# Six Layers Stripline RF-Invisible Balun

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**Introduction**

Modern MRI coils are usually multiple channel phased array antennas that need additional special circuitry for passing acquired signal for further processing. For increased decoupling between channels, matching in conjuncture with a low impedance preamplifier placement is utilized. This technique is sometimes called preamplifier decoupling and became very popular in modern phased array coils. The main point of this techniques is the reduction of the current flow in the receive coil, hence minimizing cross coupling between channels, by inserting a resonance tank composed of the capacitor, inductor and low impedance preamplifier into the receiving loop. One of the requirements of the existing preamplifiers is a "clean" and unperturbed RF ground reference. The challenge arises due to the very close proximity between preamplifier and coil element. One solution to this problem used in the past was splitting the matching capacitor into two capacitors and connecting the ground plane of the preamplifier to the so called "virtual" ground of the coil – middle point between the two close capacitors of the same capacitance. To complete the match, an inductor has to be placed in series with the preamplifier input. This approach has a clear mathematical formulation [1] and given the element's inductance and resistance, allows easy calculation of the tuning and matching capacitors as well as the required inductance for preamp decoupling.

However the problem of keeping the RF ground unperturbed by the coil elements remains a major issue because the virtual ground is not perfectly isolated and due to variability in geometry and capacitor values could never be assumed as perfect and unperturbed "zero". This issue can be addressed when utilizing a transmission line shortened at one end with the preamplifier low input impedance. The transmission line itself has to have a balun to limit the shield current. The penalty to this approach is that the inductor like behavior of the shortened transmission line is not linear function of frequency [2]. Therefore the mathematical model usually assumed in [1] is an approximation, which holds only because the bandwidth of the tuned and loaded coil element is very wide.

**Theory**

The schematics of the preamp decoupling circuitry for one coil element, including the loading, is described in Figure 1. For example in the case of an element with inductance $L = 3.4 \cdot 10^{-7}$ H and resistance $R = 9.75\Omega$ at $f_0 = 64$MHz with a requirement of characteristic impedance $Z_0 = 50\Omega$, according to [1] one can find that the following tuning and matching lump circuit components must be inserted into the circuit:

$C_t = 21.68$pF, $C_m = 112.69$pF, $L_m = 54.89$nH. If one wishes to obtain an inductor out of a Z0 transmission line, then the electrical length of that line is calculated according to the formula [2]

$$\alpha = \tan^{-1}\left(\frac{\omega_0 L}{Z_0}\right) = 23.81°$$

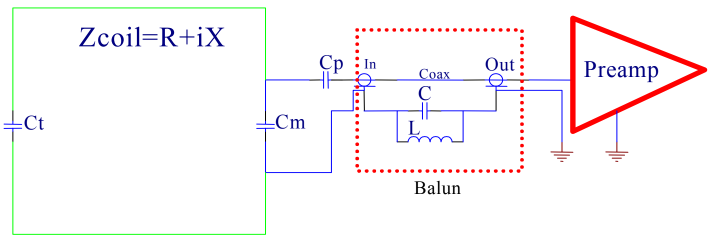


Figure 1. Preamp Decoupling schematics for Phased Array Coils at

The choice of the transmission line type is at the latitude of the coil designer, however the least loss tangent one is preferable. Special attention is paid to common current on the shield (ground ) of the line – it has to be under a certain value. The high impedance for common current is created by making a resonance circuit on the line's shield. One of the major problems is shielding of the balun itself from outside radiation. Typically it is done with a conductive box surrounding the inductor. The main disadvantage is the bulky design and additional capacitance from the metallic box been introduced into the circuit.

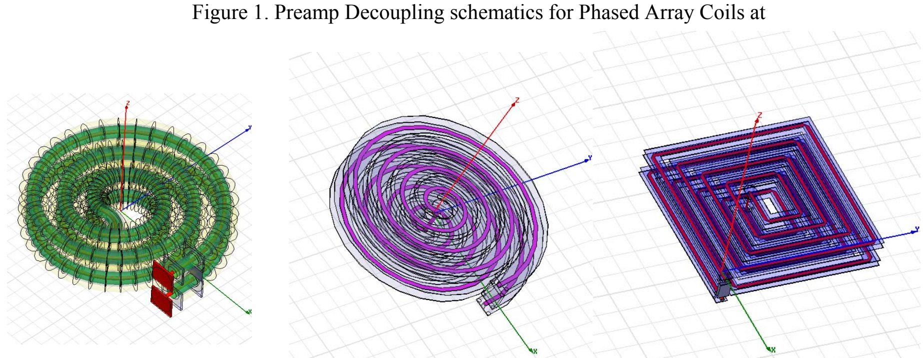

Figure 2. A) Coaxial cable self shielded balun. B) Stripline Circular 6 layer balun; C) Stripline Rectangular 6-layer balun

**Results and Discussions**

Our tests and simulation have shown, that an inductor shape can be build as a double spiral represented in Figure 2. The magnetic field in this topology is greatly confined to the region between the spirals, therefore the overall inductance can be controlled by modifying the height of the balun. The balun can be made using a coaxial cable (Fig.2a) or a 6 layer PCB (Fig. 2a&b). Its transmission line mode is represented in figure 3. By placing the balun into a PCB, the feedboard can be greatly simplified and decreased in dimensions. In Figure 4 we present and 6 layer-PCB invisible balun with the electric length of 39° and overall PCB thickness of 2.5 mm. Its predicted impedance conforms to theory and is 1700 Ohms at 64 MHz.

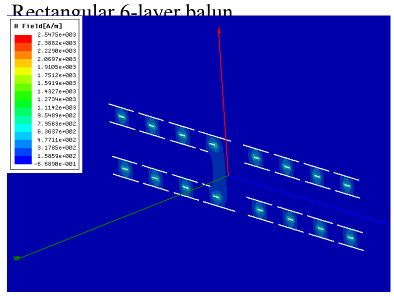

Figure 3. Transmission line mode in a 6 layer PCB

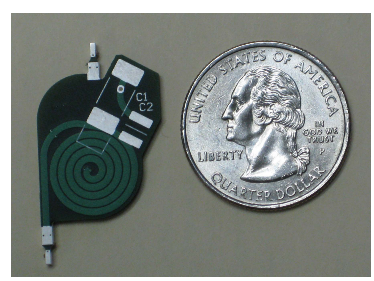


Figure 4. 6-layer PCB balun.

**References**

1. Reykowski et al., Design of matching network for low impedance preamp, MRM 33, 848-852, 1995.
2. Pozar D. M., Microwave Engineering, Third Ed.,John Wiley&Sons, 2005.