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RF endoluminal coil with NMR electro-optical conversion and transmission for colon wall imaging: Initial finding

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Synopsis (98/100w max)

Receive surface coils in MRI have proven to enable higher spatial or temporal resolution. However, the proximity of the galvanic connexions with the body when the coil is used as receiver coil together with a volume coil can lead to safety issues, in particular for inner coil. This configuration can induce currents in coaxial cable and local SAR increase can be induced. Replacing the galvanic connexions with optical ones could prevent those risks and enable safe colon wall imaging with endoluminal coils. First experimental demonstration of an electro-optic conversion based on Pockel's effect is done at 4.7T.

Intro (145/150w)

Higher spatial resolution MRI of the colon wall could lead to diagnosis and characterization of colon cancer at an earlier stage thus increasing the five years survival rate. Endoluminal coils increase the image spatial resolution at close proximity of the loop coil, therefore allowing a better analysis of the colon wall¹. Nonetheless, the coaxial cable connecting the coil to the MR system causes safety issues², as the excitation radiofrequency magnetic field B_1 induces currents in the galvanic connexion leading to a local increase of the SAR. This unwanted effect can be avoided by using optical fiber instead of metallic cable³. For that purpose, the NMR signal must be converted into light signals and converted back in electrical signal to be digitalized and reconstructed by the MR system. This work presents the first MR images obtained on a preclinical MR system after electro optical conversion using Pockel's effect.

Methods (260/350w)

Endoluminal coils previously designed and built for mouse colon imaging were used¹. The coil loop was 40mm in length and 1.6mm in width and was operating at 200.29 MHz corresponding to the proton frequency for the 4.7T preclinical MRI scanner used (Bruker, Germany). The endoluminal receiver RF output signal of the coil was connected to a MAXN-LN-20 (IXblue, France) used as electro-optical converter. The variations of the electrical field change the polarization of the 1550nm linearly polarized laser going through the crystal by Pockel's effect. An eoSense system (Kapteos, France) was used as the opto-electronic converter. To asses SNR, a cylindrical tube was filled with saline solution doped with nickel sulphate (1.25 g/L of $\text{NiSO}_4 + 5 \text{ g/L of NaCl}$) in order to reduce T1-value. The coil was inserted inside the tube and sealed. A 72mm inner diameter birdcage coil (Rapid Biomedical, Rimpär, Germany) was used as transmit coil. The figure 1 represents the optical transmission chain. MSME sequence with

TR/TE 650/14ms was performed with optical conversion and compared with galvanic connexions and a quadrature 32mm inner diameter birdcage coil dedicated to mouse.

Results (96/100w)

As predicted, the surface coil with galvanic connexion depicts a considerable gain in SNR compared to the volume coil. As seen in the figure 2, SNR profiles obtained with the galvanic transmission chain is 20 times better than the optic one. However, there is a clear correlation between both SNR profiles. Despite the fact that achieved EO conversion do not reach the targeted SNR, the SNR in the area of interest (close proximity of the loop) is still higher than with the dedicated volume coil (figure 3).

Discussion (130/150w)

As predicted, the SNR obtained with the galvanic connexion endoluminal coil has an excellent SNR close to the loop coil (target colon area), making it a good objective reference. The proof of concept of the conversion chain based on Pockel's effect was demonstrated. Beside the fact the image is noisier, the figure 4c depict a similar image in shape than figure 4b. The SNR of the optical coil is however significantly inferior to the galvanic one but above the SNR obtained with the volume at the wall of the phantom. One lead could be to improve the linearity of the converter. It depends on the operating point defined by a voltage offset, which was not studied in depth for this test. Secondly, the bandwidth of the electro-optical converter was not optimal for this application and the geometry of the crystal should be the subject of further improvements. Developing application-specific converter with suited bandwidth and operating point could improve significantly the SNR.

Conclusion (95/100w)

The concept of EO conversion based on a bulk crystal using Pockel's effect was demonstrated with an endoluminal coil for colon mouse. The next step is the improvements of the SNR and to add an efficient optical-based decoupling circuit as already demonstrated⁴. This, in addition to monitoring the induced currents with an optoelectronic Electrical field probe⁴ would pave the way to in vivo testing.

