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Design of bio-implantable acoustic power transmitter using comsol 3. 5

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ABSTRACT

Acoustic power transmi-tter was introduced using comsol multiphysics. They can provide electronic energy to other implanted devices by receiving an external acoustic wave generated from the skin surface of the subcutaneous tissue. Piezoelectric ceramics make the internal devices of the receiver, and they are directly charged, converting pressure into an extractable electrical energy. Moreover, the less weight material such as aluminium is used to design the internal devices. Additionally, the designs of transducer which can efficiently absorb the generated charges were also designed using comsol. The actuator which can efficiently generate the required acoustic waves are analysed. The shear bender model generates the required acoustic waves, they were used here to generate the required charges .The material properties for different elements were chosen to maximize the output power .The output power developed is analysed for the different tissue properties such as fatty tissue or muscular tissue .The charge developed is maximum at the top surface of transducer which are easy to extract it to other devices.

Introduction

The application of micro system technology to biomedical monitoring is currently being extensively investigat-ed. However, wireless power supplies for implantable biomedical chips remain a large challenge. Much effort has been made to develop miniaturized power generation systems for use in implantable micro devices. Power harvesting and power transmissions are frequently used methods to enable the requirements of recharge and long lifetime to be met. Typical power harvesting devices utilize piezoelectric microstructures that are excited by random environmental vibration to convert mechanical energy to electric power. Biological fuel cells that use oxide glucose to produce electricity can also be considered as power harvesting system with implanted capacity. In comparison, power transmission provides a higher power density than power harvesting.

Electromagnetic and acoustic waves are two typical carriers for delivering energy through the human skin and the human body. Unlike electromagnetic power transmission, acoustic transmission prevents electromagnetic interference in the implanted bioelectrical instrument and is associated with lower power attenuation in the presence of water in the body.

The mechanism of acoustic power transmission differs from those associated with ultrasonic medical imaging. A medical imaging machine sends an ultrasonic wave into the tissue from the skin surface or the buried piezoelectric emitters. It then detects the reflected wave and analyzes the diseases at the skin surface. On the other hand, a power transmission system receives acoustic waves and then converts the received mechanical energy into electricity. For the shallowly implanted medical devices, the earlier works invent the implantable medical designs including piezoelectric devices and the charging battery and provide the optimum resonance frequency of the transmission system.the current design is shown in figure 1. Deeply implanted medical devices suffer from significant amount of noise in received signals due to complex wave scattering effects;conversely, without considering the signal identification, the noise affecting the efficiency of the acoustic power transmission is not as strong.

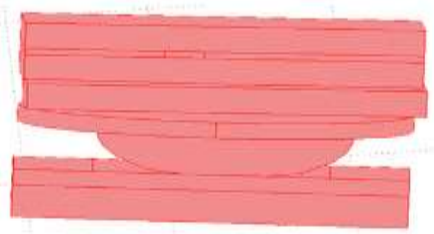

Figure1. Design of the bio-implantable Power transmitter

However, wave attenuation along the travelling path associated with diverse tissue characteristics in subcutaneous layer must be considered. This work uses a low-power acoustic emitter to transmit energy from the surface of the subcutaneous tissue to the implanted miniature devices. It can be used to recharge implanted batteries or to supply energy to specific implanted micro devices such as drug delivery system, which are implanted in tissues where the acoustic attenuation is serious. To realize portable recharges, the emitting system is a piezoelectric shear bender which is triggered by 10V, is inputted to generate acoustic signals. The acoustic power receiver should be fully packaged with biocompatible materials. In the aspect of power transmission, the power generated by the receiver can be always increased by enhancing the acoustic energy. However, the proper packaging design of the system is important in enhancing the power transmission efficiency, which is also important. The proposed receiver is implanted in the subcutaneous tissue. It is based on a micromechanical piezoelectric transducer that is packaged inside the. When a low-power piezoelectric generator emits sinusoidal acoustic waves at the external skin surface, an acoustic field is produced in the subcutaneous tissue. Then, the acoustic wave propagates into the

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package which is biocompatible. It is also sufficiency soft to absorb the incident wave and to conduct the mechanical pressure to the transducer. The transducer consists of a thick piezoelectric film on which an attached aluminium antenna can receive the acoustic energy. The piezoelectric film is sandwiched between the parallel electrodes that extract the polarized charges and, thus, generate electricity. The power transmission efficiency of the proposed device under the applied acoustic fields is examined. The frequency spectrum of the power transmission efficiency is obtained from different tissue layers.

