Alimentação remota de circuitos implantados por meio de acoplamento indutivo

Fernando Rangel de Sousa

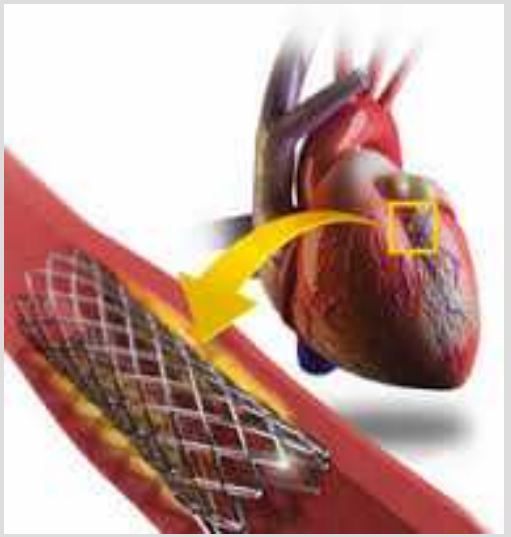
Quem somos

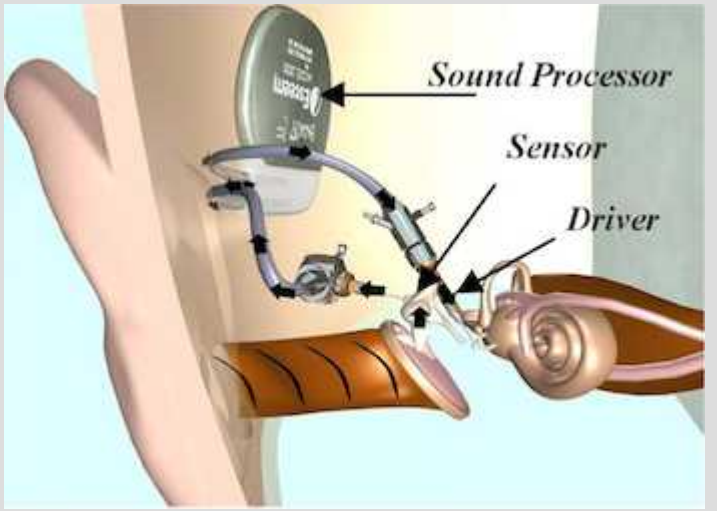
O que fazemos

- Pesquisa em Radiofrequência
- Temas multidisciplinares / transversais
  - Petróleo/gás
  - Zootecnia
  - Biomédica
  - Instrumentação e medição
  - ...
- Ferramentas (meio)
  - Microeletrônica (projetamos chips)
  - Instrumentação (com e sem fio)
  - SDI (Instrumentação + SDR)
  - Simulação eletromagnética
- Medimos o que fazemos

Implantes médicos

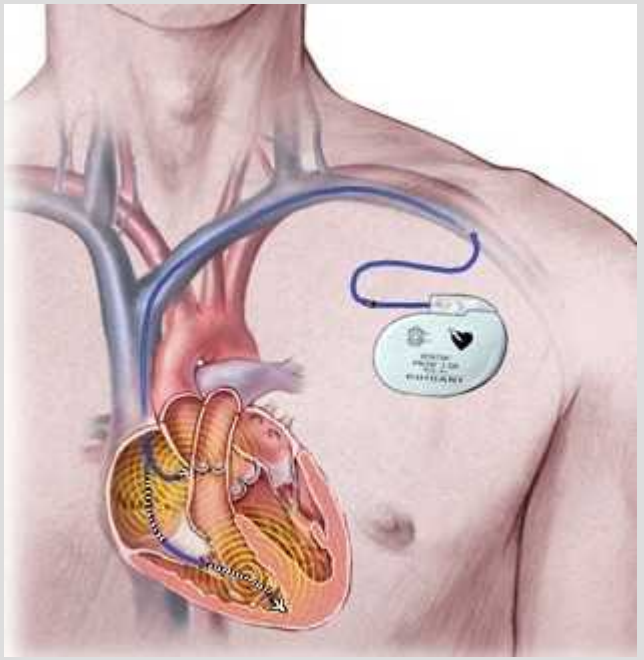
- Um implante pode ser um dispositivo médico desenvolvido para substituir ou dar suporte a uma estrutura biológica danificada, monitorar sinais fisiológicos, prover estímulos, ministrar medicamentos localmente, recuperar funções sensoriais, etc.





