Development of Multilayer Coil Using Non-planar MEMS Process for Intraluminal MRI Probe

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Introduction

Intraluminal MRI probe holds promise to achieve high resolution image of small pathological lesion such as the vessel plaque comparing to the conventional MRI scanner [1]. The MR signal receive coil is expected to be characterized by high signal-noise-ratio (SNR), good signal homogeneity and small size. By employing the developed photolithography technology on cylinder substrates, the MRI receive coil for the intraluminal application can be fabricated arbitrarily with the accurate and optimized shape. Comparing to previous single layer coil [2], this study presents the design of the multilayer receive coil for improving the imaging performance.

Fabrication of MRI prove with multilayer receive coil

The multilayer coils; saddle shaped coil and transformative solenoid, are fabricated on the polyimide tube substrate with 1.92 mm outer diameter and 0.06 mm wall thickness. The saddle shaped coil is suitable for side view imaging (tomography) and the transformative solenoid is for front view imaging. These received coils are made by non-planar MEMS (Micro Electro Mechanical Systems) process including non-planar photolithography. The technique realizes the coil patterning on cylindrical tube surface. The large tubular lumen supports the functions such as insertion of guide wire or injection of drugs. The coil wire is made by electroplating and the surface is insulated by parylene coating. For making multilayer coil, the same process is performed on insulated coil wire. The multilayer coil pattern characterizes a higher inductance; a higher Q factor and the arbitrary coil design for improving signal homogeneity by comparison with the single layer coil.

The image experiment is performed by the 1.5 T MRI scanner (Signa EXCITE XI TwinSpeed 1.5 T, GE Healthcare). Fig.1 shows the prototype MRI prove with 2-layer saddle shaped coil, which is tuned to 63.865 MHz and matched to 50 Ω with non-magnetic capacitors. Other coils are also tuned and matched as well as saddle shaped coil. Table.1 indicates the electric characteristics of proves. The Q factor with loading in saline of 2-layer saddle shaped coil is 39.4, which is 70 % higher than the one of 1-layer saddle, and the one of transformative solenoid is 30.

Imaging results of MRI prove

The imaging object is the acrylic lattice embedded in the agar phantom (T_1≈920 ms, T_2≈55 ms, which is similar to the smooth muscle [3]). SPGR (Spoiled Gradient Recalled acquisition in steady state) sequence is used for imaging (FA=29°, 256x256 matrix, FOV=2 cm, slice thickness=1 mm, TR/TE=100/10 ms).

Fig.2 shows the MR imaging results of conventional cardiac coil, 1-layer saddle coil and 2-layer saddle shaped coil (side view). It is difficult to discriminate lattice shape with the image of the cardiac coil. In contrast, the intraluminal MRI proves (1-layer and 2-layer saddle shaped coil) demonstrated high resolution, the lattice shape is much clear. Although the imaging region of intraluminal MRI proves are smaller than outside coil, it is remarkable that MRI proves have high imaging ability for small pathological lesion such as the vulnerable plaque in the vessel. The multilayer coil with higher Q factor causes an increased SNR, which results in a larger image region compared to 1-layer coil.

Fig.3 shows the MR imaging result of transformative solenoid (front view). Transformative solenoid presents front imaging region about 5 mm diameter. This indicates that transformative solenoid can effectively image front of lumen, which achieves the safety imaging for occlusive lesion that is difficult to introduce receive coil into lesion, such as CTO (chronic total occlusion).

Conclusion

The non-planar MEMS process realized multilayer receive coil. The developed multilayer saddle shaped coil for intraluminal MRI probe has a better MRI imaging performance compared to the conventional body coil and previous single layer design. The transformative solenoid demonstrated front view imaging.

References

[1] E. Larose *et.al.*, Characterization of human atherosclerotic plaques by intravascular magnetic resonance imaging, Circulation, Vol. 112, 2324-2331, 2005

[2] S. Goto *et. al.*, Development of Intravascular MRI probe Applicable to Catheter Mounting, IEEJ Trans. SM, Vol. 128, No. 10, 389-396, 2008 (in Japanese)

[3] H. Kato *et al*, "Compositional of MRI phantom equivalent to human tissues," Medical Physics, vol.32(10), pp.3199-3208 (2005)

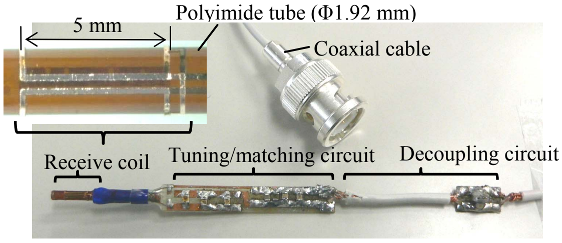


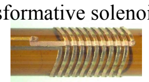
Fig.1 Structure of intraluminal MRI prove with multilayer receive coil

Table.1 Electric characteristics of MRI proves at 63.865 MHz.

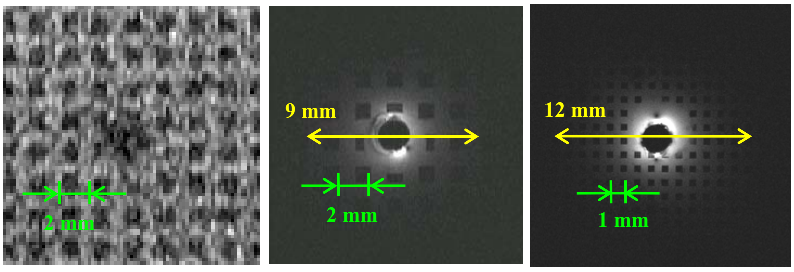
1-layer saddle

2-layer saddle

Transformative solenoid



Receive coil	L (nH)	Q
1-layer saddle	22.8	23.0
2-layer saddle	123.7	39.4
Transformative solenoid	136.0	30.0



(a) Cardiac coil (b) 1-layer saddle (c) 2-layer saddle

Fig.2 Side view imaging of saddle shaped coils compared with cardiac coil.

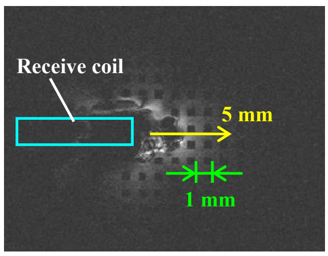


Fig.3 Front view imaging of transformative solenoid.