Optimization of Wearable Sensors for Body Area Networks

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***Abstract* — Continuous monitoring of wireless recording modules is a major consideration in body area network applications. In this work, a wireless recording module was optimized for the autonomous, real time monitoring of the neurotransmitter l-glutamate. Inductive coupling transmitter antennas were used to wirelessly power the module. The effect of receiver antenna lateral and angular misalignment on wireless recorder performance was determined. The effective coverage of an inductive coupling antenna was determined for a range of angular misalignments and distances from the transmitter antenna.**

I. INTRODUCTION

An important consideration of body area networks (BANs) is long term, autonomous monitoring of patient health. Front end recording systems are used to transmit data wirelessly to a base station, increasing the power consumption of wearable sensors. Minimization of power consumption is an ongoing challenge in the design of wearable devices. Wireless power transfer (WPT) is a favorable alternative to frequent battery replacements in wearable devices because it offers the possibility of long term operation of the device without user intervention. Implantable devices such as cardiac implants and pacemakers have been studied extensively [1]. However, these systems were designed with small relative displacements of the transmitter and receiver antennas in mind.

In this work, a wearable wireless module was designed for in vivo l-glutamate concentration recordings with randomly varying relative distance between the transmitter and receiver antennas [2]. The effects of lateral and angular misalignments on the load voltage was measured. The recording system used a power management module to enable operation with low power consumption. The effective coverage of the transmitter antenna was found for a range of angular misalignments and distances from the transmitter antenna.

II. METHODS AND PROCEDURES

A. Wireless Recording System

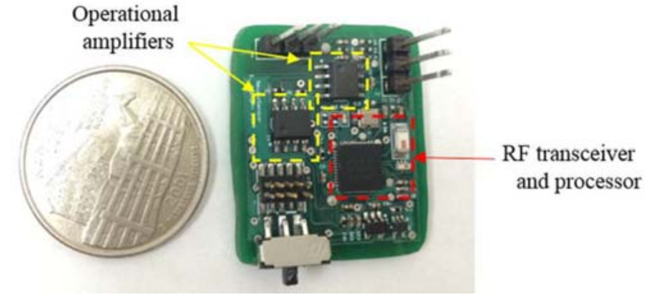

Fig. 1. Photo of the neurotransmitter sensor recording device. The module includes multi-stage amplifiers and a system-on-chip processor with integrated transceiver.

The recording system connected to the l-glutamate sensor included sensor driven circuitry, signal processing modules and an RF transceiver, described in [3]. Briefly, buffer circuitry generated a constant reference voltage of 0.7 V. A reference electrode was held at -0.7 V compared to a working (WE) and self-reference (SRE) electrode. Electrical currents of the electrodes were amplified and transimpedance amplifiers converted the readings to voltage signals. The signal difference between the WE and SRE was further amplified through a low-noise, high-gain instrumentation amplifier. A system-on-chip (SoC) processor digitized voltage signals of the cascade amplifier system and transmitted these values to the base station. Figure 1 shows a photo of the neurotransmitter sensor beside a quarter for size comparison.

B. Wireless Power Transmission

The recording system was designed for operation via wireless power transfer. At the transmitter antenna, an external power supply was used to drive a Class-E amplifier to convert a DC source into RF energy. The energy was transmitted through a spiral antenna. The transmitter and receiver antenna parameters are provided in Table I. The receiver inductively coupled with the transmitter at the same resonant frequency to harvest RF energy. The harvested energy was converted to DC power using a rectifier, and supplied to the neurotransmitter

TABLE I
ANTENNA INFORMATION

Parameters	Transmitter	Receiver
Inner radius (cm)	7	1.6
Outer radius (cm)	20	-
Turn number	20	60
Turn spacing (cm)	0.65	-
Inductance (μH)	142.3	239.3
Resistance (Ω)	20.5	212.2
Quality factor	56	8.3