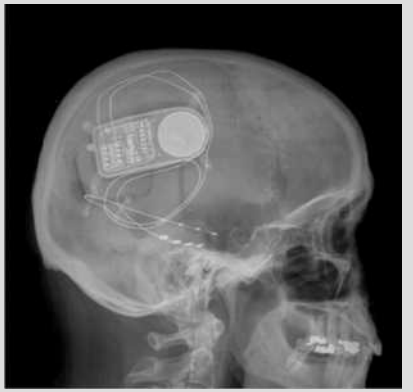
Implantes eletrônicos

- Marcapassos

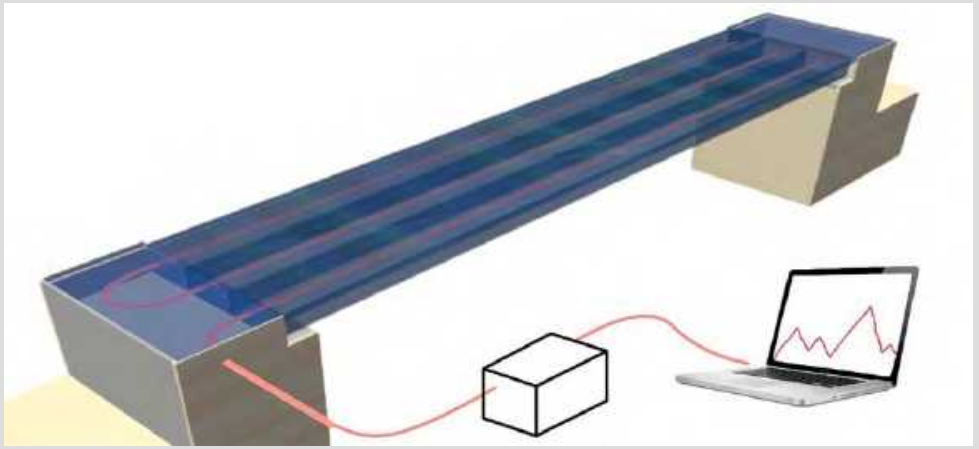


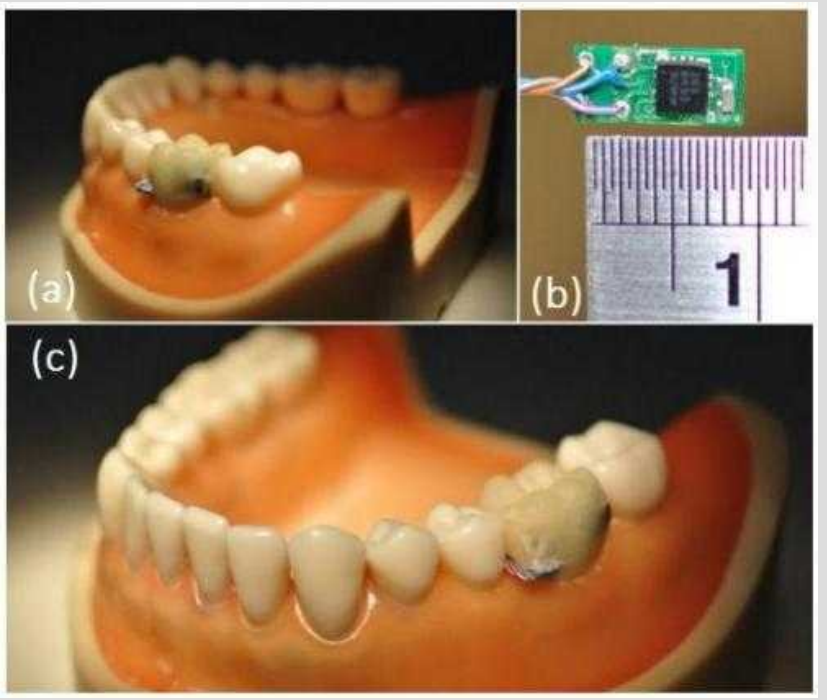
Implantes eletrônicos

- Neuroestimuladores

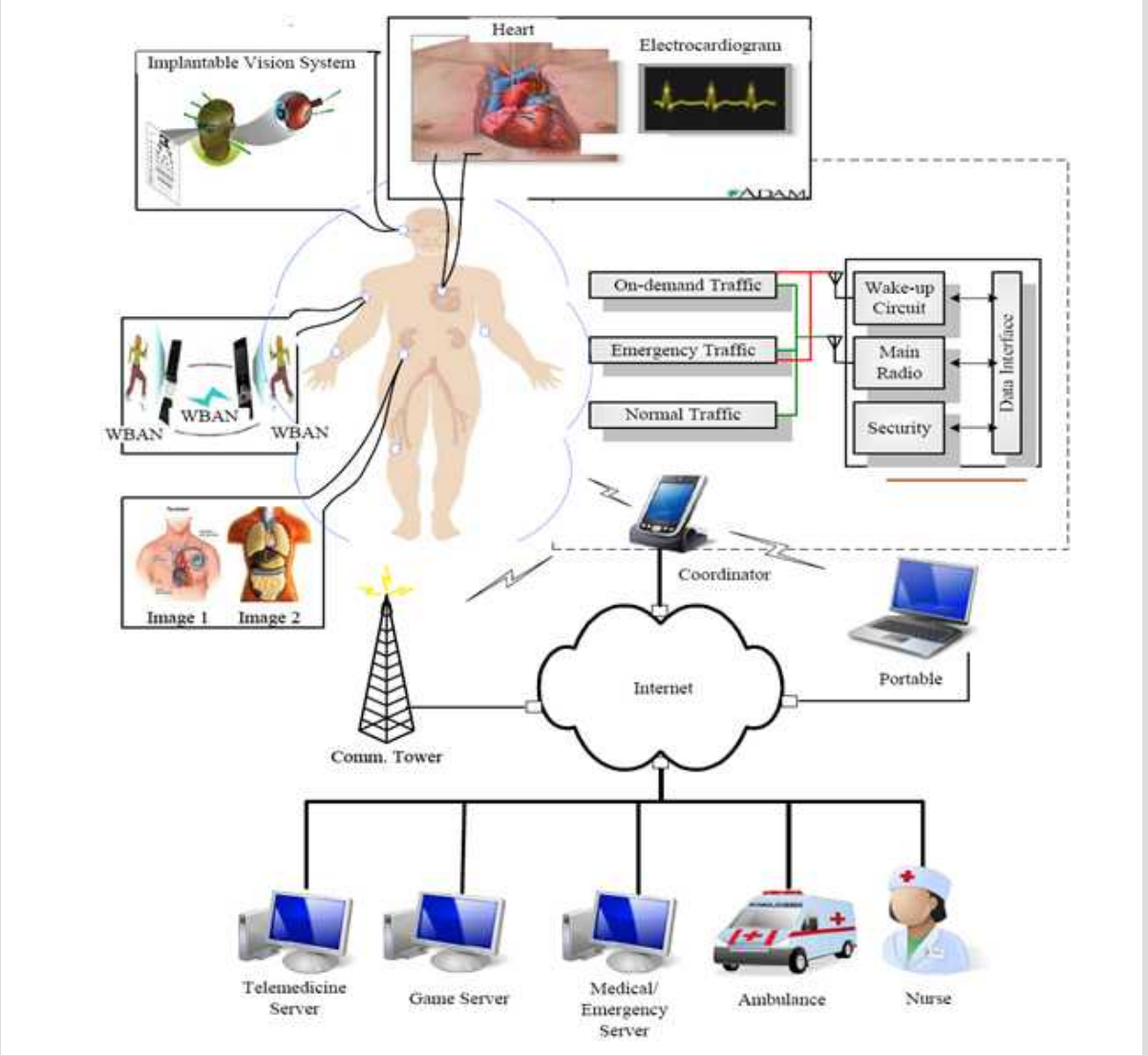


Outros implantes

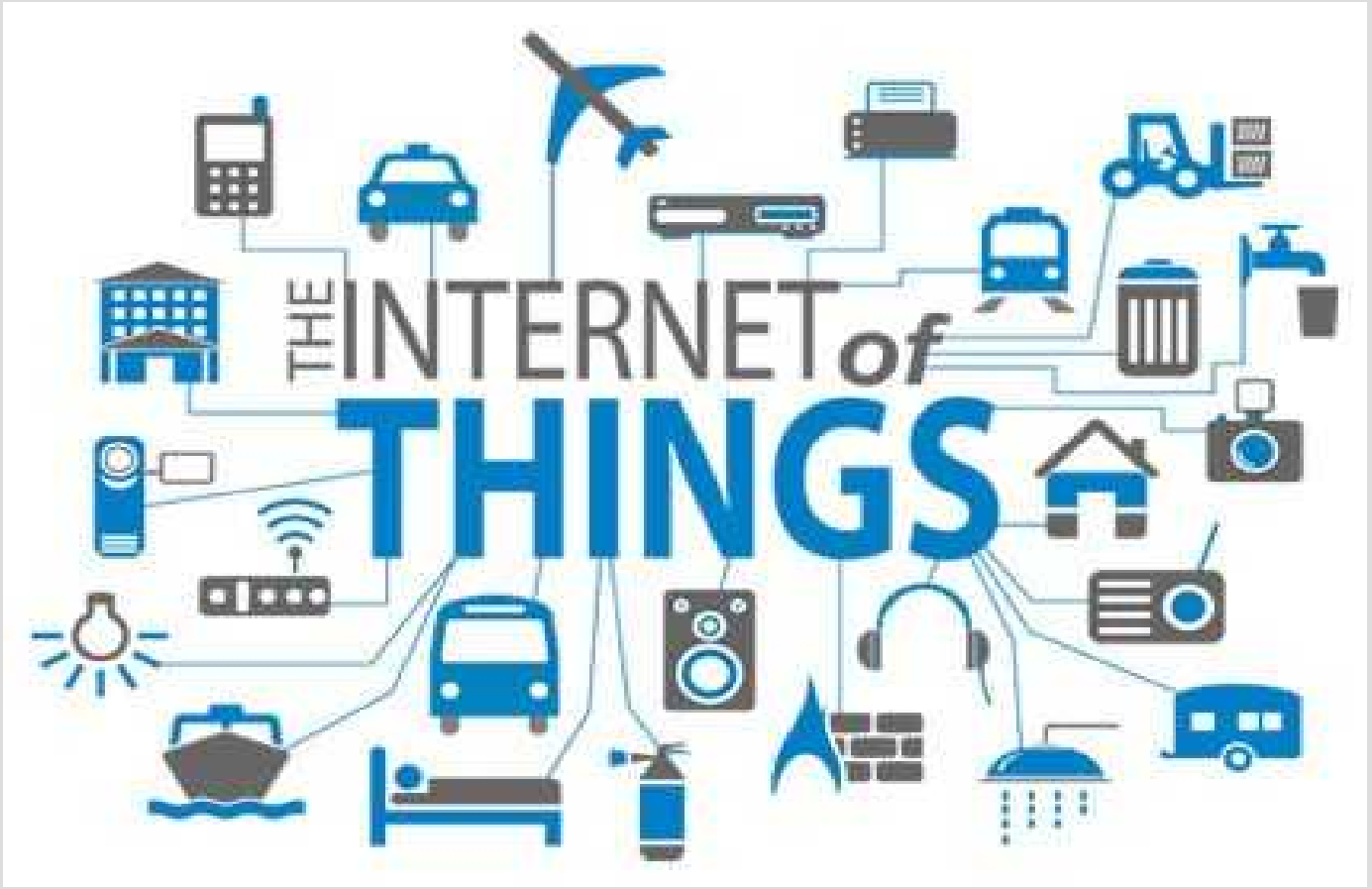




Redes corporais (WBAN)



Internet das Coisas (IoT)

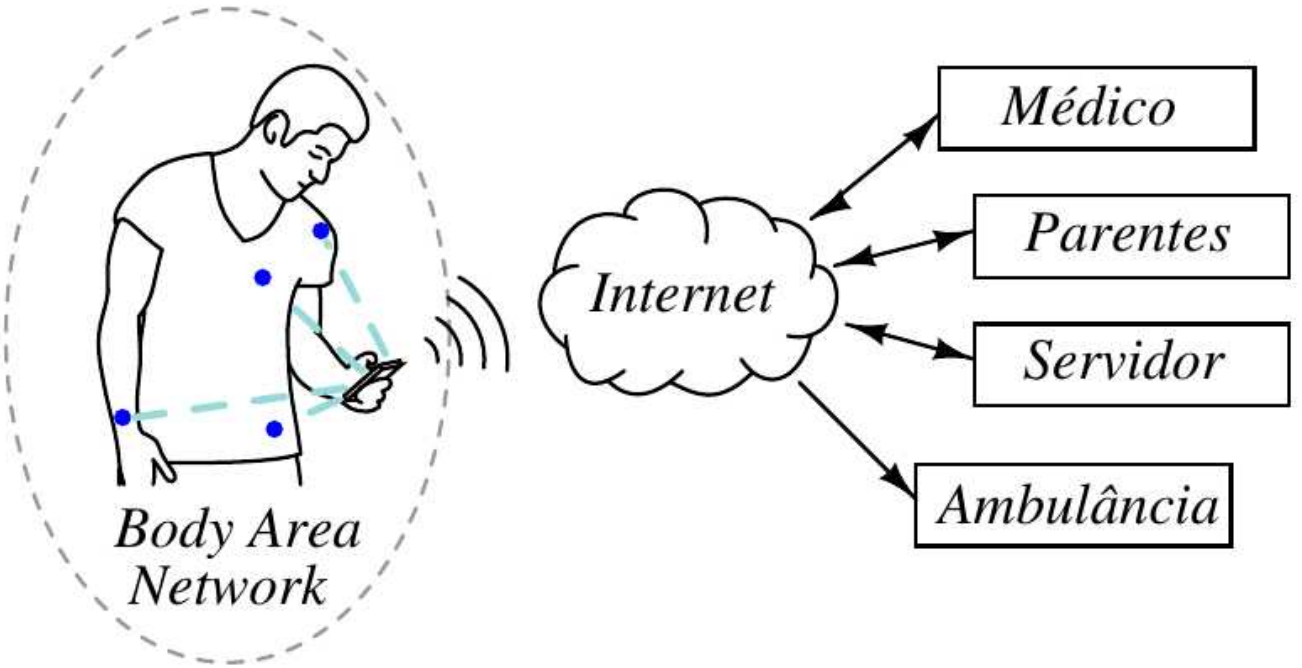


Trilhões de dispositivos conectados

IoT

- *Sensores vestidos ou implantados:*

  – *Temperatura*
  – *Ritmo cardíaco*
  – *Pressão arterial*
  – *Glicose*
  – *Movimento*
  – *Respiração*



