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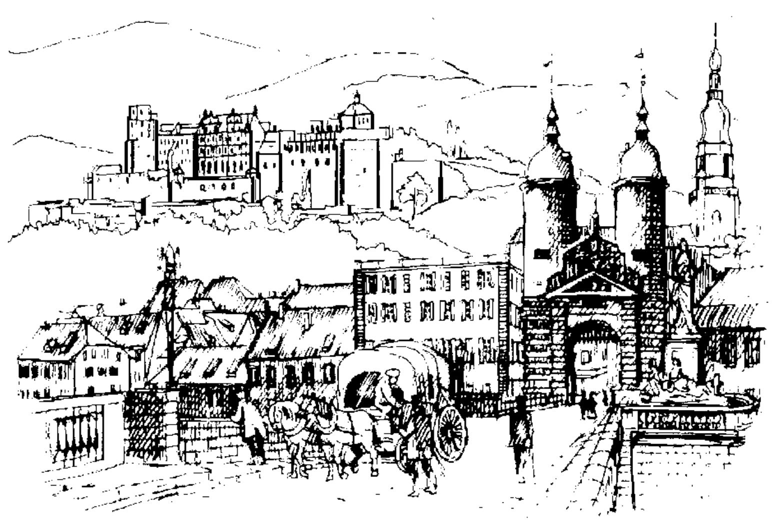

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USE OF MRI FOR MEASURING AC INTERNAL CURRENTS OF EIT: A FEASIBILITY STUDY

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This work is conducted to measure AC currents injected into an object, using Magnetic Resonance Imaging (MRI) techniques. Scott G. C. , et. al. [1] have shown that DC currents within an object can be measured by MRI. In this work, a DC current pulse is applied synchronous with a standart Spin Echo MRI sequence. This pulse is set to zero just before the read out period. This current pulse generates a magnetic field within the imaging region, which in turn causes a phase term to accumulate. The space dependent phase term is measured to find the current distribution. With AC currents, however, phase term will not accumulate because each half cycle will cancel the effect of the previous half cycle. An alternative method is developed which uses the work of Maudsley which is proposed to measure static field distribution within a MRI magnet [2]. In his work the resonance frequency of each voxel due to static field is measured. It is derived that if a time varying field is present within a voxel, a waveform which is similar to a Frequency Modulated signal is received.

Introduction:

In Maudsley's work, 90 degrees RF pulse is applied together with slice selection in z-direction. After the 90 degrees RF pulse, spatial encoding gradients in both x and y coordinates are applied. The amplitude of these gradients are incremented at each excitation such that all the coordinates in k-space are scanned. After the encoding gradients, an RF180 pulse is applied and the spin echo is recorded in the absence of any applied field gradient. During the observation period the spins therefore evolve under the influence of the magnetic field inhomogeneity perturbation effects only. The Fourier Transform of this data set with respect to spatial frequencies encoded by gradients, yields a three dimensional matrix. The two axes of this matrix are the space coordinates x and y where the third axis gives the time variation of the image in coordinates x and y. Therefore, the Fourier Transform of the data in the third coordinate gives the offset resonance frequency at coordinates x,y. The equation of the received signal is given in (1).

$$S(G_x,G_y,t)=\iint M(x,y)\exp\{j\gamma[B(x,y)t+xk_x+yk_y]\}dxdy \quad (1)$$

where, $k_x=G_x*T_G$ and $k_y=G_y*T_G$, T_G is the duration of the gradient pulses.

Taking Fourier transform with respect to k_x and k_y at each time instant yields a three dimensional data set where the two coordinates represent x and y axes and the third one represents the time axis :

$$F(x,y,t)=M(x,y)\exp[j\gamma B(x,y)t] \quad (2)$$

$$w=\gamma B(x,y)$$

If Fourier Transform is applied to equation (2) with respect to time axis, we get E(x,y,w) which is the map of offset frequencies from the center frequency on the x-y plane at $z=z_0$ (the selected slice).

If a time varying field b(x,y)cos(wt) is added to the static field, equation (1) becomes,

$$S(G_x, G_y, t) = \iint M(x, y)\exp\{j\gamma(xk_x + yk_y)\}\exp\{j\gamma(B(x, y)t + b(x, y)\sin(wt))\}dxdy \quad (3)$$

When we take the two dimensional FFT of equation (3) with respect to k_x and k_y at a constant time T_0, we get,

$$M(x,y)\exp\{j\gamma(B(x,y)\,T_0+b(x,y)\sin(wT_0))\} \quad (4)$$

This procedure is repeated for each time instant and the time variation of the signal of a voxel at coordinates x_0,y_0 is found,

$$M(x_0,y_0)\exp\{j\gamma(B(x_0,y_0)t+b(x_0,y_0)\sin(wt))\} \quad (5)$$

In this equation, $B(x_0,y_0)$ can be measured in the absence of time varying field, w is known, therefore it is possible to find $b(x_0,y_0)$.

Materials and Methods

To observe the efficiency of this method, simulations are carried out. In these simulatons, two artificial k-space data are generated. The first data corresponds to the signals received with only static field inhomogeneity. The field distribution is derived from a previously acquired field map from the z=0 slice. The second data corresponds to the signals received with the addition of time varying field. To calculate the amplitude of the time varying field, the phantom is simplified to 15 parallel wires, each carrying equal currents. The field at the center of each wire is calculated to form the total field. Sampling frequency is taken as 4KHz and 128 points are sampled from each echo. Total current applied is 100mA and two frequency values 100Hz and1KHz for the varying field are examined. The varying field is applied continuously during the sampling period of the echo signal in contrary to Scott's study. The value of $b(x_0,y_0)$ in equation (5) can be found with a Least Squares parameter estimation algorithm.

Results

Simulation results demonstrate that the given field variations with 100mA total current and both frequencies give detectable modulation on the echo signal. Experiments will be carried out to determine the minimum values for the time varying field when noise is present.

References

[1] G.C.Scott, M.L.G. Roy, R.L. Armstrong, R.M. Henkelman; IEEE Tr. Med. Img. , v. 10, iss. 3, pp 362-374, 1991.

[2] A.A. Maudsley, H.E. Simon, S.K. Hilal; J. Phys. E: Sci. Instr., v. 17, pp 216-220,1984.