# Reducing Element Coupling in Array Coils Using Off-Tuned Elements

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**Introduction:** Highly parallel array coils constructed on curving formers [1-3] often contain relatively high inter-element inductive coupling. This is especially bad in flexible arrays where geometric decoupling from overlap or shared impedances is not possible for all positions of the flexing former. While preamplifier decoupling [4] is extremely useful in these situations, it is often insufficient. To address this issue, we exploit a phenomena associated with preamplifier decoupling, which allows the array element to be tuned off-resonance from the Larmor frequency without significant degradation of SNR. This arises because preamplifier decoupling changes the traditional 50Ω measurement into a high-impedance voltage measurement since the preamplifier's input impedance, $Z_{input}$, is transformed to a high impedance in series with the loop inductance. In addition to reducing the current in the loop (and thus inductive coupling to other coils), this makes the measurement insensitive to the tuning of the loop element (the high impedance introduced by the preamplifier can be thought of as decreasing the *Q* of the loop). This allows us to purposefully mistune the loop from the Larmor frequency. If mistuned too far, the loop element will no longer present the amplifier with the load impedance which optimizes the noise performance of the preamplifier, but in our experience, a loop element can be mistuned by up to ±4MHz with little degradation of the image SNR. By purposefully detuning elements in a coupled pair in opposite directions, we show that we can reduce the noise correlation between the two channels. This might improve imaging performance for image reconstructions sensitive to the presence of noise correlations. We demonstrate the effect in noise correlation matrices and in SNR performance of simple root Sum of Squares (rSoS) reconstruction, which is sub-optimal for highly correlated noise.

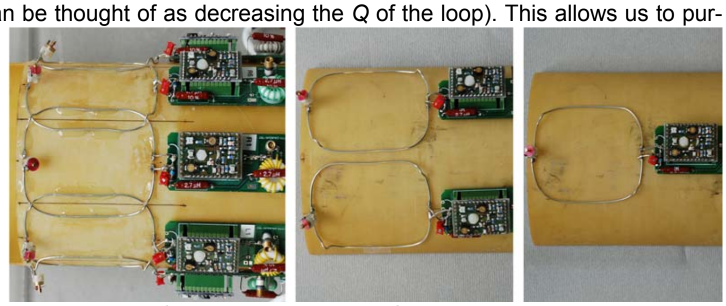

**Fig.1**: Constructed coils: 8ch(left), 2ch(center), 1ch(right)

**Material and Methods:** Figure 1 shows the three test coils studied; an 8-channel overlapped volume array, a two-channel narrow gapped coil, and a one-channel reference coil, all employing identical circuitry and mounted on a 12cm dia. fiberglass tube filled with a saline phantom. The tuning capacitor was placed on the top of the loop circuit, which allowed adjustment of the loop resonance frequency. The output circuit incorporates a capacitive voltage divider to impedance match the element's output to an optimized noise matched impedance, $Z_{NM} \approx 50\Omega$, desired by the preamplifier (Siemens Healthcare, Erlangen Germany) when the coil was tuned to the Larmor frequency (123.2 MHz). Each coil also utilized a standard active PIN diode detuning trap circuit. Preamplifier decoupling was achieved by transforming the preamp $Z_{input}$ to an inductance, which resonates with the matching capacitor, thus providing a high impedance parallel LC circuit in series with the loop. For the 8-channel array we provided only a moderate geometrical decoupling of -11dB from the coil overlap, to mimic a sub-optimum configuration of a flexible array. The two-channel coil has a gap of 5 mm, providing a strong inter-element (-6dB) coupling. The single-element coil was used to determine the effect of mistuning on the single element sensitivity.