Eletrônica Invisível (IoT)

Achieving Optimal Efficiency in Energy Transfer to a CMOS Fully-Integrated Wireless Power Receiver

Fabian L. Cabrera and F. Rangel de Sousa, *Senior Member, IEEE*

IN the near future billions of devices will be interconnected, enabled by the Internet of Things (IoT) [1]. Several applications are envisaged in different domains including transportation, agriculture, smart homes and healthcare [2]. The transition from idea to reality depends on addressing problems which remain unsolved. As stated in the visionary paper by Mark Weiser [3], *"the most profound technologies are those that disappear"*, however, the physical size as well as the cables used to deliver energy to current IoT-enabled devices are not compatible with the ongoing paradigm shift.

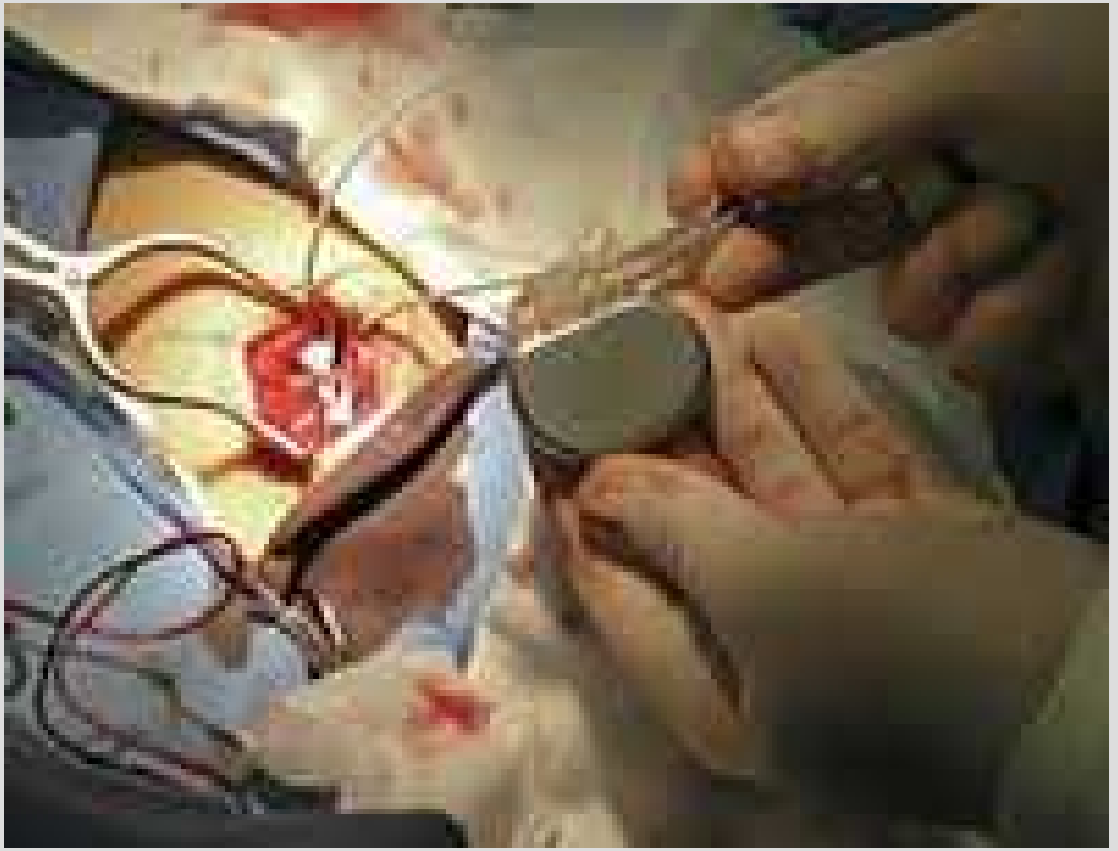
Mark Weiser

Realidade: Eletrônica Visível !

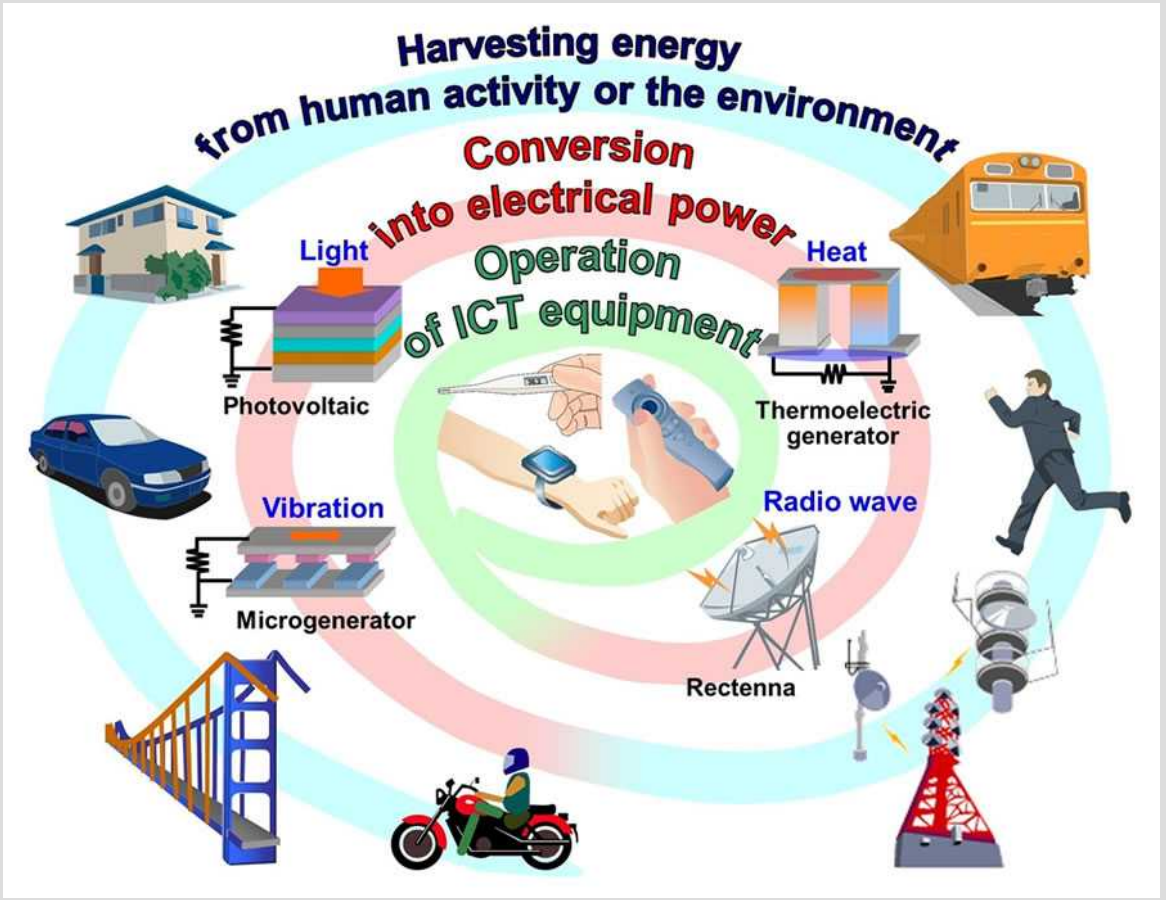
Alimentação de implantes

Baterias

Troca de baterias!



