ACTIVE OPTICAL-BASED DECOUPLING CIRCUIT FOR RECEIVER ENDOLUMINAL COIL

Reina Ayde[1], Raphael Sablong[1], Gwenael Gaborit[2,3], Lionel Duvillaret[3], Anne-Laure Perrier[1], and Olivier Beuf[1]

[1]CREATIS - CNRS UMR 5220 – INSERM U1044, University of Lyon 1, Villeurbanne, Rhone-Alpes, France, [2]IMEP-LAHC UMR 5130, University of Savoie, Rhone-Alpes, France, [3]Kapteos, Rhone-Alpes, France

Introduction: Despite the enhanced image provided by multiple-channels array coils, an accurate exploration of bowel diseases and detailed information about the gastrointestinal wall layers are still not available. The use of endoluminal RF coil located in the region of interest could potentially allow good evaluation of tumor invasion or depth of inflammatory processes [1]. However, since metallic coaxial cables are used, patient safety is threatened due to local electric field concentration that can happen and the associated local high Specific Absorption Rate (SAR) [2]. Moreover, in this case, cable isolation and traps cannot be straightforwardly employed due to limited dimension. Signal transmission based on optical fiber is an alternative to coaxial cables to solve definitively the electromagnetic issues. On a receiver coil, both signal transmission and decoupling have to be insured. For MR signal transmission, the electro-optical conversion has been partially validated based on electro-optic effect of some crystals [3]. In this work, an active optical decoupling circuit for endoluminal coil is presented and compared to a reference coil with regular decoupling using bias signal though coaxial cable.

a)

b)

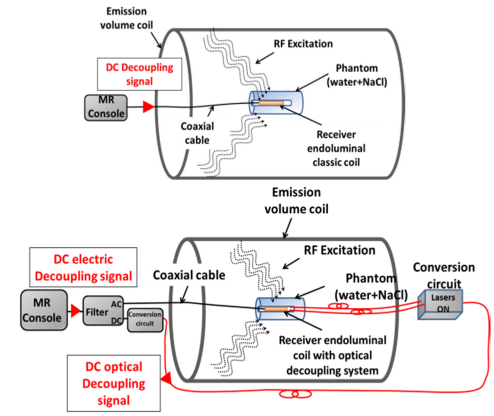

Fig.1: Schematic representation of the experience performed on a 3.0T GE Discovery MR750 system during excitation for a) the reference decoupled galvanic coil and b) the optically decoupled coil

Method: The schematic presentation of the experience is shown in Fig.1 and the equivalent circuit for galvanic decoupled reference coil and optical decoupled coil are presented in Fig. 2a and 2b, respectively. The coil was inserted in a cylindrical tank filled with a saline water solution at $5g.L^{-1}$.

Decoupling of the galvanic regular coil is insured by a PIN diode driven by a current provided by the MR data cabinet. In contrast, the PIN diode of the optical decoupled coil is controlled by two photodiodes providing sufficient current for a direct operation. The DC current provided by the data cabinet through the connector is converted into an optical signal by an electro/optic circuit conversion. A fiber optic guides the signal to an optical/electric circuit conversion where the optical signal is converted into the appropriate potential bias of two lasers diodes. Photodiodes receive optical beam from laser diodes and generate the decoupling current.

Axial images of the phantom were obtained with a Fast Spin Echo (FSE) sequences. The performances of three active decoupling circuits associated to endoluminal coils were compared: reference decoupled coil, optically decoupled coil and a constantly coupled coil (without Pin diode). Obtained images are presented in Fig. 3. In order to discriminate and quantify the performance of each decoupling system a method was applied based on the fact that theoretical SNR has a defined theoretical pattern (fig.4) and that a wrong decoupling is characterized by a non-uniform signal distribution destroying the theoretical SNR distribution. The method consists on comparing the outline of a given SNR (fig.5) to its corresponding theoretical pattern. The distance separating two equivalent points (experimental and theoretical) was calculated and the corresponding histograms were plotted (fig.6).

a)

b)

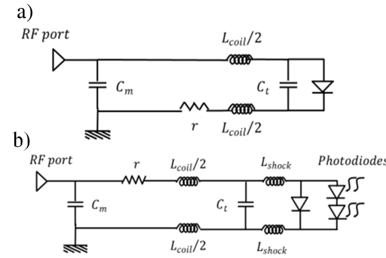

Fig.2: Equivalent circuit of endoluminal coils constituted of rectangular single loop coils (5.1 mm width; 47 mm length) a) of the reference coil and b) of optical decoupled coil. Two shock inductors separate photodiodes from the rest of the coil.

