Manufacturing Considerations for Implantable Antennas

Miguel Rodriguez, Cynthia Furse
Electrical and Computer Engineering
University of Utah
Salt Lake City, UT, USA
ma.rodriguez@utah.edu, cynthia.furse@utah.edu

Rob Franklin
Blackrock Microsystems
Salt Lake City, UT, USA
rfranklin@blackrockmicro.com

I.INTRODUCTION

Design of implantable antennas poses a unique set of challenges since antennas need to be small, biocompatible, and operate in the highly lossy environment of the human body. A recent review identified miniaturization challenges and how they have been managed in a variety of designs. [1] It also noted the sensitivity of these miniaturized antennas to fabrication tolerances. Our paper addresses another type of challenge – effective methods to manufacture these antennas using biocompatible materials (many of which are difficult to adhere with glue or solder), tight manufacturing tolerances (and practical ways to manage them), and a design that is practical both for manufacturing of individual test antennas by hand or for larger scale manufacturing. We will build on the spiral microstrip designs originally presented in [2] and expanded in [3][4].

II.MATERIALS and MANUFACTURING

Implantable antennas are required to operate within the Medical Implant Communication Service (MICS) specification of 401MHz to 406MHz. [4] The goal is to transmit as far as possible, which is usually limited by the Specific Absorption Rate (SAR) limit of 1.6 W/kg. [6] The radios normally used are 50 ohm devices, and we have chosen $S_{11} < -10\text{dB}$ as the requirement for matching.

The antennas discussed in this paper are designed to be mounted on top of a hermetically sealed titanium enclosure containing the electronics of the system as shown in Figure 1. This will also serve as the ground plane for the microstrip antenna design. The materials used for this antenna and their electrical properties are given in Table 1, and a detail of sample antenna dimensions is given Figure 3. The finished prototype is shown in Figure 3.

The antennas were designed and simulated using CST Studio Suite which uses a full-wave finite integral technique (FIT). The antenna was assembled by first molding the silicone superstrate that functions as the insulative material to separate the spiral from the body (which is conductive and would short it out). The silicone also serves as the mold for the epoxy substrate. The spiral radiating element was then cut out (by hand, or by laser cutting) from a 0.05mm thick titanium sheet and placed inside the silicone mold. Epotek 301 epoxy was added to fill the mold. The epoxy serves as the substrate to separate the spiral from the ground plane while also adhering to the superstrate and fixing the spiral in place. The shorting tab is an extension of the spiral, which is bent away from the silicone superstrate and welded to the surface of the titanium enclosure. This fulfills the requirement of providing a shorting connection without drilling through the hermetically sealed titanium enclosure. The completed antenna was then bonded to the titanium enclosure using a silicone adhesive.

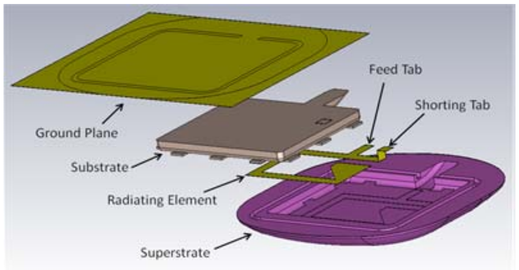

Figure 1 – Antenna Assembly

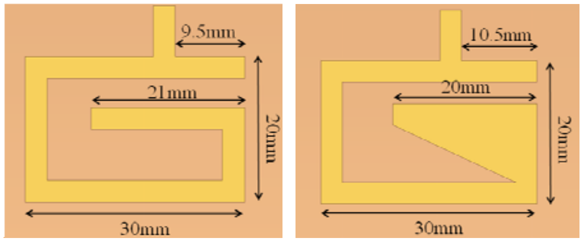

Figure 2 – Spiral Antenna Design

Figure 3 Prototype antenna

978-1-4673-5317-5/13/$31.00 ©2013 IEEE

Prototype antennas were simulated and tested inside a cylinder filled with phosphate buffered blood bank saline solution with PH 7.0-7.2 in order to emulate the conductive properties of the body. The diameter of the cylinder was 10cm and the height 11cm.