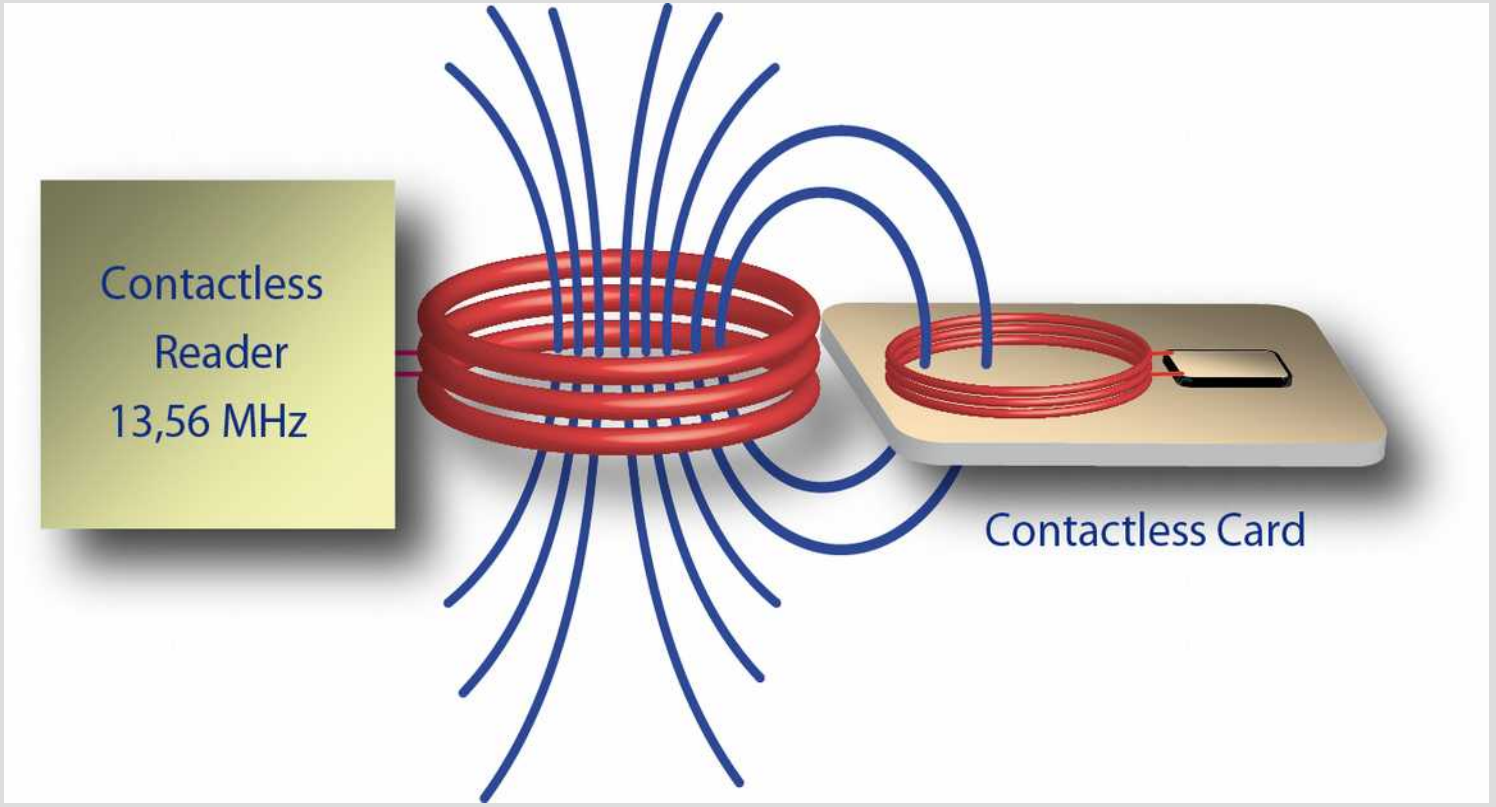
Alternativas: Energy Harvesting



Há diversas formas de energia disponíveis .
O desafio é captá-las com eficiência

Acoplamento indutivo

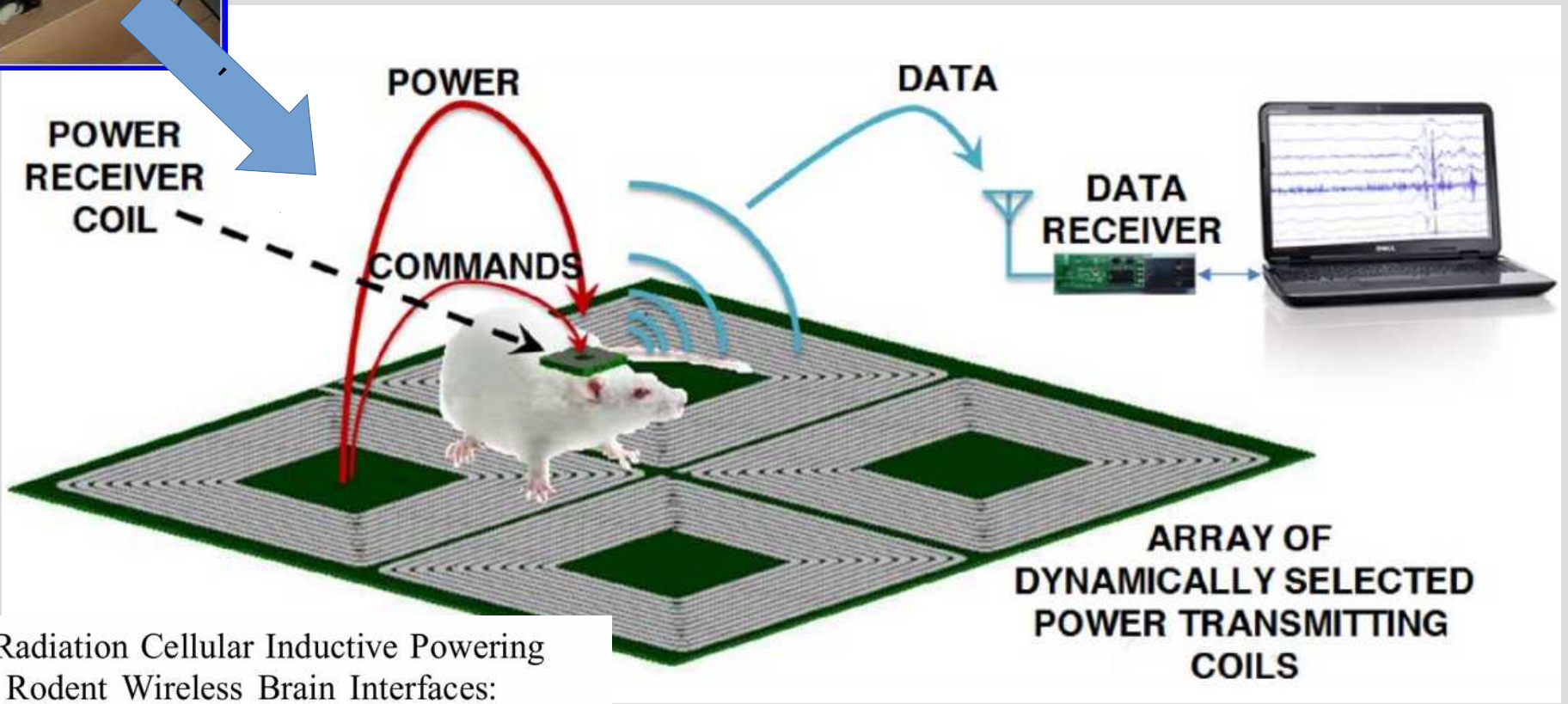
Implementado com sucesso em RFID, smartcards, etc.



Baseia-se no uso de um transformador com núcleo de ar

Acoplamentos indutivos em aplicações biomédicas

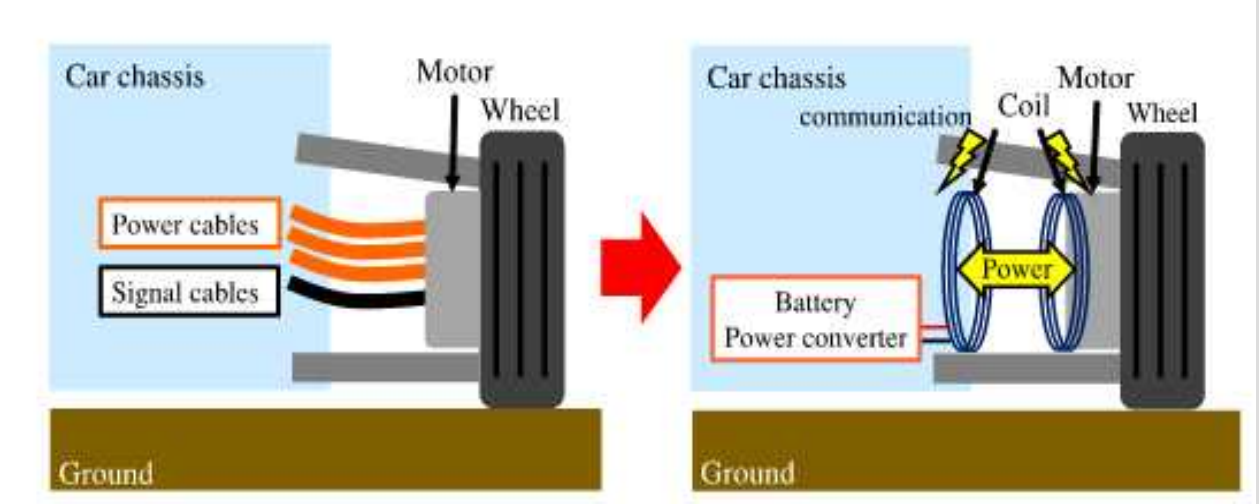
Ao retirar os cabos, permite reduzir interferência em experimentos



Low-Radiation Cellular Inductive Powering of Rodent Wireless Brain Interfaces: Methodology and Design Guide

