A Generalized Concept for Preamplifier Decoupling

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**Purpose:** Preamplifier decoupling is a valuable technique in the development of multi-channel receiver array coils. Generally, it reduces the magnetic coupling by current suppression. Although well established, there is currently no simple rule available to design a proper network with desired properties. In this work, a concept is presented to obtain the required parameters for preamplifier-decoupled arbitrary networks. In addition, the robustness of the coil against varying loading conditions of the coil was investigated as a further property of the circuit.

**Theory:** Roemer et al. [1] have described the functionality of a decoupling network in terms of resonances in detail. The basic elements of a typical receiver coil network are shown in Fig. 1. A high impedance of $Z_2$ causes $C_n$ and $L_b$ to form a series resonance pulling $L_a$ to ground when properly tuned. For this condition, $L_a$ and $C_{22}$ form a parallel resonance, which in turn suppresses the current in the coil.

However, the decoupling effect may also be explained by impedance transformations. The starting point of this alternative concept is rearrangement of the network. Using the lumped equivalent of a transmission line, which is composed of reactive elements, the network is described by the input and output reflection coefficients, $\Gamma_1$ and $\Gamma_2$, respectively. The reflection coefficient is defined as the ratio of the backward and forward traveling current waves. At each point in the network, the current is then given by $I = (U/\Delta Z_2)(\Gamma - \Gamma_1 \Gamma)$. To minimize the current in the loop, a reflection coefficient $\Gamma_1 = 1$ is required at this port. The network analysis of parts A and B thus results in the following conditions:

A) $S_{011} = S_{022} = 0$ and $S_{112} = S_{212} = \theta^{\pm \pi/2}$

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Applying the general equation for the transformation of a reflection coefficient by an arbitrary network, $\Gamma_1$ is therefore given by $\Gamma_1 = S_{112} S_{212} S_{212} S_{112} = 1$ and $\Gamma_2$ is given by $\Gamma_2 = (Z_2 - Z_0)/(Z_2 + Z_0^*)$, where $Z_0^*$ is the right-sided characteristic impedance of the network and is given by the noise match of the preamplifier.

**Simulation results:** To validate the derived expression, a circuit simulation was used (Qucs)[2]. The network in Fig. 2 was compared to a network designed according to the equation for $\alpha$ as derived above. For both designs we assumed an input impedance of $Z_2 = 5 \text{ M}\Omega$ for the preamplifier. The results are presented in Fig. 3. In Fig. 4, the current for the second design is shown for different input impedances of the preamplifier (5 MΩ, 50 kΩ, 5 kΩ). The imaginary part of $\alpha$ is also shown. Figure 5 summarizes findings for varying loading conditions of the coil. For a real and reactive change of the coil impedance, the current minimum remains stable at the target frequency.

**Discussion:** With regards to the complex nature of $\alpha$, the real part is the phase shift introduced by the network to achieve preamplifier decoupling, whereas the imaginary part is negative and corresponds to an amplification, which is not realistic with only passive elements in the circuitry. Nevertheless, the imaginary part is of some value in evaluation of the network. If its value is small, the current suppression will be nearly ideal, but it will degrade with increasing values. A further advantage of our approach is that it highlights important design aspects. In particular, two properties are important for preamplifier decoupling: (1) a mismatch and (2) a suitable network for proper transformation of the resulting reflection coefficient. Theoretically, only one network is required between coil and preamplifier. However, due to the constrain that the inductance of the coil is part of this network and is defined by the geometrical design of the loop, it is advantageous to replace the single network by two cascading networks as shown in Figs. 1 and 2.

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