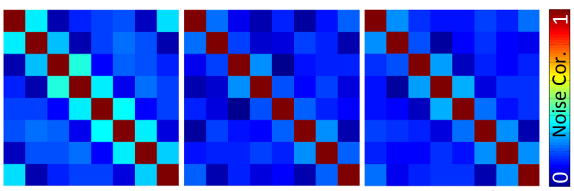


**Fig.2**: Noise correlation matrix: 8ch coil in TaM (*left*), mistuned ±3MHz (*center*) and random mistuning (*right*).

Data were acquired on 3T MRI Scanner (Magnetom Trio, A Tim System, Siemens Healthcare, Erlangen, Germany). We measured the SNR of the single loop coil mistuned in 1 MHz increments over ± 5 MHz around the Larmor frequency. For the 8ch array, we start with the elements matched to $Z_{NM}$=50Ω and tuned to the Larmor frequency (Tuned-and-Matched (TaM) configuration). We compare this configuration to two different mistuned configurations, where nearest neighbors were tuned +3MHz or -3MHz from the Larmor frequency. Additionally we studied the tuning where elements were randomly mistuned spanning a range of ±4MHz. For the highly coupled 2ch array we assessed the 50Ω TaM mode and a mistuned configuration (±4MHz).

**Results:** SNR maps from the single loop showed <3% degradation of SNR over a range of ±4MHz around the Larmor frequency. Higher off-resonances decreased the SNR rapidly. Figure 2 shows the noise correlation of the TaM and mistuned configuration and of the 8ch array. The mistuning reduces the noise correlations (especially direct neighbors). We measured an $S_{12}$ decoupling improvement between neighboring loops from -11dB (TaM config.) to -17dB (mistuned config.) Corresponding SNR maps (Fig.3) show that less inter-element coupling of the mistuned configuration yields a slightly higher SNR in the rSoS images when the array is mistuned. Similarly, the 2-channel coil decreases its strong mutual coupling from -6dB to -12dB when the elements were adjusted to +4MHz and -4MHz. This improved the mean SNR by 6% of the phantom images (Fig.4). However, when a noise correlated weighted rSoS reconstruction was applied, the SNR was similar between TaM coils and the mistuned coils.

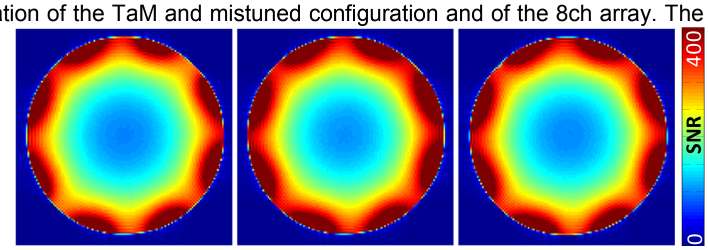


**Fig.3**: SNR maps, 8ch coil in TaM (*left*), mistuned ±3MHz (*center*) and random mistuning (*right*) configuration.

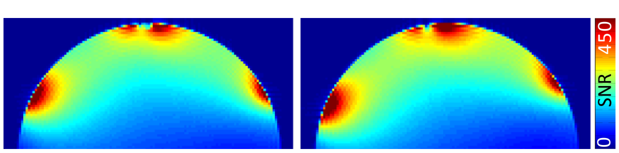


**Fig.4**: Cropped SNR map of 2ch array in tuned (*left*) and mistuned (*right*) configuration.

**Conclusion:** An intentionally mistuned approach was tested as a simple additional decoupling method for array coils. Over the range of 8MHz an individual element showed only minimal SNR degradation. However, the noise correlation matrix was significantly improved as was the correlation-sensitive rSoS reconstruction. The method has minimum impact on reconstructions, which correctly account for noise correlation, but can potentially facilitate decoupling in arrays with high element coupling and thus, improves noise correlation sensitive image reconstructions.

**References:** [1] Hardy CJ *et al*.; JMRI (2008) 28:1,1219-25. [2] Schmitt M *et al*.; MRM (2008) 59:6,1431-9. [3] Wiggins GC *et al*.; MRM (2009) 116:7,1332-5. [4] Roemer PB *et al*. MRM (1990).