Nima Soltani, *Student Member, IEEE*, Miaad S. Aliroteh, *Student Member, IEEE*, M. Tariqus Salam, *Member, IEEE*, Jose Luis Perez Velazquez, and Roman Genov, *Senior Member, IEEE*

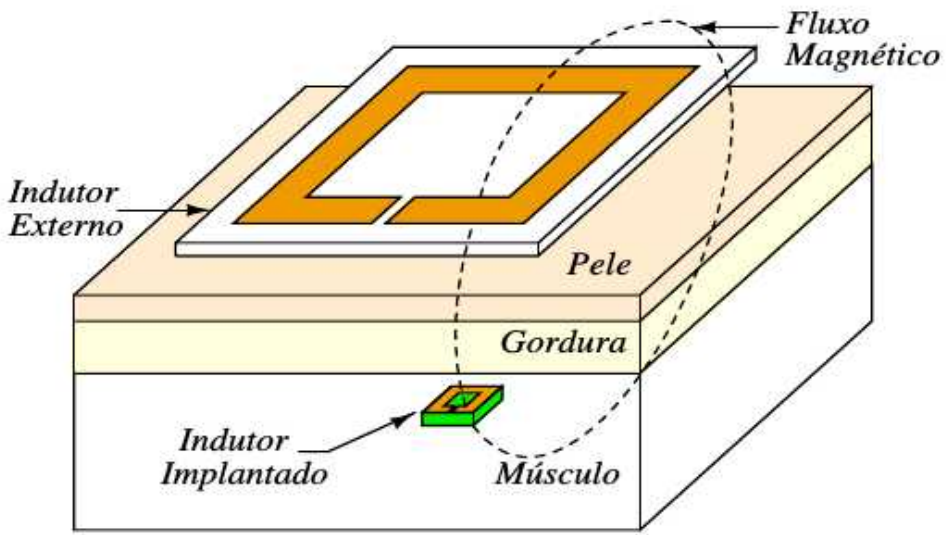
Acoplamentos indutivos em carros elétricos



Development of Wireless In-Wheel Motor Using Magnetic Resonance Coupling

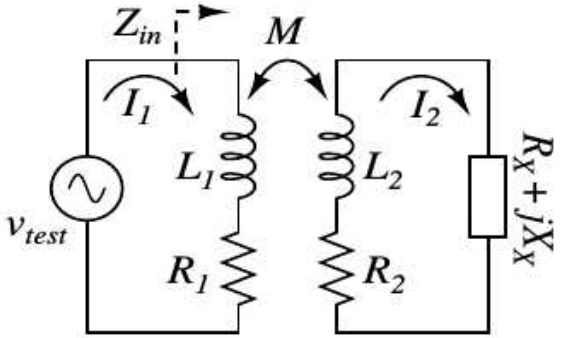
Motoki Sato, *Member, IEEE*, Gaku Yamamoto, Daisuke Gunji, *Member, IEEE*, Takehiro Imura, *Member, IEEE*, and Hiroshi Fujimoto, *Senior Member, IEEE*

Formulação do problema do acoplamento indutivo para implantes



- Máxima potência é limitada pelo aquecimento dos tecidos.
- Eficiência deve ser otimizada.
- O indutor secundário deve ser miniaturizado.
- Restrição na área do primário é mais flexível.

Eficiência na transferência de Energia



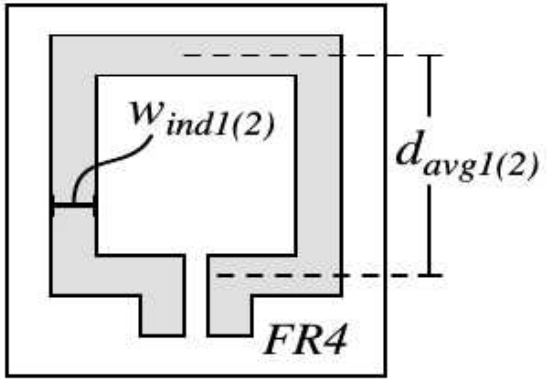
$$M = k\sqrt{L_1 L_2}$$
$$Q_1 = \omega L_1 / R_1$$
$$Q_2 = \omega L_2 / R_2$$
$$p = R_2 / R_X$$

Eficiência

$$\frac{1}{\eta} = \frac{1}{k^2} \cdot \frac{1}{Q_1} \cdot \frac{1}{Q_2} \cdot \underbrace{\left(p + 2 + \frac{1}{p}\right) + p + 1}$$

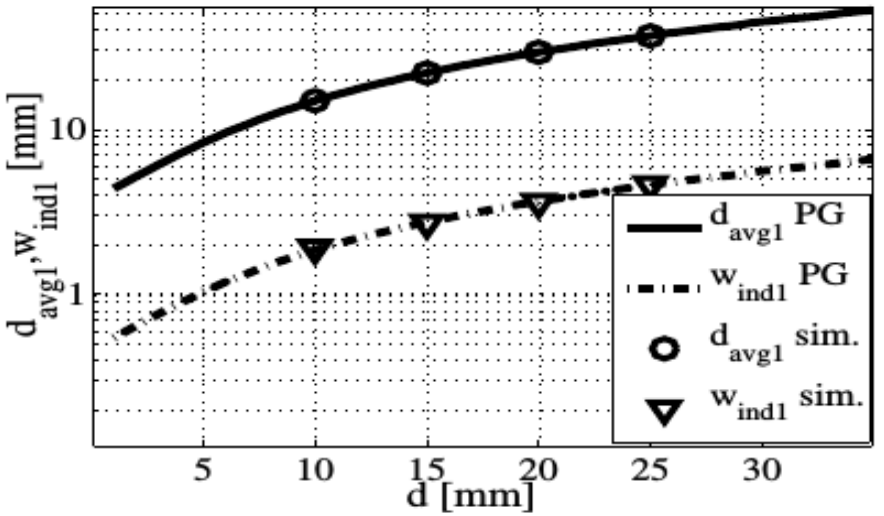
- Fator de acoplamento
- Fator de qualidade 1
- Fator de qualidade 2
- Dependência com a carga

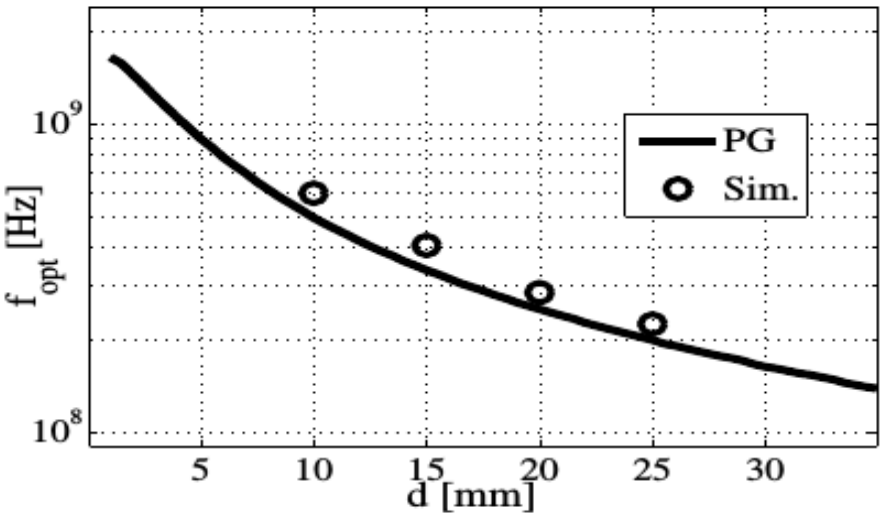
Otimização do indutor

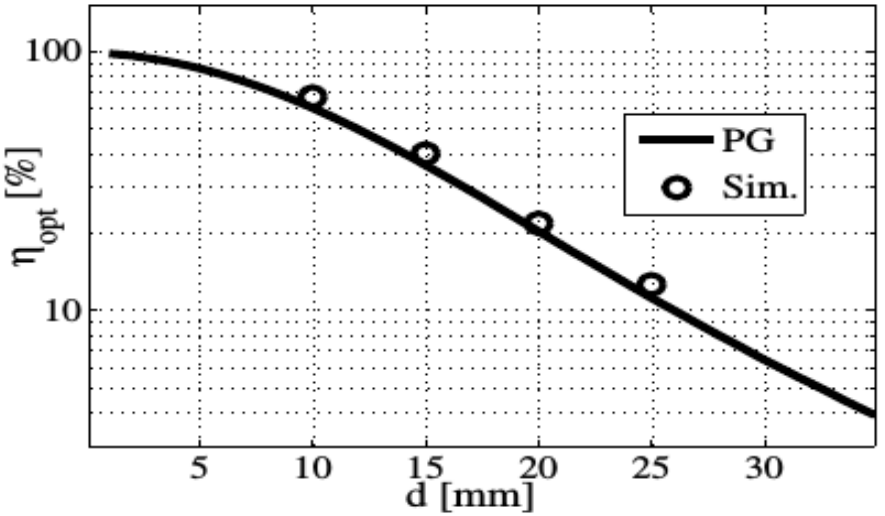


Dados:	O tamanho do indutor implantado	d_{avg2}, w_{ind2}
	A distância entre os indutores	d
Encontrar:	O tamanho do indutor externo	d_{avg1}, w_{ind1}
	A proporção da carga	p
	A frequência	f
Para:	maximizar a eficiência	η