Results: Two criteria were chosen to compare the performance of different coils: The Signal to Noise Ratio (SNR) and the radial uniformity of the signal in the close vicinity of the coil. In figure 3, the SNR of the regular coil was compared to that of the optically decoupled coil along the horizontal axe. For the reference coil, the results show that the SNR reaches 1100 at the edge of the coil, while it is about 930 for the optically decoupled coil. Concerning the radial uniformity of the signal, figure 3.c) shows clearly the non-uniform signal regions distribution caused by the transmit RF magnetic field concentration. While fig. 3a) and 3b) show that optical coupling has a performance comparable to a classic coupling system. To analyze quantitatively the performance, iso-contour line at 400 SNR value was chosen and the corresponding histograms to each coil were plotted. This latter show that relatively high distance separating theoretical data from experimental data appear in the image corresponding to a coil without decoupling system. While, classical and optical decoupling system fit so closely to the theoretical shape proving a high quality performance of the optical system.

a) b) c)

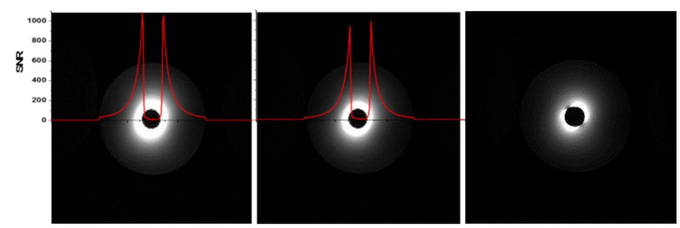

Fig.3: Images obtained with endoluminal coil using a FSE sequence with a) regular galvanic decoupling and b) optical decoupling and c) constantly coupling. *Red curve represent the SNR profiles along a horizontal line centered with the coil.*

Discussion: The proof of concept of this decoupling circuit was demonstrated. SNR show that regular coil is slightly better than the optically decoupled coil due to losses induced by added electronic components (photodiodes and inductors). However, the results of radial uniformity show that the optical-based decoupling circuit performs with adequacy.

References: *[1] O. Beuf and al., JMRI, Vol. 20 (1), 2004. [2] V. Detti , Magn. Res. Med., Vol. 66 (2), 2011. [3] R. Ayde et al, IEEE sensors journal, Vol. 13 (4), 2013*

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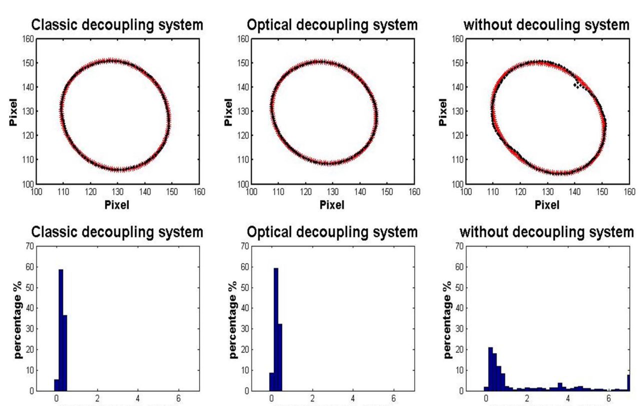

Figure 6: The first row displays the iso-contour lines corresponding to SNR=400 for different type of decoupling. The red and black curves correspond respectively to the theoretical and experimental data. The corresponding histograms of the distance separation between points for each decoupling system are shown in the row right down.

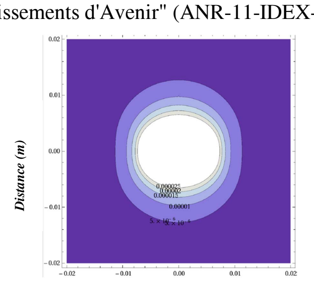

Figure 4: Theoretical iso-contour lines of the magnetic field created by a unit of current flowing in a reference coil. Since SNR is proportional to the magnetic field, then SNR has a similar geometrical form.

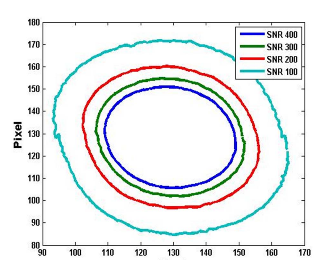

Figure 5: Plotted Experimental iso-contour lines corresponding to different SNR (400, 300, 200 and 100) for a reference coil.