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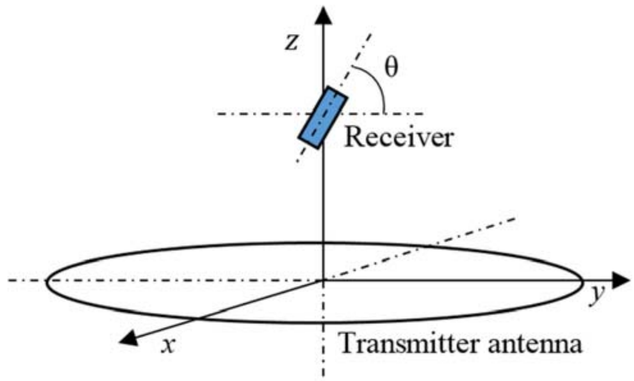

Fig. 2. Angular misalignment between transmitter and receiver antennas. Angle θ indicates the rotation along the x-axis.

sensor module. The energy was temporarily stored using a super capacitor. Since the recording module was worn by a freely-moving animal, the distance between the transmitter and receiver changed constantly and randomly during experiments. The harvested energy thus was affected by lateral and angular antenna misalignment.

III. RESULTS

A reliable and sufficient power supply is required in this design. However, the power transferred is sensitive to orientation and relative distance of the transmitter and receiver antennas. For this reason, the magnetic field distribution generated by the transmitter antenna was simulated using MATLAB software assuming a uniform current distribution in the transmitter coil. For a transmitter antenna much larger than the receiver antenna, the normal magnetic field component was found to contribute most to the harvested energy. The strongest normal field component was found at the center of the spiral antenna [4].

Angular misalignment between the transmitter and receiver is illustrated in Figure 2. The misalignment was made by rotating the antenna along the x-axis and forming an angle θ with the y-axis. Experiments were repeated by moving the receiver antenna along the x- and y- directions in 4 cm increments with the same angular misalignments θ. Figure 3 shows measured load voltages for a receiver antenna at a misalignment angle of θ = 90°.

The effective coverage of the transmitter antenna was defined as the ratio of area in which the load voltage was sufficient to operate the wireless recording module to the area of a 40 cm × 40 cm square box centered over the spiral antenna. The effective coverage at distances of 4 cm, 7 cm, and 10 cm at four misalignment angles is provided in Table II.

IV. CONCLUSION

TABLE II
EFFECTIVE COVERAGE

Angular Misalignment θ	Z= 4 cm	Z= 7 cm	Z=10 cm
0°	54.5%	56.2%	55.3%
30°	63.6%	54.1%	54.1%
60°	73.9%	52.1%	45.8%
90°	78.1%	63.6%	46.3%

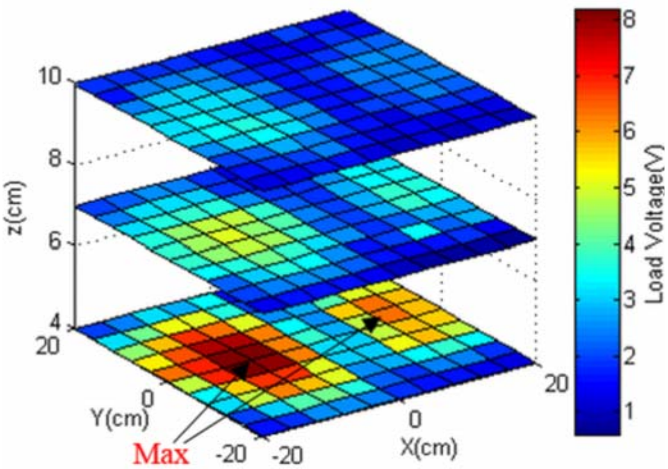

Fig. 3. Measured load voltages at distances z=4, 7, 10 cm with a misalignment angle of θ = 90°. Regions of maximum measured load voltage are indicated.

We have designed and demonstrated a wirelessly powered sensor recording system. The simulated and measured electromagnetic field distributions were similar. The neurotransmitter sensing module was operated successfully with the wireless power transfer system, demonstrating the feasibility of autonomously operated body area network sensors.

Impact of the MTT-S Pre-Graduate Award:

Receiving the MTT-S pre-graduate scholarship has encouraged me to expand my knowledge in the field of wearable device optimization. In the future I plan to attend graduate school at The University of Texas at Arlington.

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