Resultados da otimização

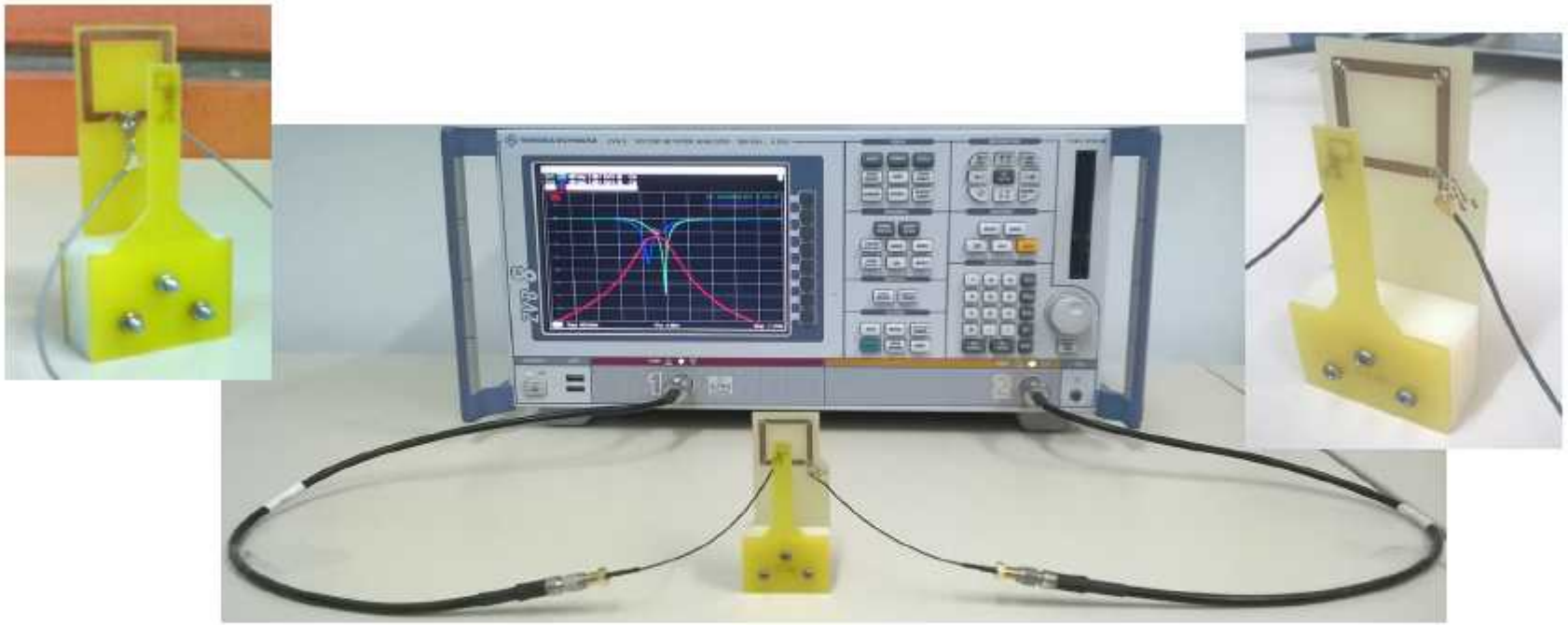






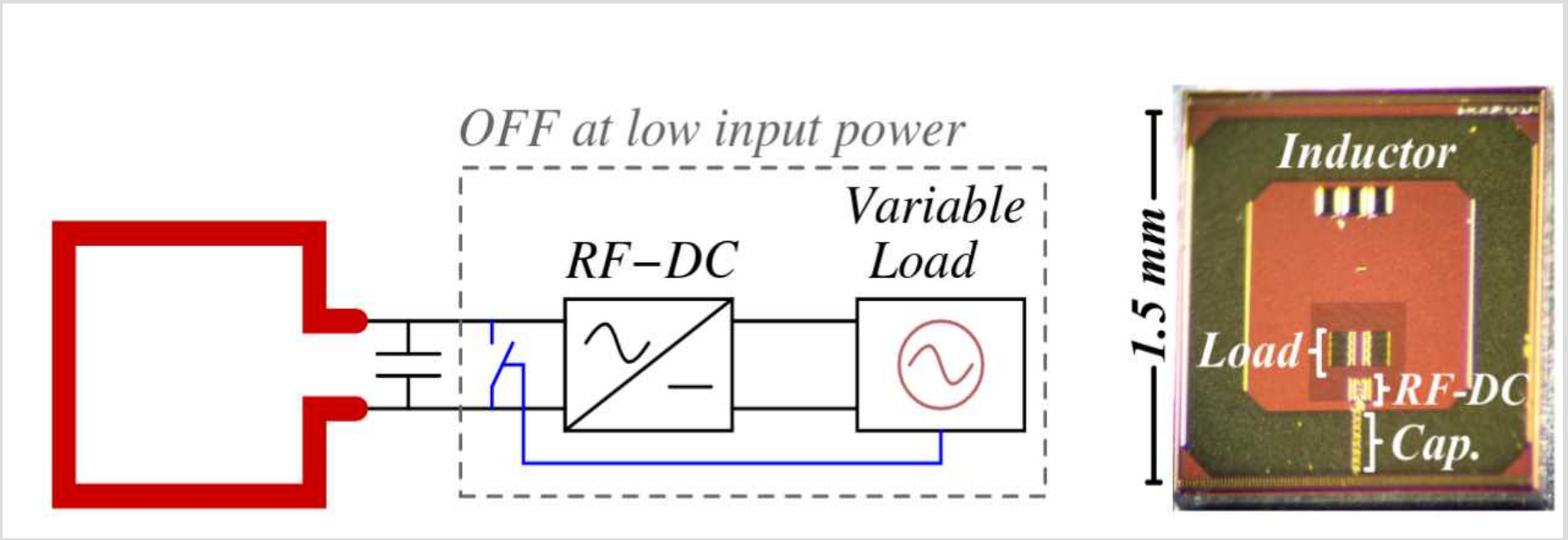
Indutor interno de 4 mm.

Verificação experimental

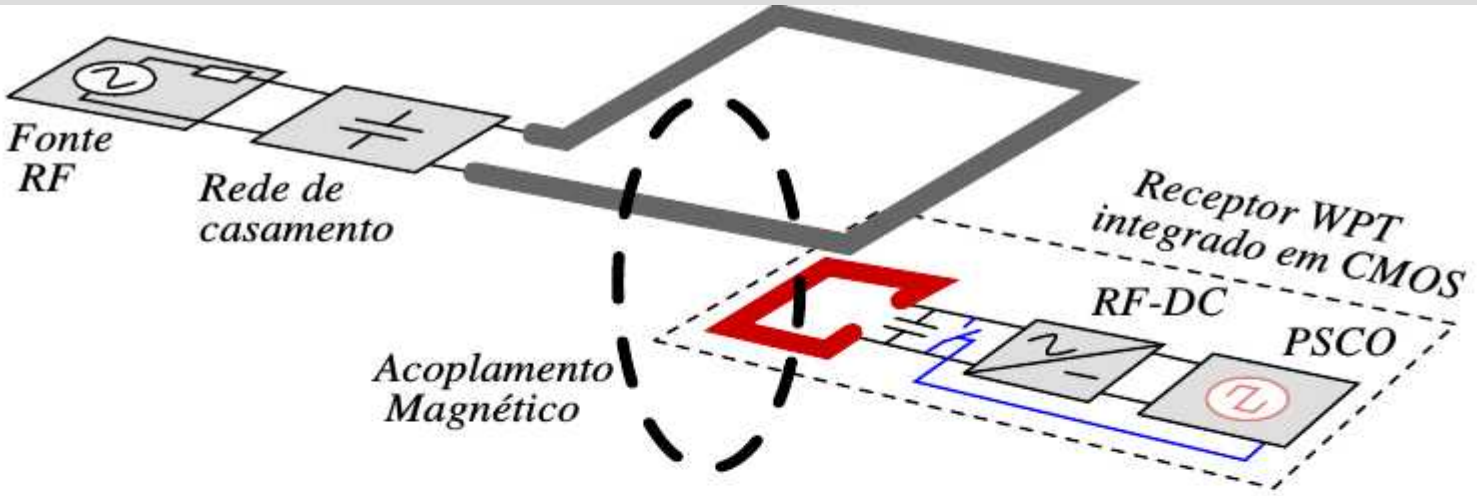


d_{avg2} [mm]	d_{avg1} [mm]	d [mm]	N	C_D [pF]	η_{max} [%]	$f_{\eta max}$ [MHz]
4	22	15	1	–	30	415
4	22	15	4	1.5	30	980

