Thin-film Catheter-Based RF Detector System

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Introduction Procedures such as biliary endoscopy require imaging modalities such as MRI if soft tissue contrast is to be improved [1,2]. Local signal detection is then required to achieve adequate signal-to-noise ratio at high resolution [3]. Small RF detector coils have been integrated with catheter probes, but the reliable combination of a coil, tuning and matching capacitors and an output cable is difficult in the limited available space. Here we demonstrate a catheter-based detector entirely formed from thin-film components.

Methods Double-sided patterning of copper-clad polyimide was used to form two-turn rectangular inductor spirals, together with capacitors for tuning and matching to 50 Ω impedance (Fig. 1a). Coil inductance and resistance were established by measurement. Appropriate capacitor values were then estimated using a simple circuit model and verified by addition of SMD components. Finally parallel-plate capacitors with the substrate as a dielectric interlayer were incorporated to form integrated resonators. Double-sided patterning was also used to form a thin-film microstrip interconnect, using periodic removal of the ground plane to achieve 50 Ω impedance at a low frequency. A suitable period a and mark-to-space ratio b/a (Fig. 1a) were established using a lumped element model of a periodic line. Detector and interconnect were spliced together and attached to a catheter with heat-shrink tubing (Fig. 1b).

Results Interconnects were fabricated in 2 metre lengths using 35 μm thick Cu layers on 25 μm thick Kapton® as shown in Fig. 2a. Conductor widths of w = 1 mm, defect widths of y = 2 mm, periods of a = 16 mm and different ratios b/a were used. The optimum ratio b/a = 1/8 gave low reflection at low frequencies compared with a uniform microstrip (Fig. 2b), with estimated impedance of 45 Ω. Low-loss propagation was achieved up to 2.5 GHz frequency (Fig. 2c). RF detectors with a coil length and width of 60 mm and 4.7 mm respectively and a track width and spacing of 250 μm were fabricated in arrays of 120 (Fig. 3a). After integration on an 8 Fr catheter, unloaded Q-factors of 45 were achieved at 63.8 MHz (Fig. 3b). Completed detectors gave excellent ^{1}H MR images of human fingers at 1.5 T using a 2D FIESTA sequence with TR = 10 ms, TE = 2 ms, NEX = 3 and a flip angle of 70° (Fig. 3c).

Discussion A complete printed thin-film RF detector system with optimised electrical parameters has been demonstrated. Further work is required to evaluate sensitivity to transmitter heating and incorporate any additional features needed to ensure patient safety.

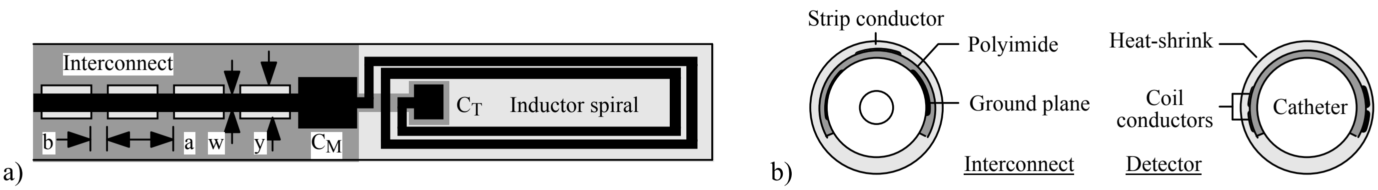

Figure 1. a) Thin-film RF detector system; b) integration on catheter.

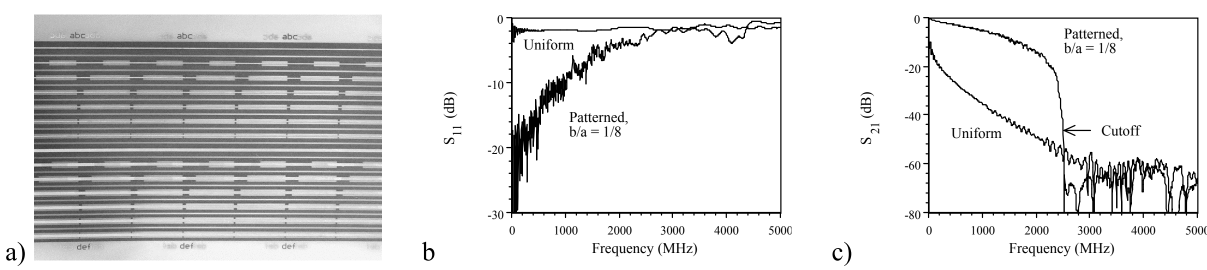

Figure 2. a) Thin-film interconnects; b) and c) frequency variations of S_{11} and S_{21} for optimum interconnect and uniform microstrip.

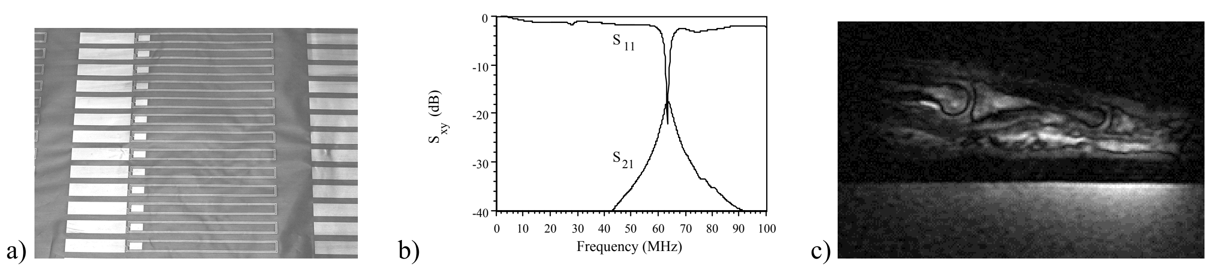

Figure 3. a) Thin-film RF detectors; b) frequency response of detector system; c) ^{1}H MR image of human finger obtained at 1.5 T.

References

[1] Baillie J., Paulson E.K., Vitellas K.M. Gastroenterology 124, 1686-1699 (2003)
[2] Manfredi R., Masselli G., Maresca G., Brizi M.G., Vecchioli A., Marano P. Abdom. Imag. 28, 319-325 (2003)
[3] Hurst GC, Misic GJ. In Encyclopedia of Nuclear Magnetic Resonance. Chichester, UK: John Wiley and Sons, 1996, p1373