Replacing Individual Baluns with Quarter Wavelength Baluns in Multi-Channel Arrays

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Introduction: In a perfect coil array each coil element would have the same SNR as if that coil element was a single one-channel coil, and there would be no channel coupling. Various effects however degrade this performance; B_1 sensitivity maps and the noise covariance matrix are used to characterize a real coil array [1]. One SNR degrading effect is mutual coupling between coil elements; geometric decoupling is not always possible, preamplifier decoupling is a widely used decoupling technique [2]. In many cases however bad SNR and high channel coupling can't be justified with poor preamplifier decoupling performance alone. Often cables, feeding lines, and the choice of cable routing are the main contributors to bad array performance. Cables are resonant structures by themselves, form additional ground loops and thus add additional resonant modes to the coil array structure. Baluns and cable traps are used to break those loops. But this approach is often done in a trial and error fashion; arbitrarily moving and adding Baluns until the coil somehow works. Here we show a more controlled approach, where ground loops formed by cables are purposely set to hold certain resonance frequencies. It turns out that in that case individual Baluns are not necessary anymore, they can be replaced with λ/4 Baluns, which is noting else than shorting individual cable shields together at the right location.

Theory: Figure 1 shows the model of two coil elements including cable connections. At some point the cable shields are connected together. This can be somewhere in the coil, at the coil connector, or in the receive chain. Let's assume the two coil elements are mutually decoupled. Without any cables connected they would be perfectly decoupled. However, once the cables are attached, and taking stray capacitance between the coil elements into account a ground loop is formed. This loop acts as a bridge between the mutually decoupled coil elements; channel coupling and SNR degradation can be the result. The closer the ground loop resonance frequency gets to Larmor frequency the more severe this effect will be. One way to prevent this from happening is by inserting individual Baluns. They break the loop and, in theory create the same situation as if no cables were attached. However, this is only necessary if the ground loop resonance frequency is close to Larmor frequency. If it's not, individual Baluns basically have no effect. So by controlling the resonance frequency of the ground loop in the first place individual Baluns won't be necessary anymore. This can easily be achieved by adjusting the location of the ground connection. Setting the ground connection at λ/4 (shorted λ/4 transmission line) gives the highest common mode impedance (see Figure 1) and basically has the same effect as individual Baluns.

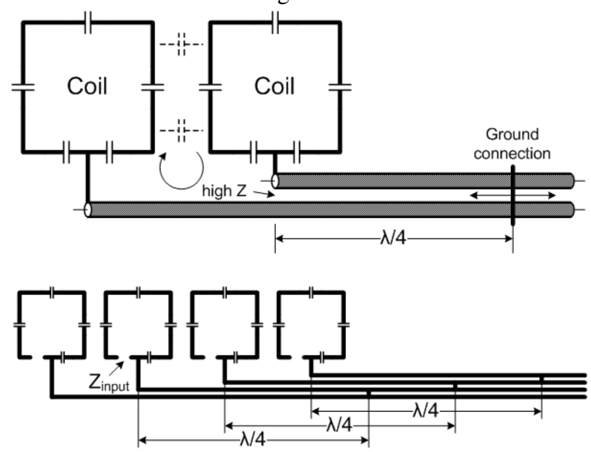

Figure 1: Model of two coil elements including cable connection. Self-resonance frequency of the ground loop formed by the attached cables depends on the location of the ground connection. Setting the ground connection at λ/4 results in highest common mode impedance. That breaks the ground loop and basically has the same effect as an individual Balun.

Methods: A 16-channel, 4 x 4 coil array with overlapped elements in z-direction, and non-overlapped elements in x,y-direction was constructed. No individual Baluns were used, instead λ/4 Baluns were applied by soldering the shields of individual coaxial cables together as shown in Figure 1. The cables were routed in two bundles along the z-direction (bore-direction). Cable traps were added on the cable bundles to prevent B_1-distortion during transmit. A nice way to confirm effectiveness of λ/4 Baluns is by measuring the real part of every open coil port impedance under unloaded conditions. This way resonant modes caused by attached cables can be observed. Those resonant modes should be away from Larmor frequency, and the real part of the open coil port impedance should be close to just the losses of the coil element.

Results: Figure 2 shows individual phantom images taken at 3T (GE MR750) using a gradient echo sequence. All channels show excellent SNR, no B_1-distortion and no substantial channel coupling, despite no use of any individual Baluns.

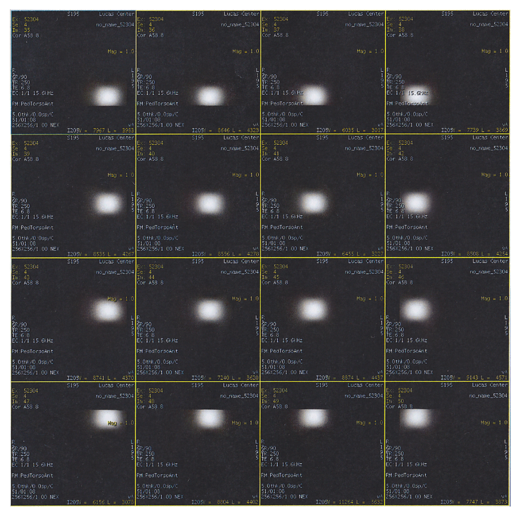

Figure 2: Individual phantom images, 2D Gradient Echo GRE (coronal scan plane, 256 x 256 matrix, 5 mm slice thickness, TR 250 ms, TE Minimum Full, 90° flip angle). All 16 channels show no distortion in sensitivity and excellent channel decoupling, despite no use of individual Baluns.

Discussion: A 16-channel coil with λ/4 Baluns has been developed and tested. It shows excellent SNR and channel decoupling despite no use of any individual Baluns. The shields of individual coaxial cables have been soldered together at specific locations to form λ/4 Baluns. For mechanical construction this might be inconvenient, however keeping the solder connection at an exact location is not really necessary for a good performance. Important is to keep ground loop resonant modes away from Larmor frequency. Future work will focus on the possibility of connecting all coaxial shields together at one location without creating any resonant modes close to Larmor frequency.

References:

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2. P. Roemer, MRM 16(2), p. 192, 1990