

UNIVERSITY OF CALIFORNIA

Los Angeles

**Implanted Antennas for Medical Wireless Communications:
Characterizations, Designs and Performance Evaluations**

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy
in Electrical Engineering

by

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2005

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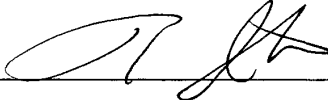
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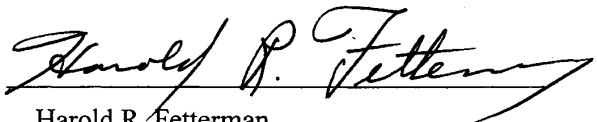
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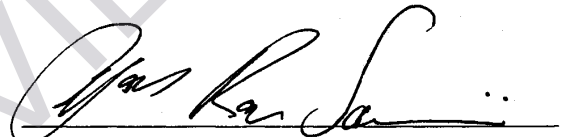
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ABSTRACT OF THE DISSERTATION

Implanted Antennas for Medical Wireless Communications: Characterizations, Designs and Performance Evaluations

by

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This research mainly focuses on antennas for implantable medical devices in a human body and subsequently includes topics related to exterior telemetry links.

Antennas inside/outside a human body are applicable to hyperthermia and telemetry. To make practical use of antennas for the medical applications, resonance characteristics of the antennas and their radiation signature outside the body are evaluated throughout this research. Most importantly, the antennas are designed with an in-depth consideration given to its surrounding environment. The spherical dyadic Green's function and finite difference time domain (FDTD) codes are applied to analyze the

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electromagnetic characteristics of dipole antennas and low profile patch antennas inside/outside a human body.

Low-profile antennas with superstrate dielectric layers are initially designed for medical devices implanted in the chest of the human body using the FDTD simulations and measured in tissue-simulating fluid. The performances of the designed low-profile antennas are estimated in terms of radiation patterns, radiation efficiency, and specific absorption rate (SAR). Maximum available power calculated to characterize the performance of a communication link between the designed antennas and an exterior antenna show how sensitive receivers are required to build a reliable telemetry link.

By applying planar inverted F antenna (PIFA) structures, meandered-shaped and spiral-shaped implanted antennas are developed on an implantable medical device. The radiation characteristic comparison between two different shaped antennas shows spiral radiator is more appropriate for wireless telemetry links. For parametric studies related to implanted antennas, it is evaluated how much the radiation performances of the implanted antenna are affected by the skin's thickness and the antenna's location.

Electrical characteristics of an electromagnetic bandgap (EBG) structure embedded in dielectric layers are studied to design low-profile loop antennas for exterior wireless links. For diversity applications, dipole and loop radiators are incorporated. The simulated and experimental results show embedded EBG structures are applicable for the low-profile antenna design. To improve the diversity performance of the low-profile dipole/loop (dual) antenna, parasitic elements are introduced in the configuration of the dual antenna.

Chapter 1

Introduction

The demand to utilize radio frequency antennas inside/outside a human body has risen for biomedical applications [1], [2], [3]. Most of the research on antennas for medical applications has focused on producing hyperthermia for medical treatments and monitoring various physiological parameters [1]. Antennas used to elevate the temperature of cancer tissues are located inside or outside of the patient's body, and the shapes of antennas used depend on their locations. For instance, waveguide or low-profile antennas are externally positioned, and monopole or dipole antennas transformed from a coaxial cable are designed for internal use [1]. In addition to medical therapy and diagnosis, telecommunications are regarded as important functions for implantable medical devices (pacemakers, defibrillators, etc.) which need to transmit diagnostic information [3]. In contrast to a number of research accomplishments related to hyperthermia, work on antennas used to build the communication links between implanted devices and exterior instrument for biotelemetry are not widely reported.

It is widely recognized that modern wireless technology will play an important role in making telemedicine possible. In not a distant future, remote health-care monitoring will be a feasible treatment for patients who have chronic disease (Parkinson or Alzheimer) by help of the wireless networks [4]. To achieve the required communication links for biomedical devices (wireless electrocardiograph, pacemaker), radio frequency

antennas which are placed at the inside/outside of a human body need to be electromagnetically characterized through numerical and experimental processes.

