Advanced MRI Coil Circuit Design & Topology Report

1. Introduction

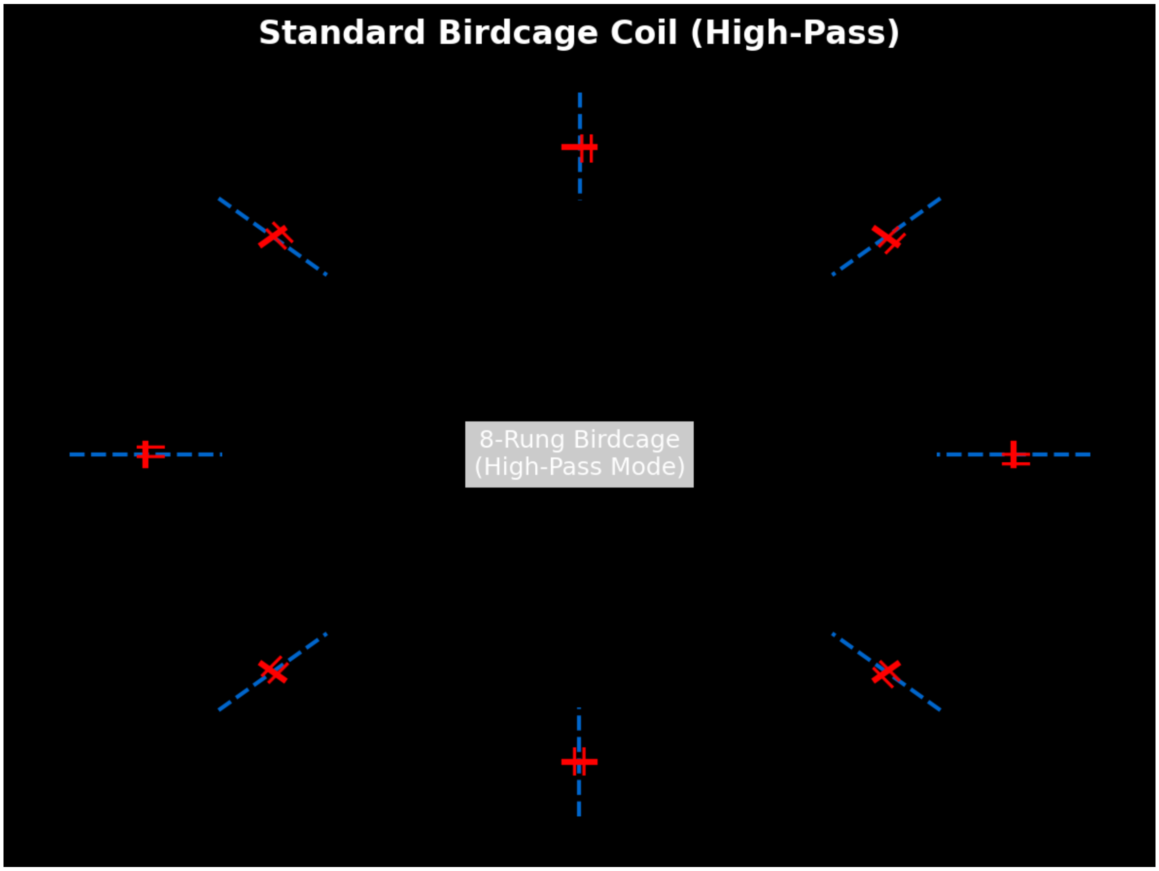
This technical report focuses exclusively on the circuit topologies used in the NeuroPulse high-field MRI system. We analyze the discrete component networks required for resonance tuning, impedance matching to 50Ω, and decoupling.

2. Standard Birdcage Coil (Quadrature/Linear)

2.1 Circuit Topology

The Birdcage coil utilizes a ladder network. In the High-Pass configuration shown below, capacitors are placed on the end-rings, while the rungs act as inductive elements (L_{rung}).

