Remote detection of implanted neurostimulator in MRI scanner

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Target Audience: MR physicists, researchers interested in performing fMRI implanted neurostimulators.

Purpose: Deep brain stimulation (DBS) using implants is an effective symptomatic treatment of conditions like Parkinson's disease, major depression and tremor. Functional MRI (fMRI) scans have the potential to decode the underlying mechanisms of the efficacy of DBS. fMRI with DBS are usually performed with externalized neurostimulators (implanted pulse generator (IPG)). In order to perform fMRI scans with implanted IPGs, it is essential to monitor the ON/OFF state of the device. However, older models of these devices (e.g. Medtronic Soletra) switch their state in the presence of a magnet (the MRI scanner) and its fringe fields. While the newer models (e.g. Medtronic Kinetra and Activa PC) can be programmed to switch between ON and OFF states in a controlled manner and in specific time intervals, the timing of this switch of state usually drifts with time. This drift is large enough to result in an inaccurate linear model and the appearance of variable activation over repeated scans. Using an AM receiver circuit, which is known to pick up an external RF signal from the IPG when it is active, we have developed a prototype of a device to monitor the state of implanted neurostimulators at 3T.

Methods: All testing was done using Medtronic 37601 Activa PC neurostimulators connected to 3387 DBS leads via 37085 DBS stretch coil extension. The IPG amplitude was set at 1.5 V and was programmed in 10 s ON 10 s OFF mode. The neurostimulation system was immersed in a polyacrylic gel phantom[1]. The device incorporates a loop antenna made of 20Ga enameled copper magnet wire that is connected through a band-pass AM filter to a battery powered AM radio (Fig 1(a) and (b)). The audio output is low-pass filtered, passed through an RF filter patch panel to the MR control room outside the exam room, and then passed to monitoring equipment comprised of an ADC converter and display (Biopac systems; www.biopac.com) that provides feedback relating to the state of the IPG. For sufficient signal to detect, the enameled loop antenna must be capacitively coupled or just touching the conducting medium (polyacrylic gel). Data postprocessing was done using Matlab. A peak in the FFT of radio signal was located

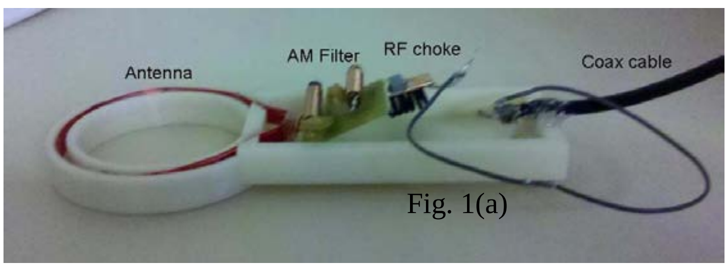

Fig. 1(a)

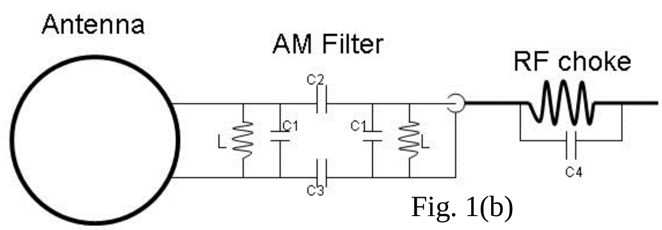

Fig. 1(b)

when the IPG was known to be ON, and the relative energy in this bin (and its harmonics up to Nyquist frequency) over all energy in fft spectrum was plotted. A brief echoplanar (EPI) BOLD-weighted scan was also acquired during monitoring, to test the sensitivity in the presence of MRI RF noise.

Results and Discussion: A plot of the energy for 1.5 V DBS, radio output, through the wall and into the Biopac acquisition is shown in Fig. 2. The ON/OFF state of the Activa PC is clearly identifiable from this plot. At 65 seconds post-recording, the EPI sequence was started. The ON/OFF state remains identifiable during the EPI scan, ending at 110 seconds. The signal identified this way can be used (i) to ensure the ON/OFF status of the IPG, and (ii) as a trigger in fMRI scans.

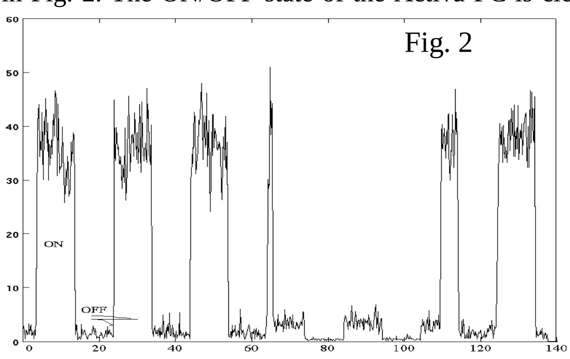

Fig. 2

Conclusion: We have developed a prototype to monitor the ON/OFF state of IPGs inside a 3T scanner, during rest periods and during functional imaging.

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References:

1. K. B. Baker, J. A. Tkach, M. D. Phillips et al. Variability in RF-induced heating of a deep brain stimulation implant across MR systems. J Magn Reson Imaging. 2006;24(6):1236.