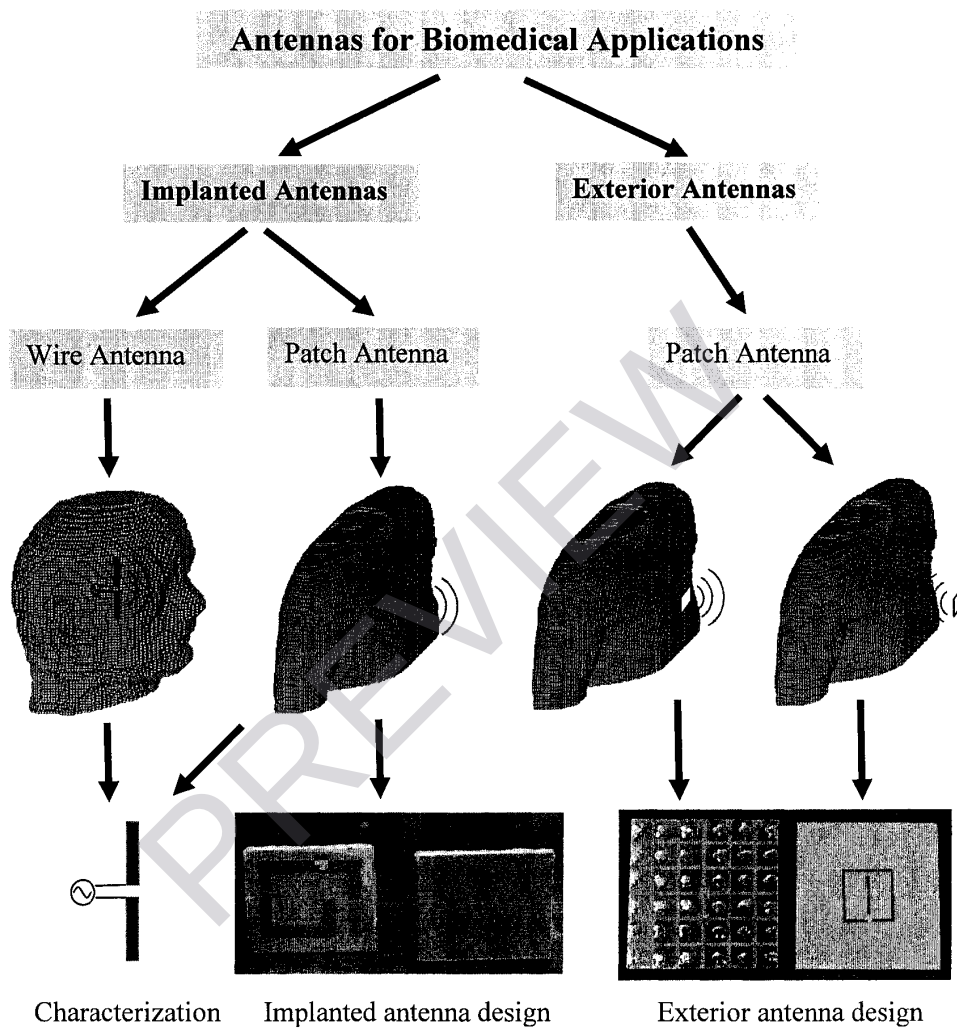


Figure 1-1 Flowchart outlining the research in this dissertation for biomedically applicable antennas inside/outside a human body.

Figure 1-1 introduces the research covered in this dissertation to characterize and design implanted and exterior antennas for biomedical applications. In the area of implanted antennas, the characteristics of wire antennas in a human body are estimated and low-profile antennas in a human body are designed and studied. In the area of exterior antennas, electromagnetic bandgap (EBG)-backed antennas are designed for telemetry communication links.

1.1 Implanted Antennas

Figure 1-2 shows the schematic diagram of the research activities for implanted antennas inside a human body. For hyperthermia and biotelemetry applications, antennas are located inside a human head and a human body and are characterized using two different numerical methodologies (spherical dyadic Green's function (DGF) and finite difference time domain (FDTD)). If an antenna is positioned in a human head, the characteristic data for the antenna is obtained using spherical DGF expansions because the human head can be simplified as a lossy multilayered sphere. This simplification provides useful capability to perform parametric studies. Numerical methodologies (spherical DGF and FDTD) are implemented to characterize antennas inside a human head/body and to design implanted low-profile antennas for biotelemetry.

For communication link applications, implanted antennas are assumed to mainly operate in the frequency band 402 - 405 MHz which is recommended by the European Radiocommunications Committee (ERC) for ultra low power active medical implants [5].