BALANCED MICROSTRIP FEEDS

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Introduction: Microstrips are well suited for use as array elements for high-field RF coils because they are easily tuned at high frequency and offer low coupling between strips. Resonant half-wave microstrip elements are commonly driven at one end (fig.1) [1], producing an asymmetric B_1^+ field along the strip length and making the strip resonance sensitive to sample loading. This abstract investigates two balanced feeding schemes for symmetrically driving microstrip coil elements (fig.2).

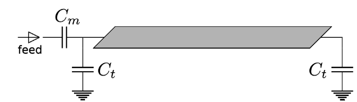

Figure 1: Traditional unbalanced feed.

Theory: Capacitively shortened half-wave microstrips resonate in the odd mode, having maximum current (B_1) at the strip centre and maximum voltage (SAR) across the strip ends. The odd mode can be effectively driven by connecting a balanced feed across the microstrip, reducing sensitivity to asymmetric loading [3]. Circuit models for balanced feeds can be simplified by using the symmetry about the strip length, producing a virtual earth at the strip centre (fig.3). The end-fed strip is modeled as a short-circuited transmission line of length $\frac{1}{2}\ell$ in parallel with a capacitor (fig.3a). The impedance at the strip end is:

$$Z_f = \frac{1}{Y_0 \coth \frac{1}{2}\gamma\ell + jB_{Ct}} - jX_{Cm}$$

where Y_0 is the characteristic admittance of the strip (determined by the width to height ratio and effective permittivity), B_{Ct} and X_{Cm} are the susceptance and reactance of the tune and match capacitors and $\gamma = (2\pi/\lambda_{eff})(1/Q + j)$ is the propagation constant [2]. By operating the strip slightly off-resonance the real part of the end impedance can be set to $Z_0/2$ and the reactive impedance cancelled by capacitor C_m. The balanced drive port is split across the virtual earth, giving a typical driving impedance of 25Ω. The geometrically matched feed (fig.2b) is modeled as a transmission line of length $\frac{1}{2}(\ell - a)$ terminated with capacitance C_t in parallel with a short circuited transmission line of length $\frac{1}{2}a$ (fig.3b). Its input impedance is:

$$Z_f = \frac{1}{Y_0}\left(\frac{Y_0 + jB_{Ct}\tanh\frac{1}{2}\gamma(\ell - a)}{jB_{Ct} + Y_0\tanh\frac{1}{2}\gamma(\ell - a)} + \coth\frac{1}{2}\gamma a\right)^{-1}$$

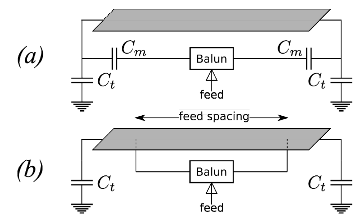

Figure 2: Balanced strip feeds using (a) balanced and (b) geometric matching.

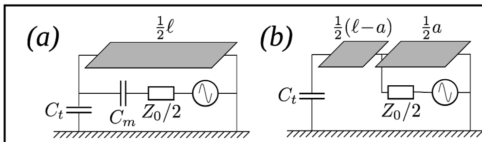

Figure 3: Half-strip equivalent circuit models for (a) capacitive and (b) geometric matching. Z_0 is the input impedance.

When the microstrip is operated exactly on-resonance its impedance is purely real at all points along its length, varying as $R(x) \approx (1/2G)\sin^2(2\pi x/\lambda_{eff})$ where x is distance from the strip centre, λ_{eff} is the effective wavelength of the strip and G is the conductance, determined mainly by dielectric loss in the sample [2]. The strip can be matched by locating the feed points at $\pm x$, such that $Z_f(x) = 25\Omega$ (fig.3b), requiring no matching capacitors. The match points may be located experimentally by varying the feed spacing about the strip centre to minimize reflection at the feed port (S_{11}).

Methods: Three driving schemes were simulated (Microwave Studio, CST), using 130×20mm^2 strips, placed 10mm above a 200×90mm^2 ground plane, using an air dielectric with a 5mm plexiglass plate above the strip. Models were loaded with a saline phantom (Ø170mm, ε_r=60, σ=0.5S/m). Three strip elements were then constructed with the same geometry as the simulation models. Balanced strips were driven via a lattice balun [4], chosen for its relatively wide bandwidth and tolerance of slightly reactive loading. It was found necessary to off-tune the lattice by ~10MHz to prevent coupling between the balun and microstrip element. All components were mounted on the back of the ground plane to reduce interaction with the strip and load.

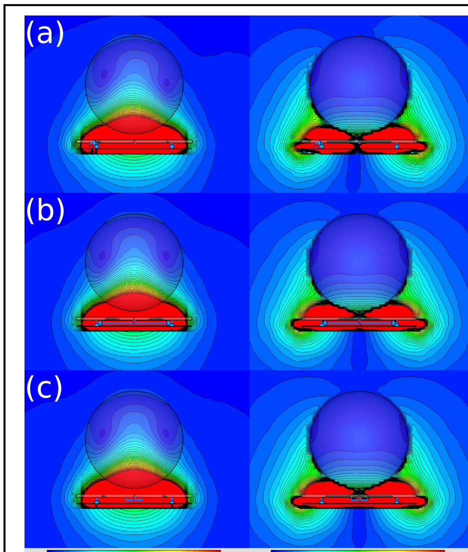

Figure 4: Simulated magnetic (left, 0-1A/m) and electric (right, 0-250V/m) fields for (a) unbalanced, (b) capacitively balanced and (c) geometrically balanced matched strips.

Results: Simulated capacitor values were found to be C_t=10.3pF and C_m=3.14pF for the capacitively matched strip, C_t=11.2pF with feed spacing a=27.1mm for the geometrically matched strip and C_t=11.1pF and C_m=1.73pF for the unbalanced strip. Figure 4 shows simulated magnetic and electric fields for the three strip configurations. The asymmetry of the unbalanced drive can be seen even though the strip is loaded by a perfectly centered, spherical phantom. Both balanced feeds produce symmetric magnetic and electric fields. The electric field is reduced for both balanced feeds, compared to the unbalanced feed, reducing SAR and resonant frequency shift under loading.

Discussion: Symmetrically driving microstrip elements helps to maintain the desired current distribution along the strip under different loading conditions. Several symmetric driving options are available. Driving the strip at the match point is effective, but harder to construct and adjust. Driving the microstrip symmetrically across the end points offers similar advantages while being easier to construct. The previously published symmetric drive [3] introduces a discontinuity at the centre of the microstrip, potentially reducing the strip Q. Both methods presented here achieve a symmetric drive without interrupting the main current path on the strip.

References: [1] Zhang et al, IEEE Trans. Biomed. Eng. 52(3), 2005 , [2] Garg *et al*, Microstrip Antenna Design Handbook, Artech House, 2001, [3] Brunner *et al*, 448, ISMRM 15, 2007, [4] Chen & Hoult, Biomedical Magnetic Resonance Technology, IOP Publishing, 1989.

Acknowledgement: Supported by CIBM of the UNIL, UNIGE, HUG,CHUV, EPFL and the Leenaards and Jeantet Foundations.