**Mitigation of inductive coupling in array coils by wideband port matching**

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**Introduction:** We suggest a method for mitigating the effects of coil coupling. It is based on a wideband matching technique which can be implemented by a simple circuit modification. The reduced effective reflection will result in less degradation of preamp noise figure in a receive array, and in lower 

**Noise coupling:** Inductive coil coupling can be viewed as a quarterwave line which is inserted between the grounds of the two source resistors. [Rey1] shows that despite preamplifier decoupling [Rey2], noise current is not preamplifier decoupling [Rey2], noise current is transmitted into an additional noise voltage at the other preamp, in effect increasing the noise temperature of the combined system. This is not visible as noise correlation, because the contributions from two preamps appear at the two outputs at +90° and -90° relative phase, and therefore cancel. The amount of degradation depends on kQ, i.e. normalized magnetic coupling k times loaded Q of the antenna, which can be derived from q-parameter measurements. With kQ greater than unity, we have 

[Fig. 1: Equivalent circuits for even and odd modes]

**Overcoupling technique:** This aims at reducing the reflections simultaneously for both modes. The two impedances 1-p/2 for both spatial modes and at the same frequency are equivalent to a single resonant circuit, observed at the two eigenmode frequencies. We propose to extend the well-known overcoupling approach to wideband matching to the problem of coupled coils. Following Wheeler [Lop], we note that minimum reflection at the band edges can be achieved by matching to the magnitude of the source impedance rather than the real part, using a transformer with an impedance ratio Zopt = 1+kQ. In practice, this can easily be achieved by tuning tight coupling of the preamp to the coil (eg. increasing the series capacitor C), creating an impedance circle which encircles the center of the Smith chart (Fig. 2). Thus |m| and noise figure at the band edges (ie. coupled modes) are significantly reduced, at the cost of some mismatch at the center frequency (ie. if the coils were decoupled):

\[ r_c = \left( \frac{1+jkQ}{1-jkQ} \right) = \frac{1+jkQ}{1+jkQ} \]

\[ |m| = \frac{kQ}{1+jkQ} \]

Fig. 3 is a plot of noise figure over a range of coil coupling levels for four match conditions. The standard match (blue line) results in a severe penalty when kQ >> 1, whereas the optimal match mitigates the penalty (dashed black line). In practice, the selected wideband match must correspond to a specific coupling level to minimize the penalty (pink, red lines at kQ = 2, 8). Experimental verification of the benefit is shown in a separate abstract. In the classic wideband matching problem, reflection can be reduced to a limited frequency range by additional resonators (multiple tuned matching, within the Fano limit). This cannot be applied to further mitigate coupling, because those correction circuits will vary their impedance only with temporal frequency (which is fixed at the Larmor frequency here), and not with the spatial mode structure.

**Multiple coils:** The overcoupling strategy is also applicable to a larger number of coupled elements or a near-degenerate bridging. Then we need to obtain the mode spectrum (eg. by eigenmode simulation or double probe measurements) and select those modes which are producing a relevant signal. Optimizing the matching bandwidth to the outermost frequencies will result in a target r_c to which each loaded coil can be matched individually.

**Resistive coupling:** This analysis has focused on purely reactive (ie. inductive or capacitive) coupling, and neglected the effect of resistive coupling which is typically introduced by the load. In this case, the general overcoupling strategy still holds, but the optimization would need to be slightly adjusted to take into account different real parts of the modal impedances.


**Fig. 2: Smith chart for wideband matching [Lop]**

**Fig. 3: Noise figure (match optimized for different kQ)**