What pMRI Scientists Want

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Abstract— **A brief discussion on fundamental issue with pMRI signal pick-up.**

I. BACKGROUND

In essence, MRI is a process by which the nuclear insides of a test subject are turned into tiny magnets. A separate signal then perturbs these magnets which, upon removal of the perturbation, return to their starting position. During this process of relaxation a time varying magnetic flux is generated. This flux can be picked up by a coil and the ensuing information processed to determine the concentration and location of nuclei generating the signal.

Parallel MRI (pMRI) accomplishes the same feat as that described in the previous paragraph except that multiple coils are used to pick up the time-varying magnetic flux. Among the first reports on this techniques occurred in [1] where total acquisition time is shortened by computing multiple slices in parallel. This differs from S. Wright's work which uses multiple coils to parallelize a single slice at a time. In any case, the general goal is the same — reduce imaging time.

Another important contribution to pMRI by Roemer *et al.* [2] focuses on the SNR advantage to be had by using multiple pick-up coils (rather than reducing acquisition time).

It is possible that other fundamental advantages can be had through the use of multiple pick-up coils, but among the applications discussed one important concern is shared: minimize the coupling between coils.

II. PICK-UP

The "flux-rule" states that when magnetic flux, Φ, passing through a conductive loop is changing with time an emf is generated (around the entire loop)

$$\mathcal{E} = -\frac{d\Phi}{dt}. \tag{1}$$

For a coil loop area, S, and magnetic field $B\cos(\omega t)$ the emf results in a potential drop across an open section of the loop

$$V_s = \mathcal{E} = BS\omega\sin(\omega t). \tag{2}$$

. This is an idealized result, a simple voltage generator, from which the power drawn depends on the load, R_L, we place across it. That is,

$$P_{drawn} = V_s/R_L^2. \tag{3}$$

Of course, to get a good MRI image the power drawn out of the source is not an important concern. Paramount is that the signal is maximized. This is equally well represented by the source voltage V_s or the power consumed (or the current drawn for that matter). Sensing any one of these to their maximum is valid at this stage of the discussion.

III. COUPLING

The model of our pick-up coil as a voltage source is obviously oversimplified. Two important considerations are the (self) inductance of the coil, L, and its series losses, r. Accounting for this leads us to the coil model sketched in Fig. 1.
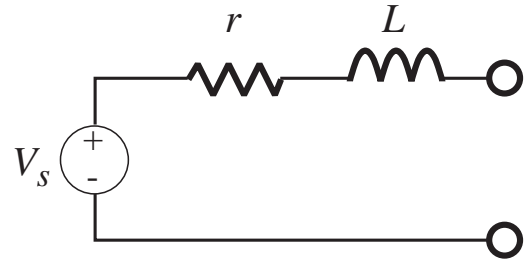

Fig. 1.   More realistic model of the pick-up coil.

What is the best way of amplifying the signal picked-up by this coil? An amplifier power matched to the circuit seems like a good start, but it can be problematic. Such a circuit will allow current to flow through L, which will in-turn generate a flux that can couple to other coils in the receiving array. For the benefit of the MRI images this should be minimized. Further, it is possible that the flux generated in L can couple back into our imaged sample, potentially further distorting the results (an MRI expert would be needed to chime in on this particular drawback).

To limit the coupling issues discussed in the previous paragraph we are led to a means of amplification that limits the current through L. This suggests that our amplifier have a very high input impedance and therefore amplify only the voltage signal V_S (and the noise associated with r). But is such an amplifier truly feasible? This and other considerations will be the topics of future technical notes.

REFERENCES

[1] J. S. Hyde, A. Jesmanowicz, W. Froncisz, J. B. Kneeland, and T. M. Grist, "Parallel image acquisition from noninteracting local coils," *J. of Magnetic Resonance*, vol. 70, pp. 512–517, 1986.
[2] P. B. Roemer, W. A. Edelstein, C. E. Hayes, S. P. Souza, and O. M. Meuller, "The NMR phased array," *Magnetic Resonance in Medicine*, vol. 16, pp. 192–225, 1990.