Exploration of the Use of Multiple Decoupling Preamplifiers on a Single Loop

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Introduction: Phased array RF coils typically employ impedance mismatched preamplifiers to greatly reduce the effect of mutual inductance between coil array elements (1). The ability to reduce crosstalk is directly related to the impedance mismatch available. It is instructive to explore the effect of using multiple preamplifiers in each loop. The authors' intuition was that simply adding a preamplifier into a standard loop with the same configuration would dramatically lower the total SNR, since each preamplifier would appear to see, predominantly, the impedance from the other preamplifier and not the coil impedance. In fact, it is possible to utilize multiple preamplifiers without loss of SNR.

Methods: The analysis of two preamplifiers on a loop is performed from the perspective of adjusting the matching/tuning parameters to produce a noise impedance matched but power mismatched situation for each preamplifier when the other preamplifier is not present. Typically this means a 50 ohm coil attached to a preamplifier with impedance of 1 to 2 ohms. Herein, D (for decoupling factor) will be used to designate the ratio of the coil matched impedance to the preamplifier input impedance (50/Rp). A schematic of the system analyzed is shown in Figure 1. Note that the preamplifiers are far from noise match when both preamplifiers are used simultaneously. It would be expected that the noise figure for each preamplifier would be very high. Each port to the coil looks like 50 ohms when no preamplifiers are attached. A circuit analysis was performed on the system with noise assumed to come from three sources: the coil resistance (sample + conductor + components) and the resistances associated with the inductors on the input of each preamplifier. An estimate of noise figure is the ratio of the variance of noise due to the preamplifier (input inductor's resistance) to the variance of the noise due to the coil resistance. For one preamplifier only, the noise figure is 1/D. When both preamplifiers are attached, the effective noise figure of each channel is approximately 2*(1+D). However, when the preamplifiers outputs are added to maximize the signal from the coil, most of the noise from each preamplifier is canceled. The noise figure for the combined pair returns to 1/D. This is because the noise from each preamplifier input is seen almost equally at both preamplifier inputs (a current ratio of D/(1+D)).

Experimental verification was made by constructing a loop with two preamplifiers, each of which could be removed independently. The individual preamplifier SNR, the differentially connected SNR, the single channel SNR when both preamplifiers were operating, the combined SNR using the Sum-of-squares (Sos) algorithm, and finally the optimally combined SNR using noise decorrelation were measured.

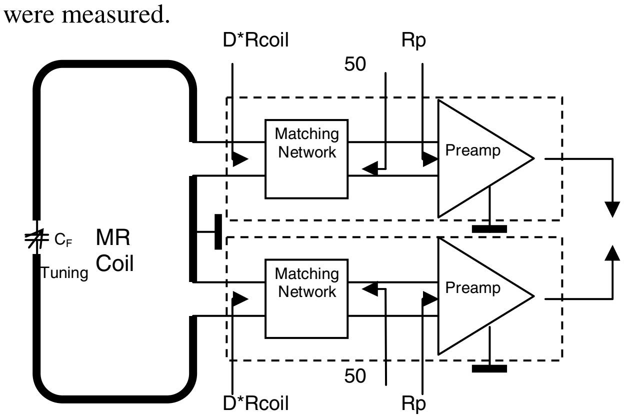

Fig. 1: Two preamplifiers attached to one coil

Results: The SNR results generally supported the analysis. The SNR values for the image from the single independent preamplifier, the differentially connected pair and the optimally combined image from the two preamplifiers were all similar. The SNR of each channel separately (from the two channel data) was lower by a factor of approximately 5, in comparison to single preamplifier results. This corresponds, from the predicted formulas, to a D=49 which, in turn, implies that the preamplifier input impedance would be slightly over 1 ohm as measured independently. The Sos algorithm fails because of the extremely high correlation of noise, however consideration of the correlation allows noise cancellation equivalent to subtraction of the channels..

Conclusion: Because of the resonant mode coupling of preamplifier input circuits attached to a RF coil, multiple preamplifiers can be used without detriment on a single loop. The possible advantages include the elimination of common mode noise and the ability to insert preamplifier high impedance locations at several spots in a large loop. The total noise figure and effective decoupling factor are the same for multiple preamplifiers and a single preamplifier.

Reference: [1] Roemer et al. MRM 16(2):192-225 (1990).