Indutor Integrado em Silício



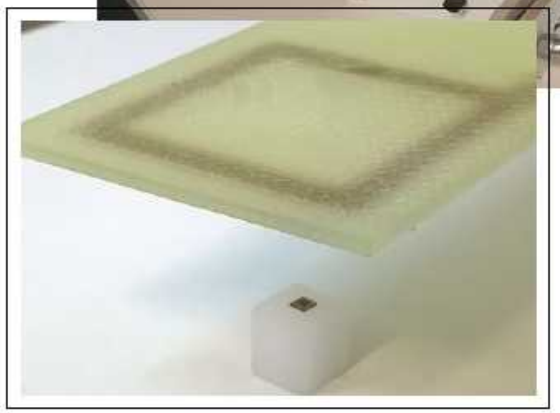
Sistema de transferência de energia para implantes



$$\eta_T = \frac{\eta_{com}\eta_{RT}}{\frac{1}{k^2 Q_{1r} Q_{2r}}\left(p + 2 + \frac{1}{p}\right) + p + 1} \qquad (3)$$

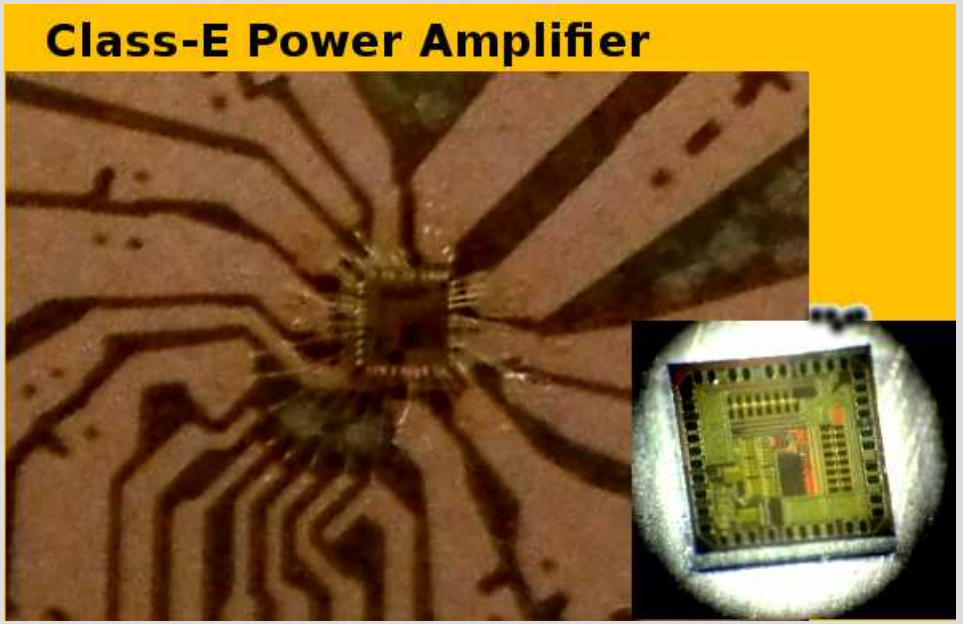
Parte	Receptor				Transmissor	
Objetivos	η_{com}	Q_{2r}	η_{RT}	p	k	Q_{1r}
Variáveis de projeto	• Valor fixo: D=0,5	• Indutor integrado • Frequência (f)	• Retificador • Carga (R_V) • Potência (P_V)		• Indutor Primário	

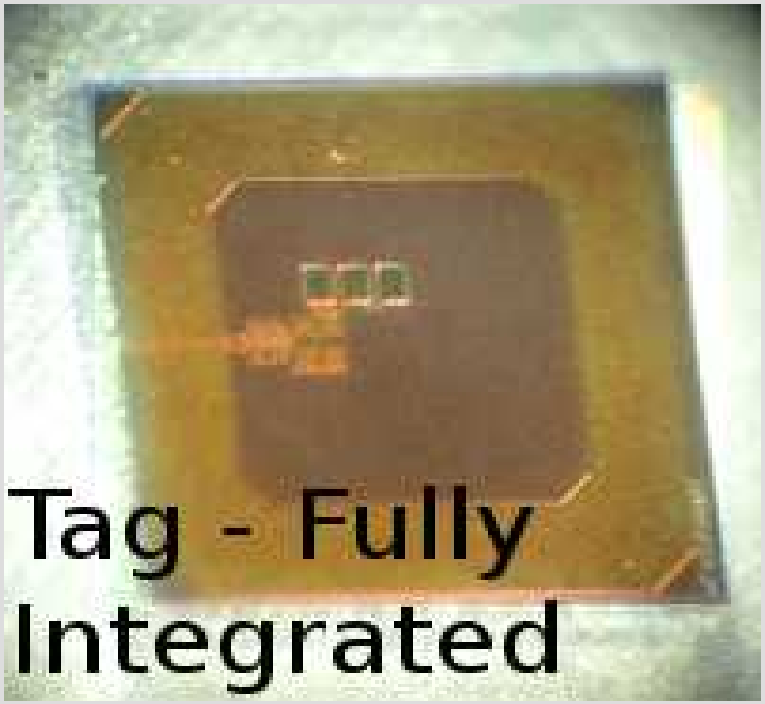
Caracterização do sistema



d [mm]	η_{max} [%]
5	7.71
10	1,02
15	0,29
20	0,07

Chips projetados para o sistema

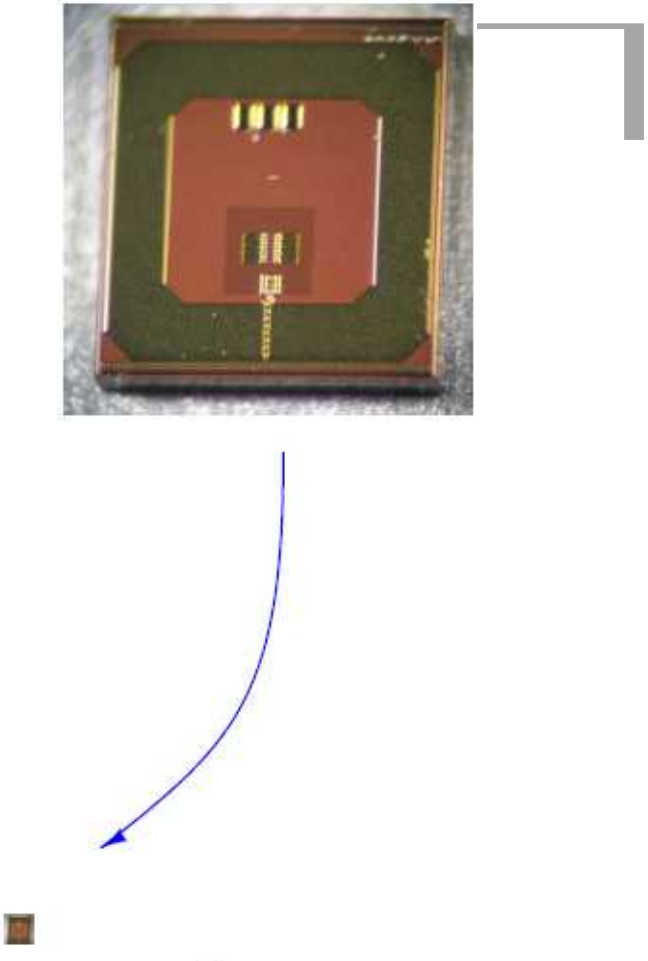




Future

12 cm^3

0,75 cm^3



0,0007 cm^3

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Outline

- WBAN Review
- **WBAN Research at UFSC**
  - HBC Channel characterization
  - RF-powered temperature sensor
  - Wireless power transmission to miniaturized implants
  - **Energy harvesting**
  - ISFET for pH and glicose measurement
- Concluding remarks

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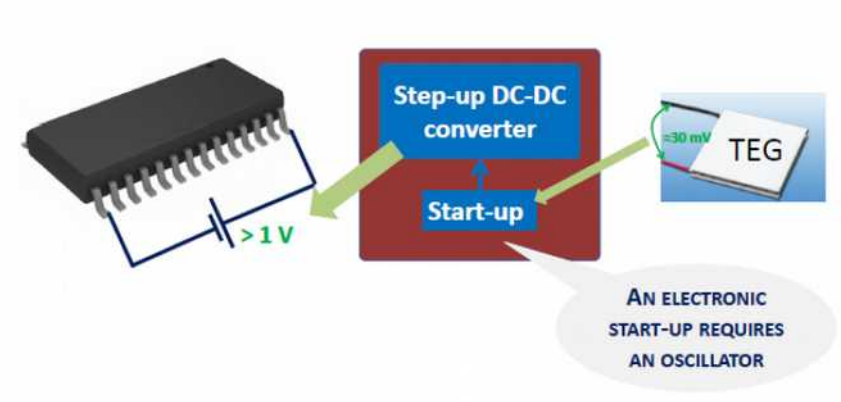
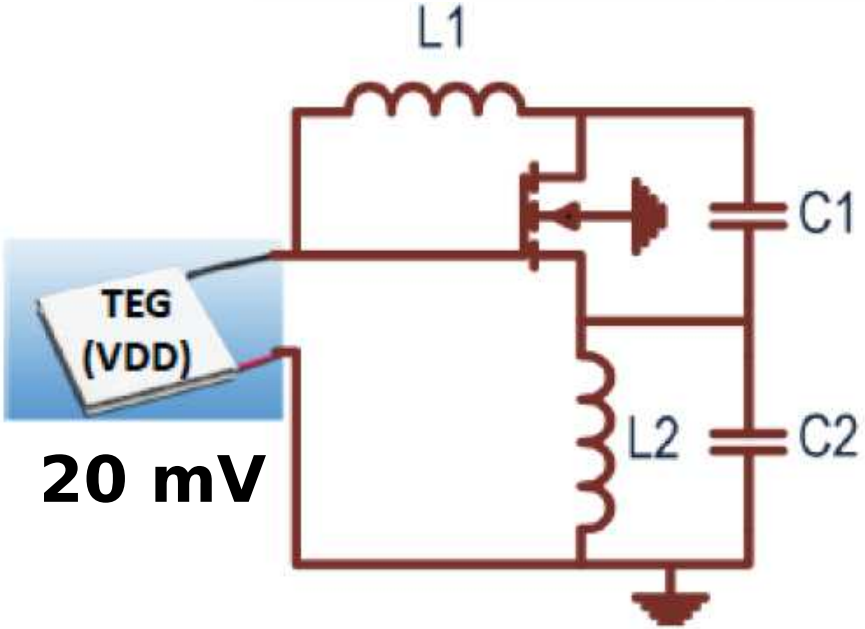
Thermoelectric energy harvesting





