Analysis and Design of Antennas for an Implantable Medical Device System for Functional Electrical Stimulation

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Abstract

This paper outlines the results of finite element analyses to study the radiation pattern of an implanted medical device. Also presented are simulation results used to design an electrically small antenna for a portable control unit that communicates with the implants over a 416 MHz to 453 MHz data link. Alfred Mann Foundation's Functional Electrical Battery Powered Micro-Stimulator system (FEBPM) uses a network of micro-stimulators [1] to sequentially stimulate various nerves and muscles. The ultimate application of this technology is reanimation for patients who have suffered stroke, traumatic brain injury, or spinal cord injury. The FEBPM device was modeled using the COMSOL CAD system (Figure 1). The human body can be modeled as a lossy dielectric [2]. The simulations used complex valued permittivity and permeability of the implant components. COMSOL was used to simulate the radiation patterns (directivity) for the implant at various depths within the human body (figure 2). Field trials showed that the simulation had predicted the actual radiation pattern within 1-2 dB. See figure 3 for patterns measured in the horizontal plane, normalized for path loss. The effect of device orientation with respect to the human body was studied. This simulation showed the direction and solid angle coverage of the antenna nulls. This is an important system level consideration in controlling link loss. COMSOL was used to predict the feed point impedance of the antenna, and to design the impedance transformation network between the implant radio and the antenna. The COMSOL prediction of 27+j3 Ohms was within 3-5% per-cent of actual measured results. Variation of feed point impedance as a function of implant depth was simulated and its effect was found to be negligible for most implant depths. Simulations accurately predicted absolute loss of radiated power as a function of implant depth. COMSOL was used to design an electrically small circularly polarized antenna (Figure 4) to address polarization loss between the implant devices and the controller. The radiation pattern in the far field and axial ratio as a function of frequency and angle along the azimuthal and elevation planes were studied. Solution of the E field over a whole RF cycle was used to study the ellipticity angle of the polarization ellipse. Various parametric sweeps over substrate thickness and geometry were used to arrive at the design. The effect of antenna substrate loss tangent was evaluated. The feed point impedance was studied at various channels to help make design tradeoffs for antenna Q. The results of S-parameter analysis were used in an RF simulator to design a feed network. COMSOL predictions for feed point impedance were within 5% per-cent of measured values. Other studies included effect of enclosing the antenna in a radome material and effect of proximity of the device electronics to the antenna's radiation pattern and feed point impedance. These results informed the

case design.

Reference

1. E. Lee, E. Matie et al., A Biomedical Implantable FES Battery Powered Microstimulator., IEEE Transactions on Circuits and Systems, December 2009
2. G. Hartsgrove, A. Kraszewski et. al., Simulated Biological Materials for Electromagnetic Radiation Absorption Studies, Bioelectromagnetics 1987, 8:29-36

Figures used in the abstract

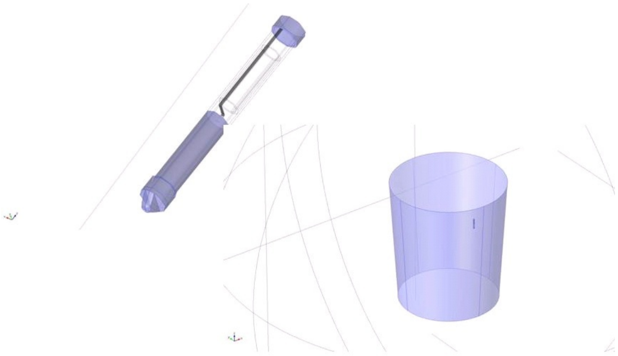

Figure 1: FEBPM Device Geometry and Phantom Model.

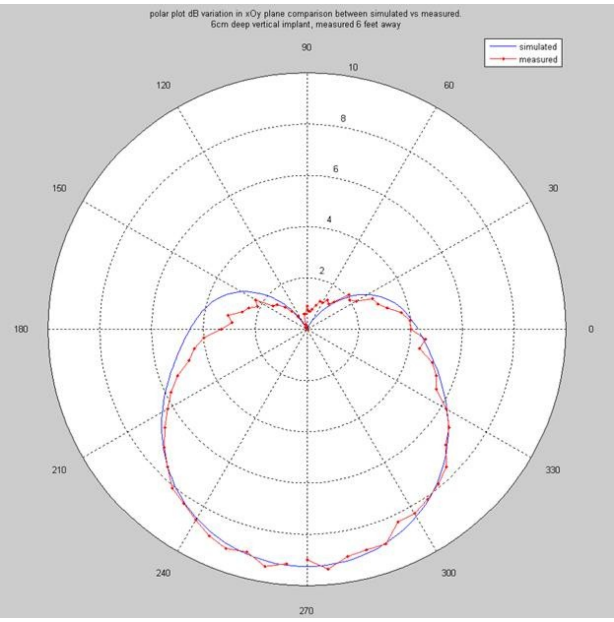

Figure 2: Gain in xOy plane.

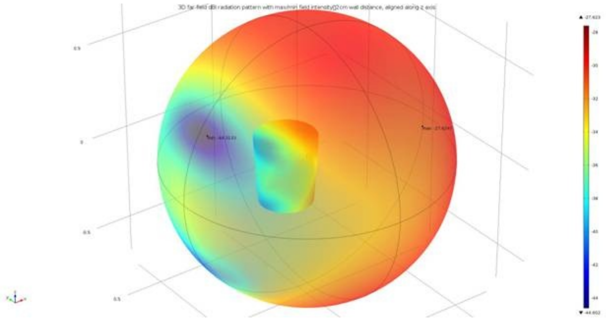

Figure 3: Directivity in 3 Dimensions.

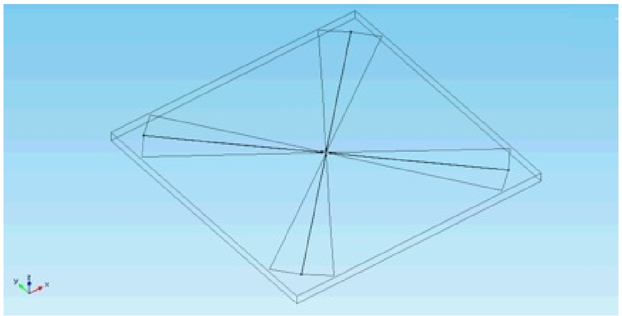

Figure 4: MCU Antenna Geometry.