Device Design

Design Concept

The acoustic power receiver is designed to recharge implantable biochips and must satisfy three major requirements. First, the package of the power receiver must be biocompatible. Second, the power receiver must be able to absorb acoustic energy from the muscular environment. Third, the power receiver must be able to effectively transform the acoustic energy into electricity.

The perfectly matched layer is used as the package material to meet the requirement of biocompatibility. Additionally, to satisfy the second requirement as aforementioned, the Young's modulus of the package material must be relatively lower than that of the muscular tissue. Otherwise, most of the acoustic waves would be scattered away from the package-tissue interface due to the increase in the mechanical impedance. Under such circumstances, the power transmission efficiency falls. Notably, the Young's modulus of the muscle depends on the age and the location in the human body. Herein, the Young's modulus is lower than that of the general human tissues and therefore, it can effectively eliminate scattering.The various properties of design were shown in Table 1.

In addition to the Young's modulus, the scattering effects of the package shape must also be considered. The power receiver is packaged within the perfectly matched layer. It has an acoustic antenna receives the refractive waves that propagate through the package, and thus, it excites vibration at its resonance frequency. The antenna is attached to an iron slab and exerts stresses to the iron slab during vibration.The motion of shear bender is shown in Figure.2. Then, the slab stresses the piezoelectric transducer that is underneath, generating electrical charges.

The antenna is an aluminium circular plate, and the design concept follows the ultrasonic transducer, as modelled.

The circular shape corresponds to the spherical package.Thecentre of the plate is slightly layer. It has an acoustic antenna receives the refractive waves that propagate through the package, and thus, it excites vibration at its resonance frequency. The antenna is attached to an iron slab and exerts stresses to the iron slab during vibration.The motion of shear bender is shown in Figure.2. Then, the slab stresses the piezoelectric transducer that is underneath, generating electrical charges.

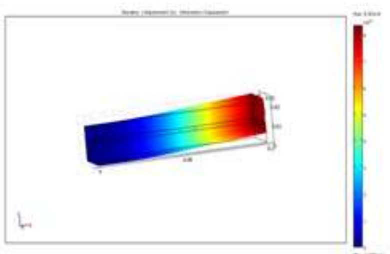

Figure.2 Motion of the actuator to produce acoustic waves whose frequency is 20Hz-20KHz

concave by embossing to mechanically support the antenna on the iron slab. The material of the antenna should be stiff enough to avoid unexpected bends. Aluminium was chosen as the antenna material to reduce weight. To maximize reception of the refracted wave, we locate the antenna in the middle of the spherical package to meet its maximum refractive area.

Numerical Simulation

Finite-element simulations are carried out to validate the design concepts and to improve understanding of the propagation of waves inside packages. The power receiver is buried inside the tissue.

A modal analysis of the power receiver in the absence of a package and surrounding tissues is conducted. The models of the complete packages buried in the fatty and muscular tissues are established. The same frequency. One unit of pressure is applied to the surface of the muscular tissue. Since the dominant frequencies of the muscular tissue are well below that of the internal micro devices, they cannot efficiently trigger the muscular tissue but only the area located inside the packages. The main responding areas in the cubic and spherical packages occur at the top and at the spherical boundary, respectively.

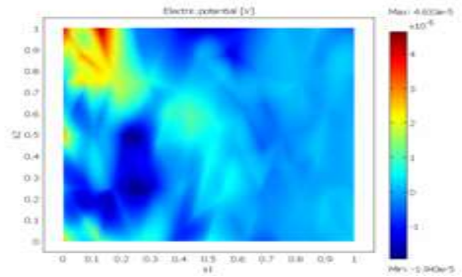

Figure.3 Potential developed in the absence of tissue layer

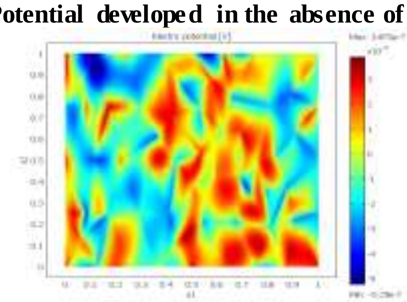

Figure.4 Potential developed in the presence of FATTY tissue

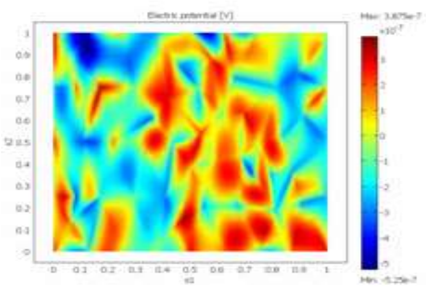

Figure.5 Potential developed in the presence of MUSCULAR tissue

In conclusion, the numerical results reveal the characteristics of the internal micro device with different muscle properties.In the absence of muscle layer potential developed is 46 micro volts as shown in figure 3.In the presence of the muscle layer potential developed is 38 micro volts as shown in Figure 5.