Acknowledgements

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Summary of Main Findings (220/250c)

This experiment showed that coaxial cables used with endoluminal coils could be replaced with optical fiber. Both conversions (opto-electronic and electro-optic) must be specific to the application in order to preserve the gain in SNR from the endoluminal coil.

References

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Figures

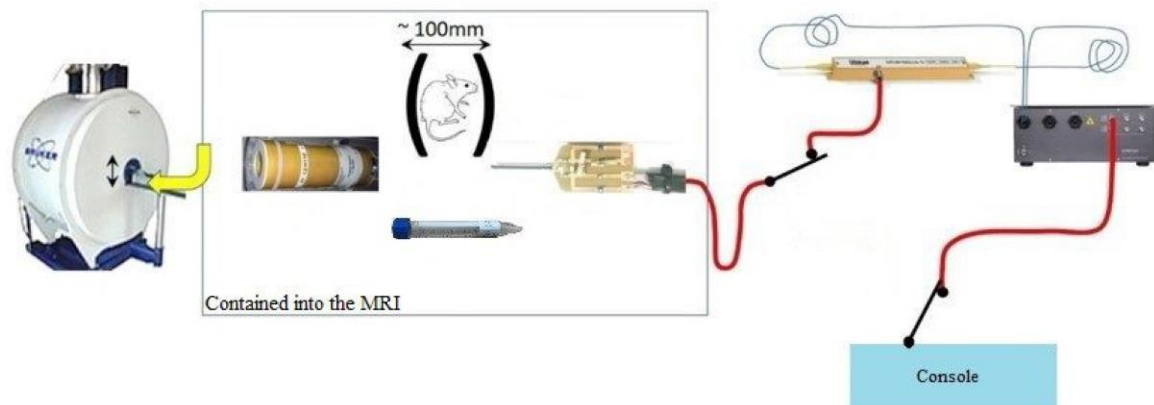


Fig. 1. Diagram of optical conversion chain. Inside the MRI from left to right is the emission coil, the phantom mimicking the mouse's colon and the endoluminal coil. Outside are the converters and the processing MR console to reconstruct the images.

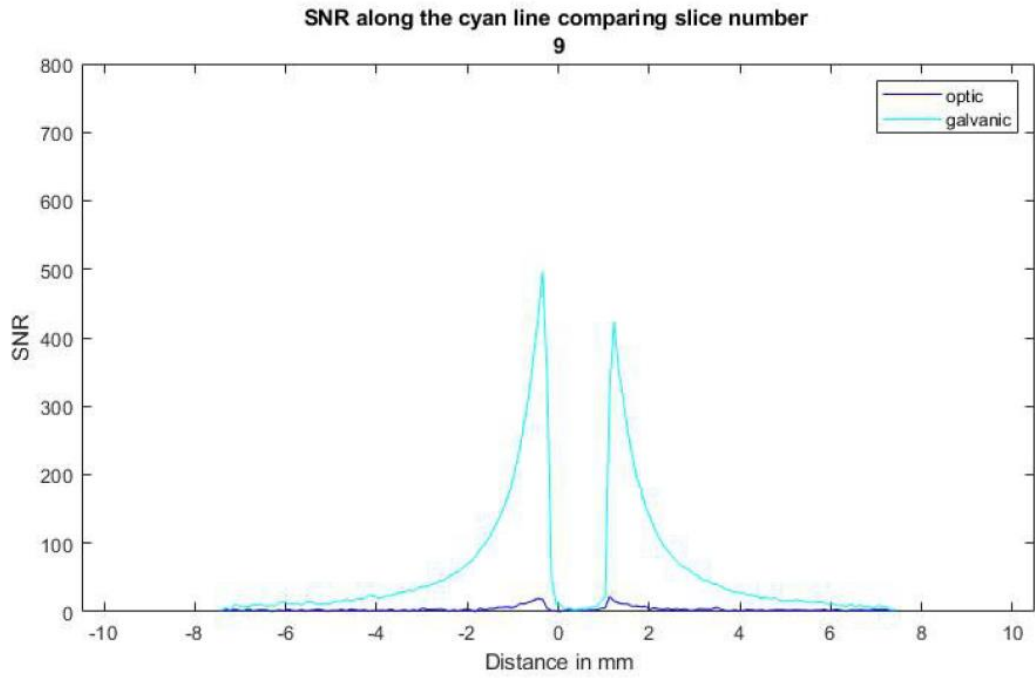


Fig. 2. Comparison of the local SNR profiles for the endoluminal coil with galvanic cable (in cyan) and with optical fiber (in blue).

