe design optimised for ^{1}H MRI of rabbit knee; the purpose is to delimitate the size of cartilage, which makes high resolution and homogeneous sensitivity the basic requisites.

II. MATERIALS AND METHODS

Field homogeneity is the main inconvenience of surface coils, specially circular coils. The field histogram for a 50 mm circular coil has been simulated in *fig. 1* according to the method described in [3]. The theoretical spatial B_1 distribution of the RF coil was calculated computing the magnetic field in coronal slices with a custom software. The ROI selected for each plane was a square area. The horizontal axis of the histogram represents the PFD (Percentage Field Deviation), which is defined with respect to the magnetic field at the centre of each plane ($B_{1centre}$), and the vertical axis is the NPD (Normalised Population Deviation), which represents the PFD population. The expressions for PFD and NPD are:

$$PFD = \frac{B_1 - B_{1centre}}{B_{1centre}} \cdot 100$$
$$NPD = \frac{N(PFD_i)}{\sum_i N_i(PFD_i) \cdot PFD_i} \qquad (1)$$

being $N(PFD_i)$ the number of times the value PFD_i is repeated. The higher and narrower is the peak, the better is the field homogeneity. The histogram is in good agreement with the one obtained from a phantom image (a 50 mm diameter sphere filled with water) and shows that the homogeneity for circular coils is very poor. The greater the distance between the sample and the coil is, the less homogeneous the B_1 distribution is, and therefore the image resolution decreases.

On the other hand, the SNR of the coil can be improved by reducing the different loss mechanisms: coil losses and sample losses.

The losses associated with the coil are caused by the skin

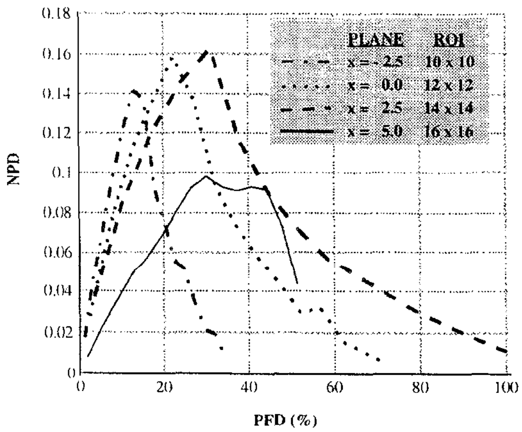

Fig. 1. Theoretical field histogram in four coronal planes for a 50 mm circular coil placed at x=0. B_1 has been sampled uniformly in 2500 points inside the ROI. All measurements in mm.

effect resistance. It is necessary to increase the wire section and, if possible, to use platted wire to diminish the resistance.

The dielectric losses in the sample, due to the alternating electric fields that heat the sample by absorption, are the more critical mechanism that reduces the sensitivity of a surface coil. They are reduced with a balanced design of the electronic circuit of the probe.

Several inductively coupled, series-tuned surface coils of different dimensions has been designed and constructed. The probe we present consists of a resonator (L_R and C_R) and a coupling loop (L_C) (*fig. 2a*). L_R is a 4 mm diameter platted copper tube loop that minimises resistive losses. L_C has been built with a 2 mm copper wire. C_R is actually a ceramic chip capacitor (ATC) and a trimmer (Voltronics) (*fig. 2b*). They have been distributed along the coil in such a way that the electric field inside the resonator becomes minimal, so the dielectric losses in the sample are reduced [2,4].

Tuning is achieved by varying the value of the trimmer C_R, and the matching is done by adjusting the separation between L_R and L_C with a mechanical system (not illustrated in fig. 2). This inductively coupled RF coil allows a nearly perfect balanced circuit with respect to the sample, and facilitates tuning and matching procedures [2,4]. Both coils are placed around a Teflon support, which permit a good coupling between them. The design of that support matches the shape of the rabbit leg (*fig. 2a*), placing the knee where the sensitivity of the coil is higher and more homogeneous.

III. RESULTS

The coil probe was used for transmitting and receiving NMR signals. It is tuned to 200 MHz and matched to 50 Ω. The quality factor (Q) of the probe was measured at 200 MHz with a RF network analyser (Hewlett-Packard model 8711A): the unloaded Q is 500, and loaded with a 50 mm diameter sphere filled with water it is 375 [5].

Images were acquired on a Bruker BIOSPEC-BMT 47/40 operating at 200 MHz. A coronal image *in vivo* obtained with our probe is shown in (*fig. 3*). Image depicts excellent B_1 field homogeneity with no 'hot spots'.

IV. CONCLUSIONS

An inductively coupled probe for high resolution small tissues visualisation has been designed and constructed. On its design, all losses mechanisms have been reduced. Preliminary images acquired with this prototype demonstrate that good homogeneity and improvement on the visualisation of small structures has been obtained.

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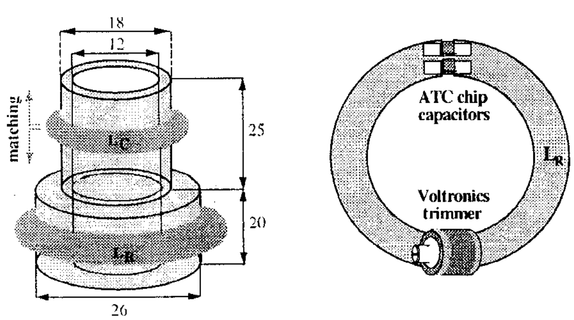

(a) (b)

Fig. 2. **(a)** Measurements of the probe in mm. **(b)** Detail of the resonator. Diameter=30 mm.

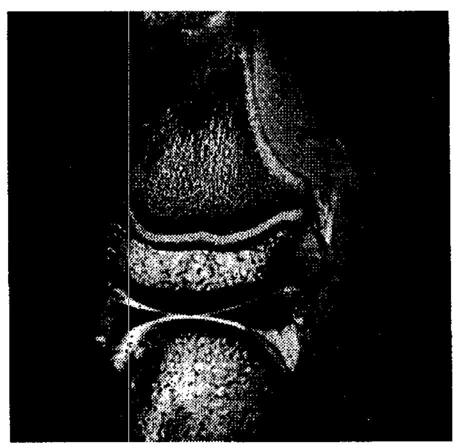

Fig. 3. Coronal image obtained with RARE sequence, FOV=25 mm, resolution=256×256, TR/TE=2000/13, slice thickness=0.5mm, NEX=8.