Faster imaging for MEG-MRI

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Purpose

Low field MRI (LF-MRI) systems are suitable to be integrated with Magnetoencephalography (MEG) but a big issue is the low intensity of the NMR signal to be detected. We present a reduced scale system, compatible with MEG and operating in a MEG magnetic shielded room at B_0=8.9 mT (375 kHz), that is not based on the use of prepolarization pulses. It allows an easy integration with MEG detection channels (SQUIDs), with the Magnetically Shielded Room and can be enlarged to a human full scale device with a manageable power consumption and weight[1]. After a careful optimization of our system we present our results that show how our approach can improve performances if compared with existing devices based on the prepolarization technique.

Methods and Results

Our small scale technological demonstrator[1] has a 8cm inner bore. Figure 1 shows the NEX dependence of SNR behaviour of a 3D Spin Echo sequence (T_R=500ms, T_E=19ms) on water phantom doped with $CuSO_4$ (T_1 = 130 ms, similar to brain tissues values at the working frequency) with 3mm isotropic resolution and 6.3cm isotropic FOV (T_{acq}=3.6min for NEX=1). Figure 2 shows slices from 3D acquisition of a rabbit head from our device and the same image taken at high field (3T Philips), down sampled and co-registered. From Figure 2 we see how head anatomical features are distinguishable and well contrasted.

Discussion

The above results inspired us to consider the expected acquisition time for a human sized system. We decided to consider a 3 times larger system taking into account a 1/3 factor for the field sensitivity and another $3^{1/2}$ factor for the coil noise (assuming the noise is coil dominated and mainly due to the DC contribution) with a total expected SNR reduction by a factor of 5. The larger system requires 3 times the phase and frequency encoding steps as well as 3 times the bandwidth resulting in a SNR increase by a factor 3. The latter can be increased by a factor $\sqrt{2}$ with a quadrature receiver system (not present in our prototype because of its small dimension) for a total reduction by a factor of 0.84 and a NEX=1 acquisition time of 32min. The above estimate, together with the results presented in Figure 1, shows that a low-field MEG-MRI system without prepolarization and working at 8.9mT would meet the criterion SNR > 20 for adequate anatomical imaging[2] with NEX=1 and a total acquisition time of 32min (with T_R=500ms). The above result gives indication of an improvement by a factor of two in voxel volume and a factor of 3 in time when compared with present performances of pre-polarized MEG-MRI systems with detection in the kHz range[3,4].

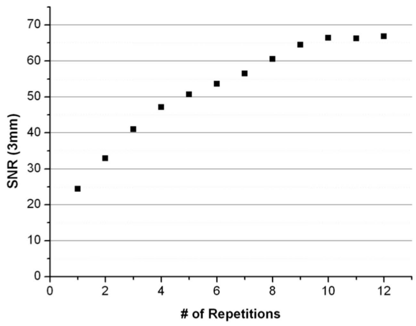

Figure 1: SNR at different NEX values.

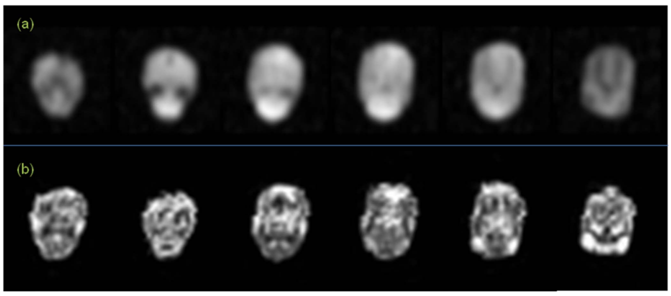

Figure 2: Rabbit head LF MRI slices from 3D acquisitions (a) and the same slices imaged using a 3T scanner (b). Images in the lower strip are rescaled to the LF resolution.

Conclusion

From our test system we suggest that an integrated MEG-MRI device might be faster if no pre-polarization is performed but the reading field is increased in the tens of mT region where flux trapping phenomena are still absent in the MEG detectors. For the main field below 10mT it is unfeasible to improve the isotropic resolution below the 3mm threshold while keeping acceptable total scan time. This goal can be reached increasing the main field in the 30mT region. The low resolution imaging makes questionable if LF-MRI alone can be enough to provide the necessary morphological information to improve the source localization capability of current MEG systems. However, LF-MRI integrated with MEG could improve MEG results through co-registration of low and high field images.

References

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