Schematic Diagram:



2.2 Design Equations

For an N-rung birdcage, the capacitance C_{ring} required for resonance at ω_0 in the dominant $m=1$ mode is:

```
C_ring = 1 / (ω0^2 * L_eq * (1 - cos(2π/N)))
```

Where L_{eq} is the equivalent inductance of the mesh.

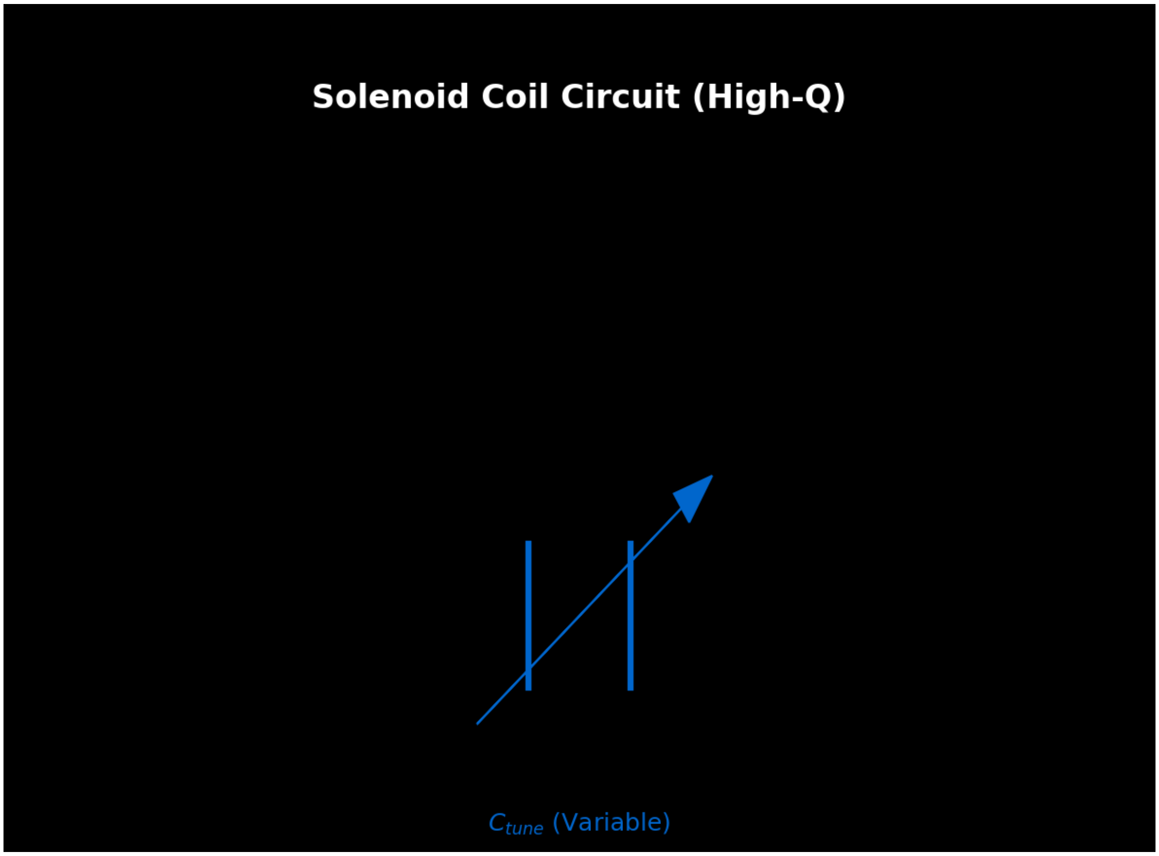
---

3. High-Q Solenoid Coil

3.1 Circuit Topology

A solenoid provides the highest possible Q-factor for small volume imaging. The circuit is a simple parallel LC tank with a capacitive divider for matching.