TABLE I. MATERIAL PROPERTIES

Description	***Material***	***Loss Tangent tan δ***	***Dielectric Constant ε_r***	***Conductivity σ (in S/m)***
Ground Plane	Titanium	NA	1	2.38×10^6
Substrate	Epotek 301 Epoxy	NA	3.5	7.81×10^{-12}
Spiral	Titanium	NA	1	2.38×10^6
Superstrate	Silicone, P.N. MED16-6606	0.0025	3.1	NA
Surrounding Media	Phosphate Buffered Blood Bank Saline Solution	NA	77.5	1.83

III.RESULTS

The effect of various antenna design parameters have already been well studied in [2]-[4]. Basically, increasing the length of the antenna decreases its resonant frequency, increasing the substrate thickness also decreases its resonant frequency. Manufacturing capabilities that can impact design choices include tolerance on the dimensions of the radiating element, substrate, and superstrate. The metal used to make the radiating element and can and the type/location/precision of the grounding pin are also key elements in the manufacturing process. We also considered the shape of the radiating element for ease of (by-hand) prototyping. Of these dimensions, the dimensions of the spiral were the most important and difficult to control. Given that the antenna is so small, minor changes in each leg of the spiral can add up to shift the desired resonant frequency.

A. Choice of Metal

The metal radiating element requires high conductivity and long term biocompatibility. Four different types of metal sheet (titanium, iridium, platinum-iridium 90/10 and 80/20) were tested. No significant difference on antenna performance was found, so titanium was chosen for its lower cost and ease of manufacturing.

B. Effect of Spiral Shape

The spiral radiating element can be easily and accurately cut using laser cutting, so the designs in [3][4] are fine for that type of manufacturing. For individual prototypes however, this method is expensive and involves delays. To provide a cost effective option, the antenna was redesigned with the inside leg of the spiral cut at a diagonal, as shown in Figure 1. The diagonally cut antenna had shorter overall length L, but the right angle cut antenna was less affected by changes (manufacturing tolerances) in length.

C. Optimal Shorting Tab Shape and Location

The shorting connection of planar antennas is typically provided by drilling a hole through the ground plane and radiating element and soldering a pin between the two. [3][4] This breaks the hermetic seal on the can. Instead, we used a shorting tab rather than a shorting pin and fed the antenna from the top (where the header feedthroughs of the medical device allow easy access without breaking the seal). The shorting tab can easily be provided as an extension of the spiral, and it was welded to the can.

The antenna in Figures 2 and 3 resonates at 410MHz. The S_{11} parameters over the MICS frequency range are from -12dB at 402MHz to -14dB at 405MHz. The measured antenna pattern also closely resembles simulated results.

REFERENCES

[1]A.Kiourti, K.S.Nikita, "A Review of Implantable Patch Antennas for Biomedical Telemetry: Challenges and Solutions [Wireless Corner]," *Antennas and Propagation Magazine, IEEE* , vol.54, no.3, pp.210-228, June 2012

[2]C. Furse, R. Mohan, A.Jakayar, S. Kharidehal, B.McCleod, S.Going,L.Griffiths, P.Soontornpipit, D. Flamm, J.Bailey, I.Budiman , M.Hullinger, “A Biocompatible Antenna for Communication with Implantable Medical Devices,” IEEE Antennas and Propagation International Symposium, June 16-21, 2002, San Antonio, TX

[3]P. Soontornpipit, C.M. Furse, Y.C. Chung , “Design of Implantable Microstrip Antenna for Communication with Medical Implants,” Special Issue of *IEEE Transactions on Microwave Theory and Techniques* on Medical Applications and Biological Effects of RF/Microwaves , Vol. 52, No. 8 Part 2, Aug. 2004, pp. 1944-1951

[4]J. Kim,Y.Rahmat-Samii, “Implanted Antennas Inside a Human Body: Simulations, Designs, and Characterizations,” *IEEE Transactions on Microwave Theory and Techniques*, **52**,8, August 2004, pp. 1934-1943

[5]Medical Implant Communications Service (MICS) Federal Register, “Rules and Regulations,” vol. 64, no. 240 (Dec. 1999): 69926-69934.

[6]“FCC guidelines for evaluating the environmental effects of radio frequency radiation,” FCC, WashDC, 1996.