Non-oscillating Enhancement of Preamplifier Decoupling based on Directional Feedback

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Introduction : Signal decoupling in parallel outputs of a receiving phased array coil is an important part of array design since it allows us to exploit the advantages of parallel imaging, such as improved SNR and higher acceleration factor, to the maximum possible extent. The decoupling can be achieved by means of either passive decoupling circuits, which include geometrical layout of the loops, inductive or capacitive decoupling [1-2], and combination thereof, as well as active decoupling circuits using the method of low input impedance low noise preamplifier [3]. Practical coil array designs normally include both methods since neither of them, by itself, can provide sufficient decoupling. It is worth noting that with the growing number of channels in modern MRI systems (≥32), the simultaneous implementation of both decoupling approaches may create a number of technological problems, which, in turn, dictates the need in improvement of each of them. Among the factors limiting the efficiency of active approach is the relatively high input impedance of the preamplifiers (≥ 2 Ohms) in most commercial preamplifiers and dependence of decoupling efficiency from insertion losses and electrical length of transmission line between the coil and the preamplifier. Recently, significant progress has been reported [4] in phased array coil designs with ultra low input impedance (a few tenths of 1 Ohm) preamplifiers. However, this input impedance is still positive and, therefore, insufficient to compensate for transmission line losses, dictating, as a result, the close proximity of preamplifier to the loop. The latter is not always convenient or easily achieved in the coils with 32 or more parallel channels. Further lowering of input impedance may create another type of problem - the parasitic preamplifier oscillations. A novel circuit presented below: 1) allows for practically infinite decoupling impedance at the input of the loop; 2) is less sensitive to the value of the input impedance of the preamplifier; 3) can be installed remotely from the loop without a loss in the decoupling efficiency; and 4) offers improved stability against parasitic oscillations.

Theory and Method: The induced current in the coupled loop, I_2, is related to the current in primary loop, I_1, by the formula: $I_2 / I_1 = kQ/(1+R_{dec}/R_{coil})$ - where: *k*-coupling coefficient, Q – quality factor, R_{dec} - decoupling impedance measured at the point A (see Figure 1) with the loop disconnected, and R_{coil} – loop resistance. Typically, R_{dec}/R_{coil} is in the range of 10÷15 in conventional preamplifier decoupling circuits at 1.5T. Our target is to achieve $R_{dec} = \infty$ thus completely eliminating the coupling. The schematic layout of the circuit is presented in Figure 1. It includes 90° balun, impedance transformer and 20 dB directional coupler in front of low input impedance (>2 Ohms) preamplifier and a feedback consisting of output sampler (variable resistance), and phase shifter connecting a feedback to the coupled port of a directional coupler. Without feedback in place the circuit operates as a conventional preamplifier decoupling circuit. The addition of feedback allows for the improved decoupling performance making $R_{dec} \rightarrow \infty$ by means of properly tuned variable resistor and phase shifter. This condition, due to presence of insertion losses in practical transmission lines, is equivalent to preamplifier with negative input impedance. The excess of power at preamplifier output allows for remote installation of the feedback circuit and makes the circuit operation only weakly dependent on the input impedance of the preamplifier. Two possible causes of parasitic oscillations in the circuit are: 1) an increase of the signal at the input of the amplifier due to the feedback or 2) the reflection of the feedback signal from a mismatched loop. The following condition guaranties the absence of oscillations due to the first cause: $\beta ASi < 1$, where: β - feedback factor, A – open loop gain (typically <30dB), and Si - isolation in directional coupler (typically <-50dB) at MRI frequencies. Therefore, 15dB margin or more is readily available in practical circuits. The oscillations due to second reason depend on the value of the loop resistance. With higher loop resistance, larger ratio R_{dec}/R_{coil} can be achieved without parasitic oscillations.

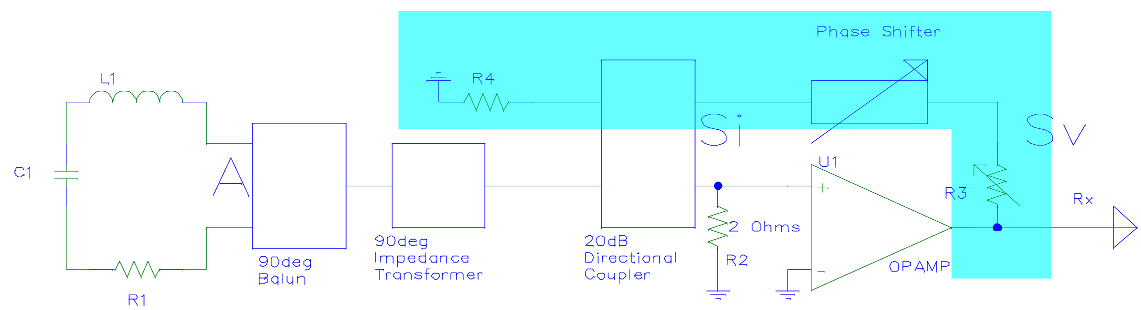

Fig. 1. Layout of the preamplifier decoupling circuit enhanced with the directional feedback (blue – external feedback.)

Results: The circuits corresponding to different preamplifier decoupling methods (conventional, ultra-low input impedance, and novel) have been built and tested in the laboratory for low 0.3T(13 MHz) and high 1.5T(64 MHz) magnetic field strengths. The ratios R_{dec}/R_{coil} have been measured and presented in Table 1. Note, that though R_{dec} was measured at the point **A** with the loop disconnected, the preamplifier outputs did not show the oscillations with the loops in place.

	Conventional Method	Ultra Low Input Impedance (≈0.4 Ohms) Method	Novel Decoupling Method
0.3T	13	22	>100
1.5T	14	89	>220

Table 1. R_{dec}/R_{coil} as a function of the magnetic field and the decoupling method

References:

[1] J.Wang, Proc. 4th ISMRM, 1996, pp. 1434. [2] J. Jevtic, Proc. 9th ISMRM, 2001, pp.17. [3] P.B. Roemer, *et al.*, Magn. Reson. Med. 16, 192-225, 1990. [4] Sc. B. King, St. Varosi, D. Molyneaux, R. Duensing, *et al.*, Proc.10th ISMRM, 2002.