A History & Future of Implantable Antennas

Cynthia M. Furse, Andrew Chrysler
Electrical and Computer Engineering
University of Utah
Salt Lake City, Utah USA
cfurse@ece.utah.edu

***Abstract*—Implantable antennas have been used for communication with medical implants for decades. This paper traces their roots from early transcutaneous inductively coupled devices to the microstrip and wire antennas in use today. A suggestion for where this technology may go in the future as medical devices shrink is also given.**

I. Introduction

Implantable antennas have been used for communication with medical implants for decades. Since then, wireless medical telemetry systems and their associated implantable antennas have expanded rapidly. Implantable medical devices now touch virtually every major function in the human body. Cardiac pacemakers and defibrillators [1], neural recording and stimulation devices,[2] cochlear [3] and retinal [4] implants are just a few of the many implantable medical devices available today. Wireless telemetry for these devices is necessary to monitor battery level and device health, upload reprogramming for device function, and download data for patient monitoring.

Emerging medical telemetry devices have led to recent advances in the design of small, biocompatible antennas that can be implanted in the human body. This paper will track the types of antennas seen in the past, the technologies that enabled these changes, and prospects for future implantable antennas for medical applications.

II. Implantable Antenna Design Challenges

Antennas are critical elements in all communication systems. They are typically one of the largest system components, causing real estate challenges for any miniaturized communication and power transfer system. Antennas are inevitably one of the largest if not the largest component of the telemetry communication system and are generally mounted on or in the implanted battery pack, usually in a body cavity. This limited real estate significantly constrains the performance of implantable antennas. Typical battery packs today for cardiac devices are under 4cm long [5] and new devices for neural recording and stimulation are under 4mm in size. [2] Half wave antennas in the MedRadio band (402-405MHz) [5]-[8] are 36 cm in air and 6cm plus in the body. In addition, implantation in the body cavity means the antennas have to transmit several cm through multiple layers of body tissues, where significant power is lost. Lost power means lost distance and lost battery life.

Designing antennas for medical implants is particularly challenging because (1) Significant power is lost (deposited) in body tissues. This reduces antenna efficiency, plus power deposition is limited by RF safety regulations [8]-[12] (2) The antenna size is constrained by the size of the battery pack, which is shrinking.[5][13] For example, the Utah Electrode Array, is used for cochlear and optical implants, treatment of depression and Parkinson's disease, and eventually perhaps to repair the spinal cord and other neural injuries. Current designs use inductive coupling, but longer ranges and higher data rates are desired.; (3) Implantable antennas are easily de-tuned by variation in body size, shape, composition, electrical properties, placement, etc. [14] [15]

III. Implantable Antenna Designs

Today's implantable antennas include various shapes of microstrip patch antennas [4], [16]-[21],[30] dipoles or monopoles [22]-[23], inductive coils[24]-[29], and genetic algorithm (GA) designs [19].The battery pack serves as the ground plane for many designs. For smaller implants, a microstrip patch antenna has been successfully used for a retinal prosthesis [35], and a small dipole has been designed for communication with a brain implant. [33]

An insulated wire antenna has also been used, and this wire may be used as the lead between the heart and the battery pack/controls of the pacemaker. [31] The antenna can be treated as a waveguide, where the lossy body acts as the outer conductor of the waveguide. The insulated antenna in matter may be matched with a load resistor connected to the conducting medium in order to reduce or eliminate the reflection. Another type of antenna used for communication with cardiac devices is the circumference antenna, which is a monopole antenna that is mounted around the edge of the pacemaker case. [32]

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