Coaxial Stub Matching Strategies for Intravascular Coils

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Introduction In traditional impedance matching of MRI coils, shunt-series or series-shunt capacitor combinations suffice to tune the coil. The capacitors almost never pose a size constraint. For intravascular coils [1], miniaturization of the tuning capacitors, and their placement away from the coil without SNR loss is essential. Stripline microwave amplifier design techniques offer a solution [2]. We propose to use open circuit stub transmission line techniques as a means of fabricating arbitrary capacitors. The probes would be tuned by trimming coax lengths.

Transmission Line Capacitors MRI compatible chip capacitors (eg ATC100A series) are limited to 1.4mm dimensions. The smallest NPO grade capacitor, EIA code:0402, has dimensions of (LWT) $1.02\times0.51\times0.63$ mm, but contains a nickel barrier layer in the solder terminations. Fortunately non-magnetic micro-coax is available in diameters down to 0.2 mm. Coax cable lengths under a quarter wavelength, with $Z_o \approx 50\Omega$ and $\omega = 4\times10^8$ rad/s (64 MHz) give an equivalent open circuit capacitance or short circuit inductance of

$$C \approx 50\tan(\beta d)\text{ pF}, \quad L \approx 125\tan(\beta d)\text{ nH}.$$

In effect, we form coaxial capacitors that may be several centimeters long, yet have a cross-sectional diameter (with micro-coax) as low as 0.2 mm. Since the coax stubs can run parallel to the main coax, they do not compromise catheter delivery. Several design strategies are outlined in Figure 1. Open circuit stubs can act as a series (a) or shunt (c) capacitor with discrete components separated by transmission line segments. Balanced configurations using feedthrough structures (b), or matching solely by coax stubs (d) are also feasible. Transmission line segments could allow 0402 size capacitors with nickel barriers to be mounted remotely beyond the field of view distortion point.

Cable Losses Smaller coaxial cables have higher attenuation per meter, α. The attenuation factor plays a major role, not simply by limiting length, but by limiting the allowable range of coil impedance swings and the location of its matching elements without degrading SNR. When mismatched to a load by Γ_o, and with $\beta = 2\pi/\lambda$, the impedance transforms to [3]

$$Z(d) = Z_o\frac{1+\Gamma_o e^{-2\alpha d}e^{-j2\beta d}}{1-\Gamma_o e^{-2\alpha d}e^{-j2\beta d}}$$

For open circuit stubs, $\Gamma_o = 1$. Table 1 gives the results for equivalent C and component Q for Tempflex 50MCX-04 0.5 mm coax. It appears larger capacitance should be fabricated by paralleling several short high Q stubs instead of a long low Q stub.

Length cm	C pF	Q
50	107.4	7.1
40	60.5	16.2
30	36.9	35.2
20	21.7	84
10	10.4	>100

Table 1: Coaxial C apacitance and Q at 63.9MHz

Conclusions Coaxial capacitors formed by open circuit transmission lines offer a viable means of miniaturizing capacitors for intravascular coils. The key design issues will be optimizing the stub lengths, diameter and number subject to the attenuation effects on component Q.

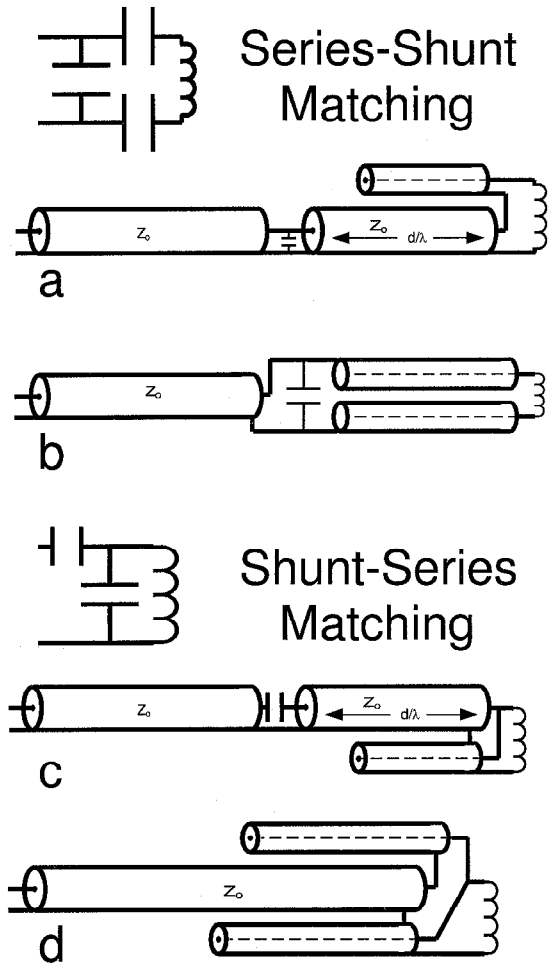

Figure 1: Coaxial Capacitor Matching Topologies.

References

[1] Hurst, GC et al, *MRM*, 24:343, 1992.
[2] Gonzalez, G, *Microwave Transistor Ampl.*,1984.
[2] Paris D, Hurd F, *Basic Electromagn. Theory*,1969.