Satu Arra

Acoustic Power Transmission into an Implantable Device

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TAMPERE UNIVERSITY OF TECHNOLOGY

Future Electronics Research Programme (TULE 2003-2006)

"Wireless Physiological Sensors for Ambulatory and Implantable Applications"

Tampere University of Technology
Institute of Electronics
Personal Electronics Group

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Acoustic Power Transmission into an Implantable Device - outline

- Premiss
  - Why Ultrasound?
- Ultrasound properties and generating power with a piezoceramic disc
- Proof of concept equipment and results of test measurements
- Conclusions

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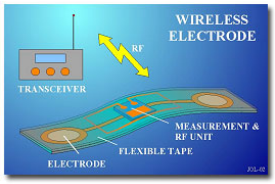
Premiss:



- Implantable electrocardiogram (ECG) measurement platform without batteries
- Uses an inductive link in transmitting power and data
- Minimum power requirements ~3V, 0.9 mA = 2.6 mW without the inductive link's transponder circuit

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Why ultrasound?

- EMC problems:
  - Magnetic field coupling in an inductive link
  - RF disturbance in a radio link
- With ultrasound, power can be transmitted even when strong electromagnetic fields are present
- Ultrasound does not interfere with electronic devices' fields and functions

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Introduction to ultrasound properties

- Attenuation = energy loss due to absorption and scattering
- In tissue ultrasound energy is attenuated according to exponential law:

$$I(x) = I(0)e^{-2\mu x}$$

- Attenuation coefficient (μ) depends on frequency: the higher the frequency, the stronger the attenuation

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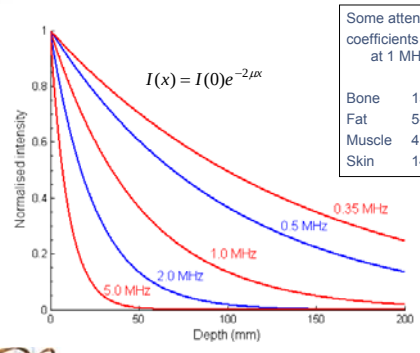
Attenuation of ultrasound in soft tissue.

μ=10 Npm^{-1}MHz^{-1}.

$$I(x) = I(0)e^{-2\mu x}$$



Some attenuation coefficients (Np/m) at 1 MHz

Bone	150-300
Fat	5-9
Muscle	4.4-15
Skin	14-66

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- Part of the ultrasound is reflected on interfaces. Reflection can be minimized by a matching layer:
  - ultrasound gel
  - solid gel pad
  - coating material (e.g. resin) on the transmitter
- The proportion of reflected power can be expressed as

$$R = \left(\frac{Z_1 - Z_2}{Z_1 + Z_2}\right)$$

,where Z is the acoustic impedance

- Air bubbles cause significant losses

Some acoustic impedances (10^6 kg/m^{2}s)

Water	1.48
Air	0.00041
Living skin	1.80
Muscle	1.61 - 2.07
Ultrasonic gel pad	1.60

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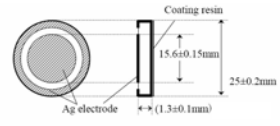
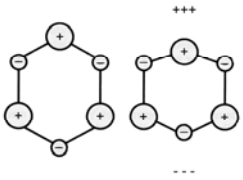
Piezoceramic discs as power generators

- The current implementation uses 1.7 MHz lead zirconate titanate (PZT) discs



- Reverse piezoelectric effect = expansion and compression of piezoceramic crystal lattice due to an applied electric field



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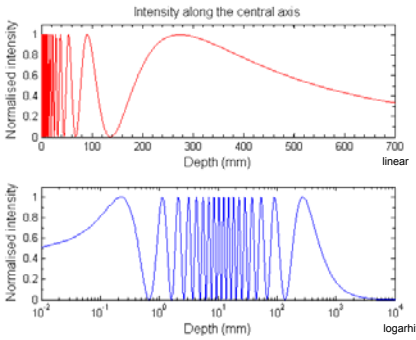
$$I(x) = I(0)\sin^2[(\pi/\lambda)(\sqrt{a^2+x^2}-x)]$$

a = diameter of the transducer



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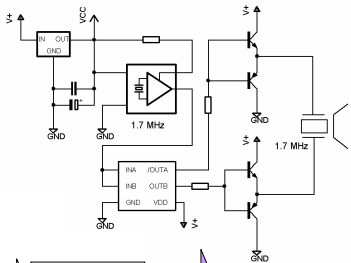
Measurement equipment - the transmitter

Voltage regulation → 1.7 MHz oscillator → Voltage amplification → Current amplification → Ultrasound transmission



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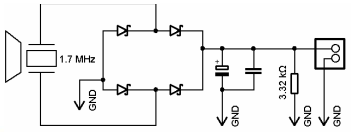
Measurement equipment - the receiver

- 3.32 kΩ corresponds to the implant's current and voltage requirements

Ultrasound reception → Rectifying and leveling the current → Measuring the output



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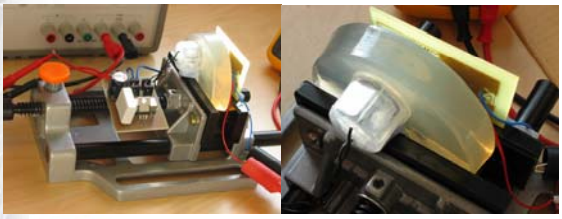
- Interstitial tissue was modelled with an ultrasound gel pad, a chicken leg, a piece of moistened leather or a combination of them
- Ultrasound gel was used on the interfaces



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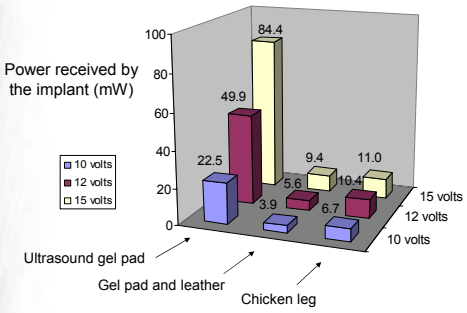
Results



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- 2.6 mW needed
  - minimum total efficiency 0.05 % at a 3 W/cm² acoustical input
- efficiency is affected by
  - attenuation
  - air bubbles and reflection on interfaces
  - distance between the transducers (maximum points)

Average total efficiencies (%)	Gel pad	Gel pad and leather	Chicken leg
	0.95	0.13	**0.20**

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Conclusions

- Ultrasound is applicable
- Further development:
  - slightly focusing transmitter, evenly distributed field
  - temporary energy storage, pulsed ultrasound
  - data transmission?

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Thank You

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