Sub-Sampling parallel MRI with unipolar matrix decoding

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A method is proposed of parallel array scan, where signals from coils are combined by a summing multiplexer and decoded by unipolar matrix inversion is suggested, which reduces acquisition channels to a single pre-amp and A/D. The results would be, an independent individual separated signals as if acquired through multiple acquisition channels, and yet at a total acquisition time similar to acquisition time of multiple channels,

Background

In a standard parallel array technology, N coils simultaneously cover N FOVs by reading N k-space lines simultaneously over N independent data sampling channels. These k-space lines are phase weighted to maximize SNR and then FT converted to N independent images with an increased SNR[1]. In current accelerated PI techniques, some of K-space lines are skipped physically, and are replaced by virtual k-space substitutes using preumed spatial sensitivities of the coils in the PE direction [2-5].
Based on the method described recently [6,7] a new scanning procedure is described here.

The Method

1. Have all coils be connected through a single summing multiplexer unit (**MUX**) which allows, at our discretion, selecting N-1 coils to be actively connected while a single coil is deactivated electronically, to a single summing common output (SCO). Let the summed signal from these N-1 coils be sampled by the single acquisition channel (**ACQ**) having a single pre-amp and single A/D.
2. Scan 1/Nth of the total k-space lines while having N-1 coils actively connected to the ACQ by the MUX unit.
   Repeat the above scan procedure over another 1/Nth part of k-space, this time with another set of N-1 coils actively connected, and 1 coil deactivated.
   Keep these scan procedures N times, until all k-space lines were acquired over all N possible permutations of selections of N-1 coils out of N.
3. There are now exactly N summed acquisitions at our hands. Using an inverse of a unipolar matrix, these can be now decoded back to the original individual k-space lines, $$\sigma_m(k_x,k_y) = \sum_{\substack{k_y \subset K/N \\ p \neq m}} s_p(k_x,k_y)$$. where summation is over all picked activated coils p, except for coil m which is deactivated. Only k_y lines belonging to 1/Nth of k-space (K/N) are being applied. A matrix representation of the above is $\sigma = \mathbf{M}\cdot\mathbf{s}(k_x,k_y)$ which is equivalent to $\sigma_i(k_x,k_y)=\sum_{k=1}^{N} m_{ij} s_j(k_x,k_y)$, Where m_{ij} = 1 for i≠i and 0 otherwise.

M is therefore a **unipolar matrix** of order N which inverse is m^{-1}_{ij} = 1/(N-1) for i≠i and –(N-2)/(N-1) otherwise. The solution is: $\mathbf{s}(k_x,k_y)= \mathbf{M}^{-1}\cdot\ \sigma$.

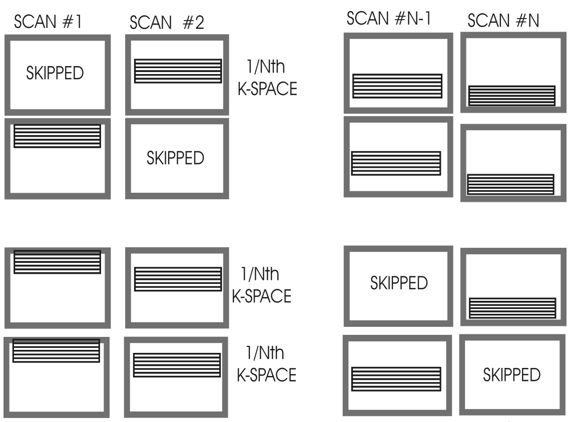

Figure 1 – Partial sampling N-1 coils with 1/Nth of k-space

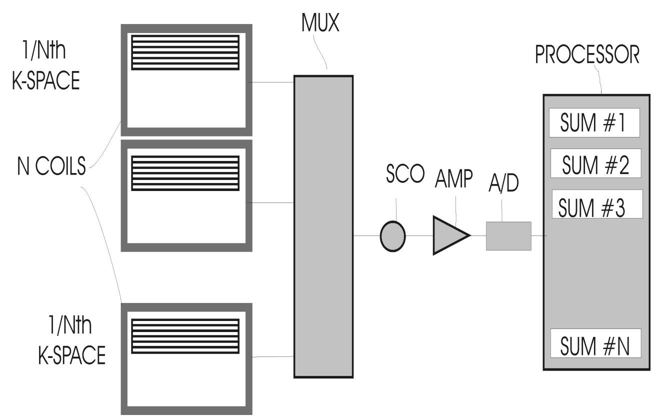

Figure 2 – Partial sampling hardware and acquisition method

CONCLUSIONS

The end result of this scanning technique is as follows:
Total scan time is (T/N) x N, same as for a standard acquisition time T of N coils with N independent channels in parallel.
Nearly full k-space coverage is obtained (1/Nth part of k-space is omitted from each coil).
For a large number of coils, the missing k-space becomes negligible.
The advantage of the method is that there is only one acquisition channel and hence reduced channel noise.
The weak link of this method is the multiplexing unit (MUX) where careful design considerations must be given in order to prevent cross-over coupling between switches and to reduce electronic noise that may be due to active switching circuits.
There is no need for noisy phase weighting circuits and the decoding by inversion of M is straight-forward with a negligible processing time.

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