LETTER TO
THE EDITOR

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Comments on "Ensuring Safety of Implanted Devices Under MRI Using Reversed Polarization"

Yigitcan Eryaman, Sinan Hersek, and Ergin Atalar*

In the work titled "Ensuring Safety of Implanted Devices Under MRI Using Reversed RF Polarization," the authors propose a method based on reversed polarization, which can be used as a prescan technique for patients with implants. In their work, to visualize qualitatively the induced radiofrequency (RF) currents on a metallic lead inside the patient, they propose to reverse the RF polarization for the transmit and/or the receive procedure. They performed simulations and experiments to investigate the performance of this technique and correctly identified the dangerous coupling currents that may cause risk to the patients. They formulated the RF field that is generated by an induced current on a straight wire, and they calculated its effect on the image intensity in both the forward and the reversed polarization cases. They compared these analytical test results with the experiments and showed that the results accurately match. They claim that the coupling currents can be visualized with better sensitivity when reversed polarization is used. According to the authors, the transmit polarization reversal provides better background suppression, making it easier to distinguish signal variation in the vicinity of the lead from variations due to anatomy. With polarization reversal, they claim that better wire-signal accuracy is provided.

Although using reversed polarization to visualize the coupling currents is an innovative idea and could enhance the safety of patients with implants who are undergoing MRI, with this letter we would like to note that there may be certain situations where the proposed method may not work efficiently to accurately visualize the induced currents. In these specific cases, the RF safety of the patient could still be under question.

In the Discussion section of the paper (p. 831), the authors state that using reversed polarization in transmit mode exposes the wire to an electric field distribution that is not necessarily equivalent to the forward case with asymmetrical loads. The authors also state that this problem should be investigated further.

For the implant modeled as a spherical perfect electric conductor with a helical bare wire, shown in Fig. 1, the tangential electric field on the wire has a constant magnitude and a linear phase variation (1). In Fig. 2, the phase of the incident tangential electric field on the wire is plotted for the forward and the reversed excitations. The results are obtained from EM simulations made by using the commercial software FEKO (EM Software & Systems-S.A, Stellenbosch, South Africa). Although the magnitudes of the electric fields are the same, the phase variations are different for the two different excitation methods.

An asymmetrical current distribution is obtained on the wire with the forward and the reversed excitations, as shown in Fig. 3. The induced current near the free end of the wire for the reversed excitation is significantly less than the induced current obtained with the forward excitation, as can be seen in the figure. Note that the local specific absorption rate (SAR) at the tip of the wire is proportional to the square of the tip current, as mentioned in the work titled "Ensuring Safety of Implanted Devices Under MRI Using Reversed RF Polarization."

Because of these results, a 8.5-times higher SAR is expected at the tip due to the forward excitation, as compared to the reversed excitation.

To verify these results experimentally, we made phantom experiments with the helical copper wire, as shown in Fig. 1. The phantom was prepared with commercially available gel (Dr. Oetker Jello, Izmir, Turkey).

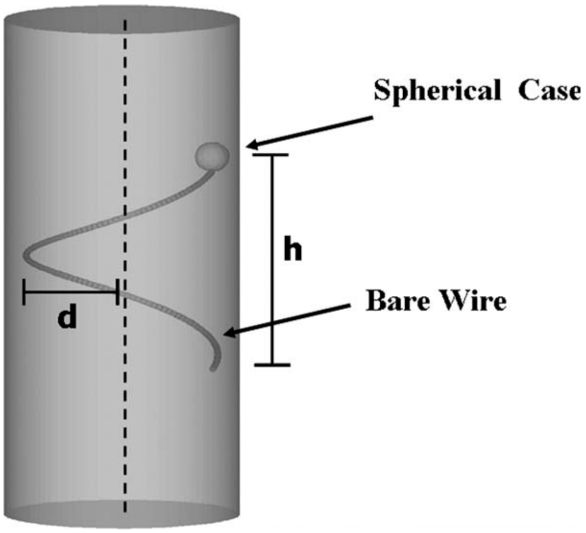

FIG. 1. A bare wire with a helical geometry attached to a spherical implant case is placed inside a uniform phantom model. The length and radius of the phantom are chosen as 40 cm and 7.5 cm, respectively. The height (h) and the radius (d) of the helix formed by the wire are chosen as 16 and 6 cm, respectively. The diameter of the wire is 1 mm.

Department of Electrical and Electronics Engineering, National Magnetic Resonance Research Center (UMRAM), Bilkent University, Ankara, Turkey.