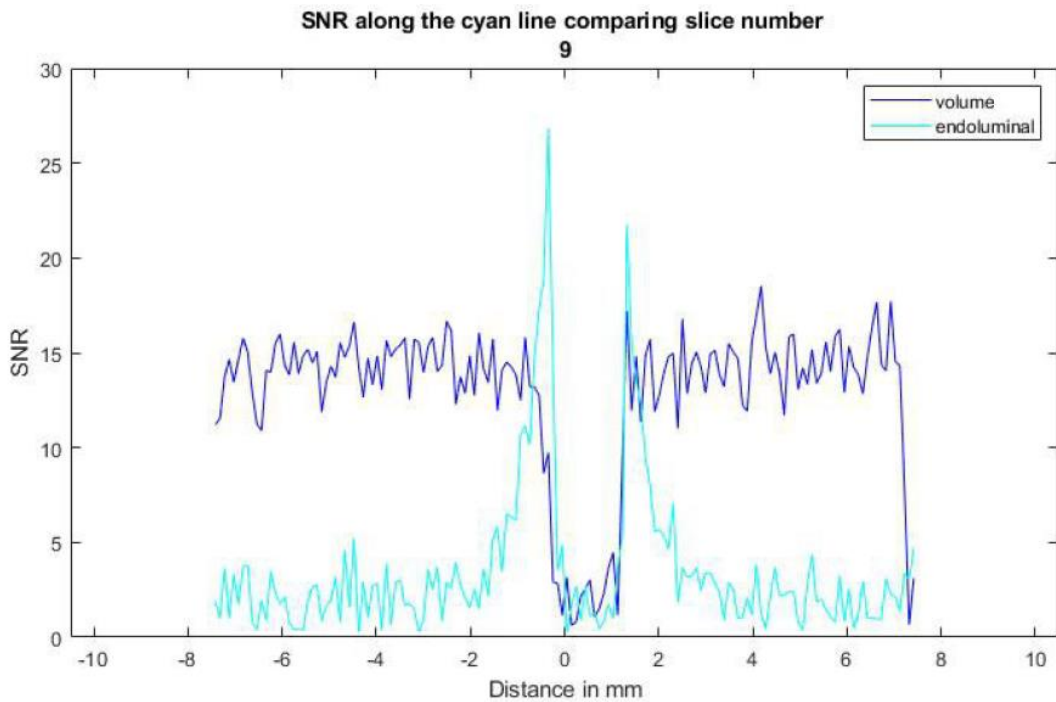
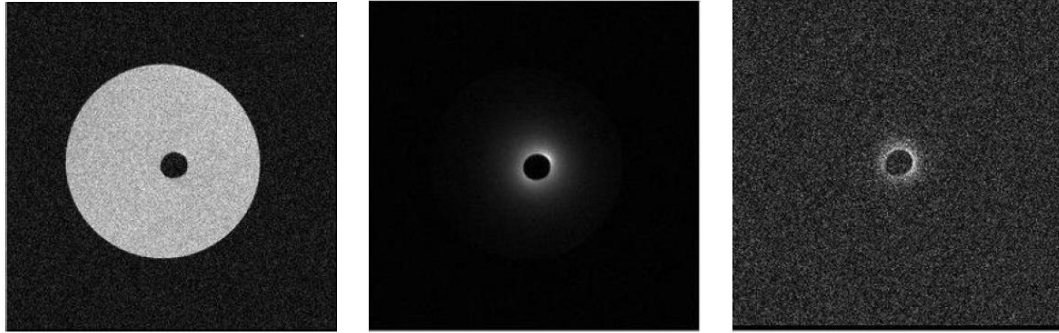


Fig. 3. SNR profiles obtained with 32 mm inner diameters quadrature birdcage coil (in cyan) and endoluminal coil with optical fiber. While the volume coil has higher average SNR, the endoluminal is almost 2 times better at the expected location of wall.



(a) *Volume coil*

(b) *Endoluminal coil*

(c) *Endoluminal coil with
optic transmission chain*

Fig. 4. Images of the saline solution tube obtained with the different coils. For reference, the outer diameter of the tube is 1.6mm