Schematic Diagram:



3.2 Matching Network

To match the high tank impedance $Z_{tank} = Q \omega L$ to $Z_0 = 50\Omega$:

```
X_match = sqrt(Z_tank * Z_0)
```

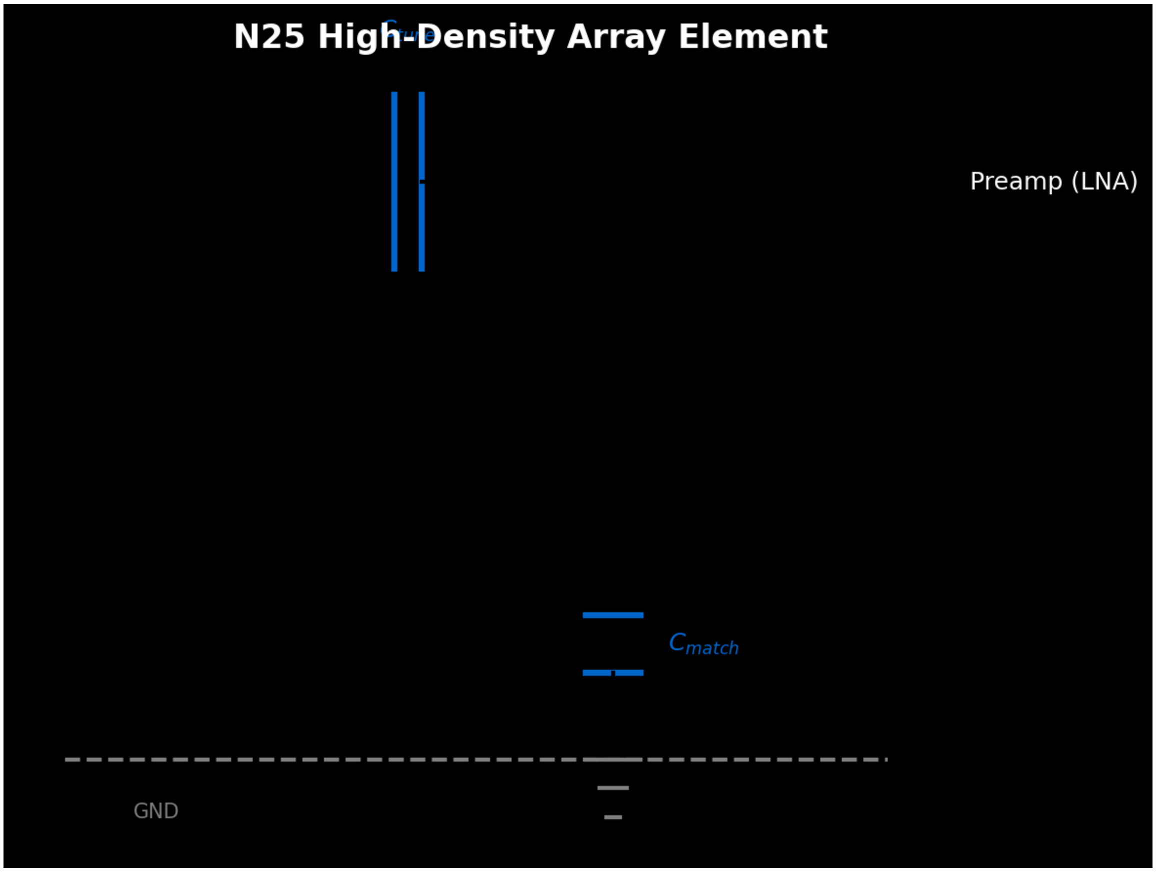
---

4. N25 High-Density Array Element

4.1 Circuit Topology

Each element of the N25 array is a loop inductor (L_{loop}) tailored for high-density packing ($d < 5cm$). The circuit uses a series tune (C_t) and parallel match (C_m) topology, often referred to as an "L-C-C" network.

Schematic Diagram:



4.2 Decoupling

Decoupling is achieved via:

1. **Geometric Overlap:** Critical overlap of $\approx 0.1d$ cancels mutual inductance M.

