Optimizing the SNR performance of the Tunable Strip detector

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Introduction

Strip-line based detectors, employing distributed series and parallel lumped capacitors on a resonant strip, are finding increasing application in parallel MRI at higher field strengths [1-3]. Here we present an optimal design analysis for a Tunable 'T' section planar strip element for 1.5 T, and compare its Intrinsic Signal to Noise Ratio (ISNR) with loop coils. The strip element can have one or more parallel tuning capacitors forming multiple 'T' section elements without significantly affecting ISNR performance.

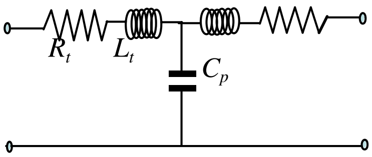

Fig. 1. Single 'T' section planar strip element. R_t, L_t, C_p refer to distributed resistance, inductance and lumped parallel capacitor.

Methods

A transmission line matrix analysis of the equivalent circuit (Fig.1) reveals that a single 'T' section element can have a wider tuning capacitor range, $C_p \leq \sqrt{2}/R_t\omega$, compared to a 'pi' section strip element [2] when the section is tuned to $\lambda/4$ with one end grounded. The SNR performance of the strip detector was analyzed numerically by electromagnetic Method of Moments (MoM) simulation by computing the transverse magnetic fields and noise resistances of detector elements for unit current excitation. The optimum strip geometry is a function of the substrate dielectric constant, ε_r, the dielectric thickness or strip spacing from the ground plane, h, strip width, W, the number of lumped tuning elements n, and the strip length, L. Intrinsic SNR calculations were done for detectors in a body-sized phantom (conductivity = 0.37 Sm^{-1}; ε_r=77) using *Feko* EM software and systems, (South Africa) over a practical range of design parameters (10 cm $\leq L \leq$ 30 cm; $1 \leq \varepsilon_r \leq 10$; $0.2 \leq W/h \leq 10$; $0 \leq n \leq 10$).

To test the numerical analysis, multiple planar strip lines were fabricated and matched. The ISNR of these detectors and several loop coils were measured. Finally, the SNR in a 20-l saline phantom, of the best performing two-strip detector and an optimal 3" loop coil, were compared.

Results and Discussion

The ISNR of the planar strip did not vary significantly with strip width W, but increasing the substrate thickness h > 5mm negatively impacted ISNR. Air dielectric (ε_r=1) performed better than other substrates, which was also evident in Q measurements (unloaded Q = 128 for air versus 75 for epoxy glass with ε_r=5). The number of tuning capacitors did not significantly affect ISNR, confirming the initial equivalent circuit assumption. The ISNR as a function of strip length at points directly above the strips (Fig. 2) shows the non-uniform sinusoidal signal profile of the $\lambda/4$ strip, and predicts an optimal value for $L \approx 1.3\ d$ for any given depth, d. Comparing the ISNR of strips and loops shows that strips designed based on the results of the numerical optimization have comparable ISNR to loops optimized for the same depth (Fig. 3a, b), although the strips generally exhibited a lower loading factor, in practice, than loops. Fig.3 (c,d) show a sagittal image of a healthy volunteer's spine and axial signal profile of the 2-strip detector on a saline phantom.

Thus, numerical optimization of strip detector design results in optimally performing MRI detectors.

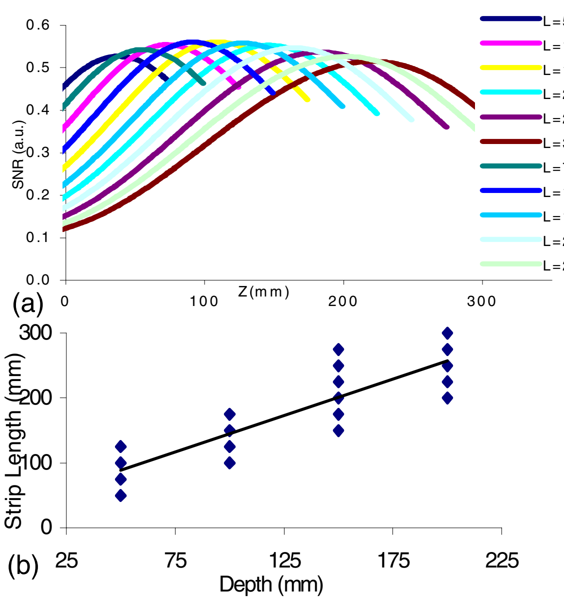

Figure 2. (a) SNR profiles of planar strips along their lengths at 10 cm above strips. (b) Length of strips that perform within 2% of maximum SNR at each depth.

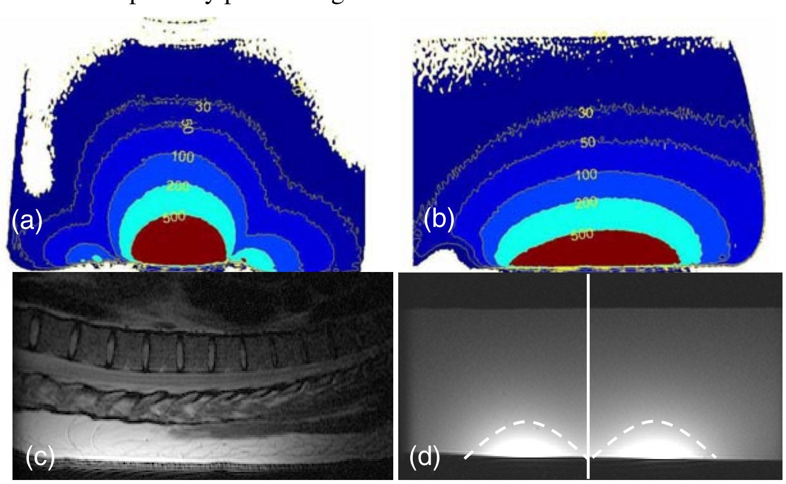

Fig. 3: Sagittal SNR profiles of 3" loop coil (a) and a two-strip detector (b) along middle plane of strips(coupling, S_{21}=-26dB). (c)Sagittal spine image of healthy volunteer. (d) Axial SNR profile of two-strips on a saline phantom.

Reference:

1. Kumar A, Bottomley PA. Proc ISMRM 2002.p.322.
2. Lee RF, *et al.* Magn Reson Med 51:172-83(2004).
3. Zhang X, *et al.* Magn Reson Med 46:443-450(2001)

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