In the presence of fatty layer potential developed is 23 nano volts as shown in figure 4.

Discussion

The efficiency of the implanted device depends on the depth of the device, the acoustic frequency the material properties of the tissues, the emission system, the reflection loss, and the refractive absorbability of the device.

For wave propagation, long travelling path causes serious attenuation. Compared with shallowly implanted devices, such as the cardiac pacemaker, the defibrillator, and the nerve/muscle stimulator, the current device is aimed at the devices used in the intraabdominal space. Because of the serious attenuation, this study also takes shape of package into account to absorb energy.

The power efficiency also depends on the frequency of the travelling waves.Figure.3, shows the potential developed in the absence of tissue. High-frequency waves attenuate quickly, and the triggering frequency has to match up the dominant frequency of the receiver .In this study, the best performance which is the resonant frequency of the internal device is considerd.

The material properties of the subcutaneous tissue are discussed by the types and the stability. For the types of tissues, the transmission efficiency relies on the impedance matching in paths of emitter-to-tissue and tissue-to-package interfaces. For the stability of the experiments, it has been noticed that the material properties of the subcutaneous tissues are unstable. Since organisms, comprising of cells, biological tissues, and organs, are not homogeneous, the interaction of a wave and an organism is more complex than other materials. Additionally, the material properties of the organism may vary with saturation, marbling, pressure, temperature, and time.

An appropriate emission system is considered to improve the transmission efficiency on the tissue surface. Second, intimate contact between the emitter and the tissue surface is required. Acoustic gel, in medicine, is useful for this purpose. In this case, however, the shear bender is seriously adhered onto surfaces by liquid instant glue. Furthermore, the external press- ure on the experimental procedure.

The reflection loss depends on the impedance matching at the paths by the interfaces, such as the emitter and tissue, tissue and package, and package and internal device, as discussed in this section. In addition, the refractive absorbability of energy depends on the shape of the package. In this study, the efficiency of the cubic package is greater than that of the spherical one in a fatty cavity.

In addition to the power efficiency, the recharge duration is considered. The power of the emitter triggered at 35 kHz is 1.23 mw. Under this condition, the receiver in spherical case buried in a single muscular tissue can generate 23 nW power. When considering the battery for the drug delivery system, the power requirement is still uncertain. Although a heart pacemaker is not appropriated here, its required power for the battery is just taken as an example. The required power for the battery is 25 microJ, and it takes 18.1 min to recharge the alkaline battery by using the presented device.

Conclusion

This investigation has proposed an implantable and fully packaged receiver that can receive the acoustic energy and provide electronic power.

The design concept is based on a biocompatible package and optimized to absorb the incident wave. Furthermore, the finite-element method (using comsol) is employed to confirm the dynamical models of the designed packages.

The devices have been designed and have successfully detected acoustic signals. The device is primarily a PZT transducer, which buried in the human tissue. In order to simulate the human muscle test, the effects of the buried transducer in the fatty, muscular, tissues are needed to be considered.

To conclude, for a human with a fatty layer in which receivers cannot be buried deeply, the efficiency will low compared to the efficiency of the power received in muscle layer. The output voltage generated is in micro volts. The pace maker ,cardiac defibrillator,neurological simulator ,drug pumps require the output voltage in this range .Thus the power required for the above devices can be easily obtained from the acoustic power transmission method.

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Table I- Material properties and dimensions

Fatty Tissue	Density	1000[kg/m^3]
	Young's modulus	1.3x10^3[pa]
	Poisson's ratio	0.4
Muscular tissue	Density	1000[kg/m^3]
	Young's modulus	2.62x10^3[pa]
	Poison's ratio	0.4
Aluminium Antenna	Density	2698[kg/m^3]
	Young's modulus	7.0x10^10[pa]
	Poison's ratio	0.33
Iron Slab	Density	7874[kg/m^3]
	Young's modulus	2.0X10^11[pa]
	Poison's ratio	0.25
PZT Ceramic	Density	7500[kg/m^3]
	Young's modulus	6.3x10^10[pa]
	Poison's ratio	0.25
	Frequency constant	2000[Hz-m]