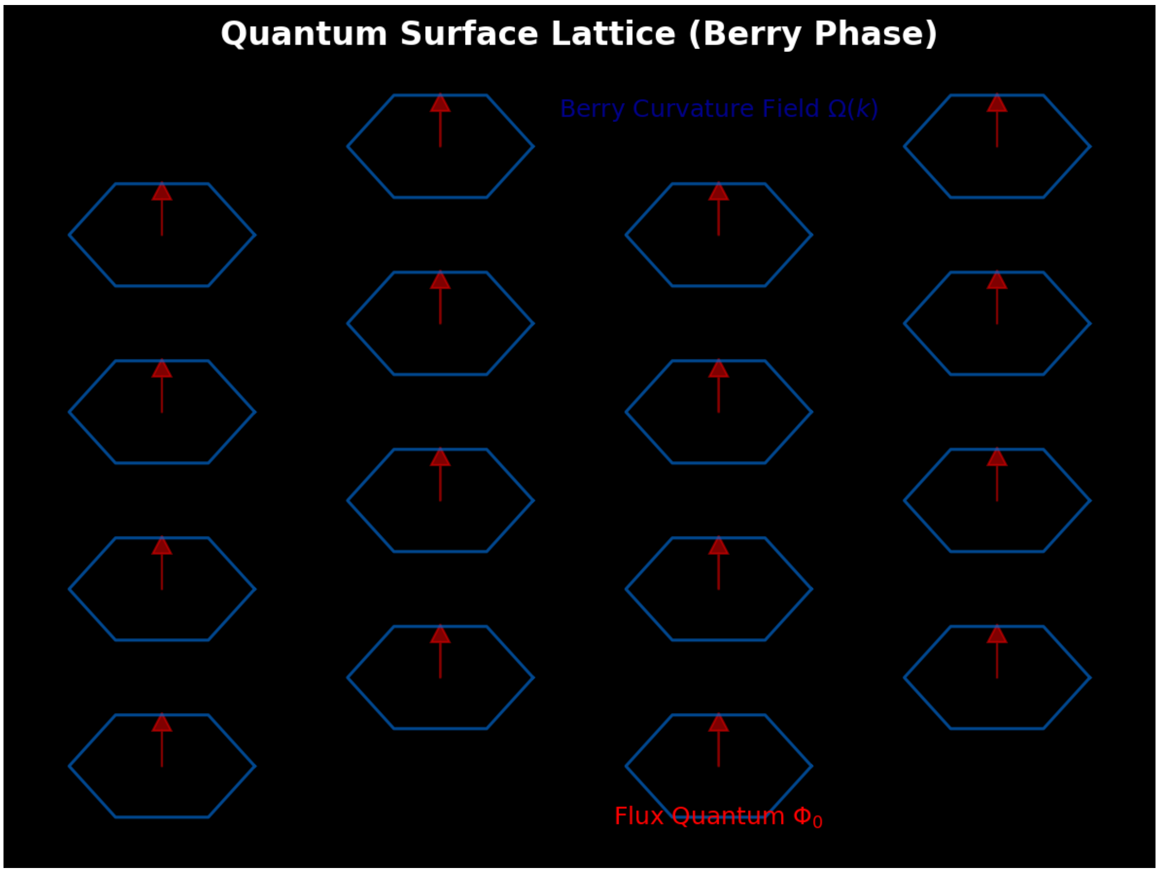
2. **Preamplifier Decoupling:** The "To Preamp" port connects to a Low Input Impedance Preamplifier (LNA), creating a "virtual open" in the loop, suppressing noise currents.

5. Quantum Surface Lattice (Topological)

5.1 Circuit Topology

This novel design treats the coil mesh not just as lump elements but as a continuous lattice guiding surface currents. The "Berry Phase" flux loops shown in the diagram provide topological protection against thermal fluctuations.

Schematic Diagram:



5.2 Flux Quantization

The lattice is designed such that the magnetic flux Φ through each hexagonal cell is quantized:

$$\Phi = n * \Phi_0 = n * (h / 2e)$$

This quantization enforces stable current modes even in the presence of dielectric loading shifts.

Generated by NeuroPulse RF Division - 2026