*Correspondence to: Ergin Atalar, Ph.D., Department of Electrical and Electronics Engineering, National Magnetic Resonance Research Center (UMRAM), Bilkent University, Ankara 06800, Turkey.
E-mail: ergin@ee.bilkent.edu.tr

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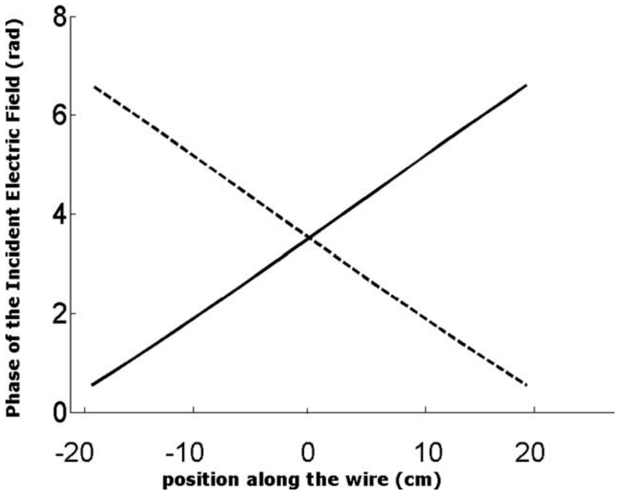

FIG. 2. The phase variation of the electric field along the helical wire is plotted for the reversed (dashed line) and the forward (solid line) polarization.

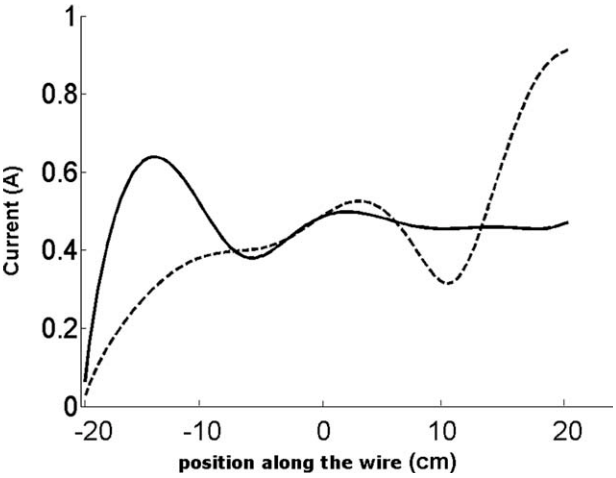

FIG. 3. The variation of the current along the helical wire is plotted for the reversed (dashed line) and the forward (solid line) polarization.

To measure the relative permittivity and the conductivity, a method based on cylindrical transmission line setup measurements was used. A relative permittivity of 70 and a conductivity of 0.5 S/m were obtained with 2.5 g/L of salt in the gel solution (2).

We exposed the wire to forward and reversed excitations using a Siemens 3.0 T Trio scanner. We also repeated the same experiment with a commercial DBS device placed inside the same phantom with the exact same geometry and orientation with respect to the helical bare wire.

A GRE sequence with a 1.94-ms TR was used, and a peak SAR of 4.4 W/kg was obtained with this sequence. Each scan lasted for 60 s.

A signal conditioner (Neoptix ReFlex) with fiber optic temperature sensors (Neoptix, Quebec City, Canada) was used for temperature measurements. The temperature variations at the wire/lead tips were recorded.

The standard temperature progression data was observed at the wire/lead tips, starting with a fast rate of change that slowed down with time. The maximum temperatures obtained at the tip after 60 s with reversed and forward scans were 0.6 and 3.8°C, respectively. To estimate the local SAR at the tip due to different excitations, we measured the initial rate of change of the temperature with respect to time. The local SAR ratio between the two cases is estimated as 7.1. The values are very close to the values obtained with simulations. The experiment was repeated with a commercial DBS lead (Medtronic 33877 DBS electrode, Medtronic, Minneapolis, MN) using the same setup that was used for the bare wire case. The maximum temperatures obtained at the tip due to reversed and forward scans were 1.1°C and 9.4°C, respectively. The local SAR ratio between the two cases is estimated as 8.8, by comparing the initial slopes of the temperature data.

As demonstrated by simulations and experiments, forward and reversed excitations may cause substantially different local SAR at the tip of the implant leads. Because of the difficulties in precise matching of the simulation and experimental models, some error was expected in the results. The difference between the SAR ratio obtained from simulations and the experiments was less than 15%.

The results were obtained by using a birdcage coil excitation and a uniform phantom model. With these assumptions a symmetrical electric field magnitude variation was obtained in longitudinal direction. For more complicated body models the magnitude of the electric field variation along the lead may be more complex (3). In these situations, the difference in implant lead heating due to forward and reverse polarizations should be investigated further.

An exact helical lead shape is unlikely to be encountered in real life. However, the above condition for the local SAR may occur with different lead and coil geometries, as well. The possibility of such a condition and the related risks should not be neglected while using the proposed method of reversed polarization.

Yigitcan Eryaman
Sinan Hersek
Ergin Atalar
Department of Electrical and Electronics Engineering
National Magnetic Resonance Research Center
(UMRAM), Bilkent University, Ankara, Turkey

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