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Outline

- WBAN Review
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  - ISFET for pH and glicose measurement
- Concluding remarks

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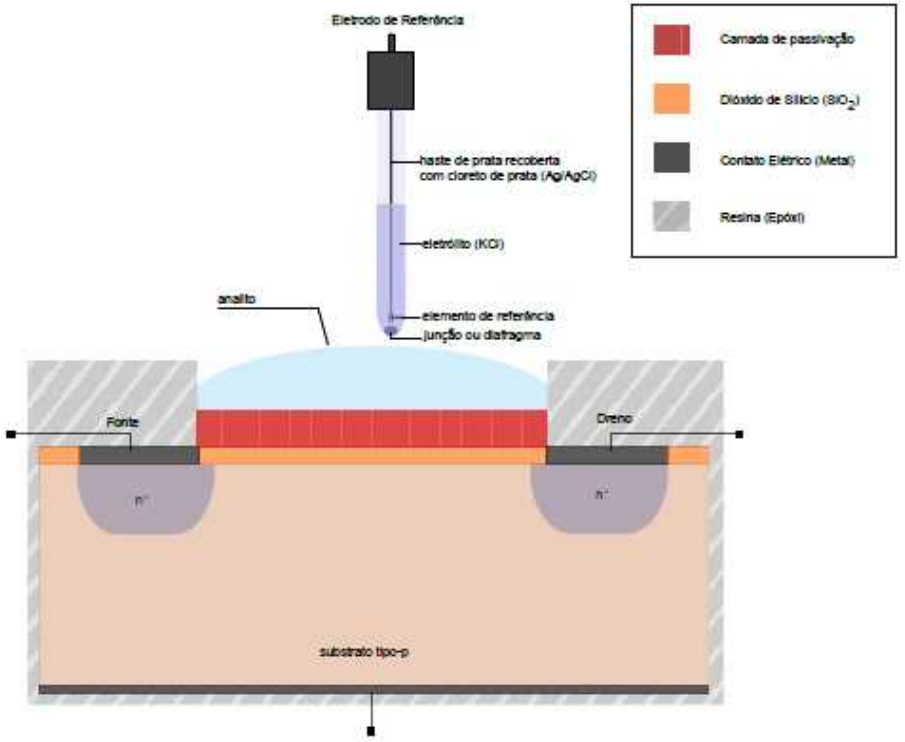
ISFET sensor

- Partnership with CCS/UNICAMP



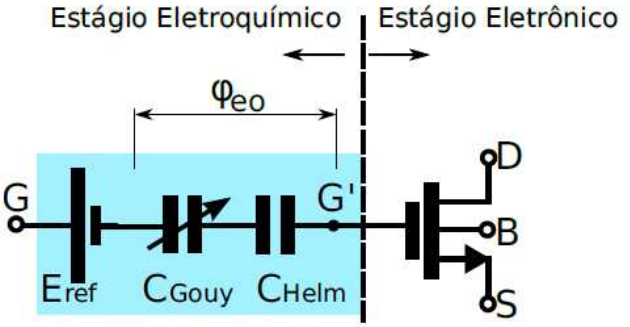


Figura 3: Macro-modelo do ISFET

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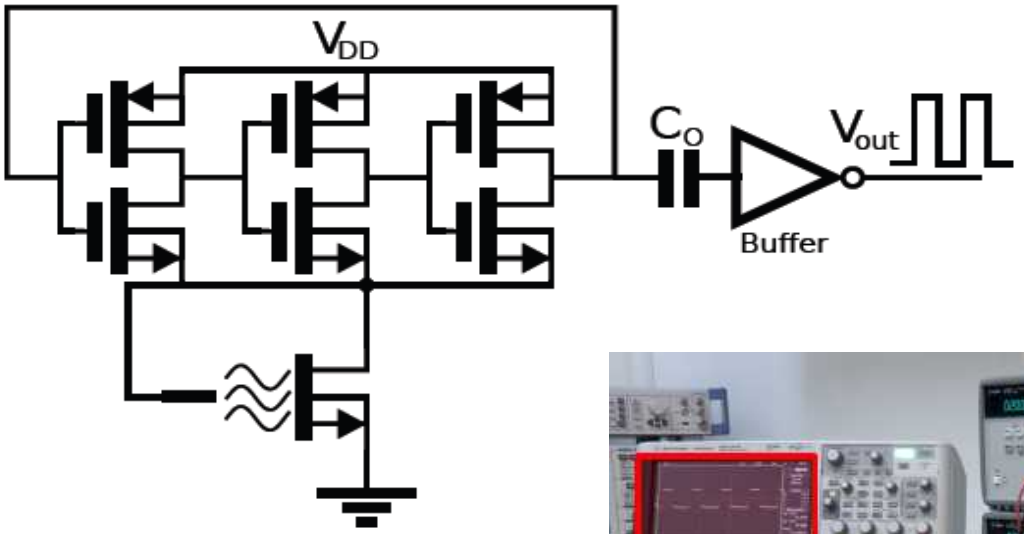
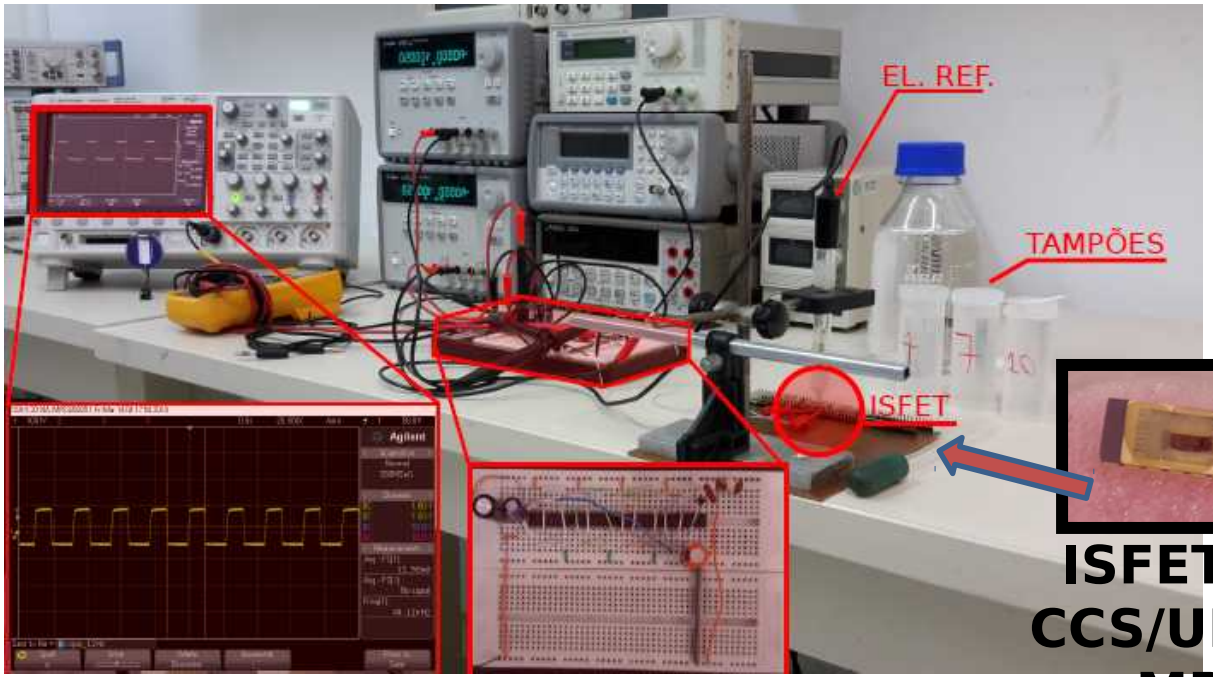
PH controlled oscillator – PHCO





ISFET do CCS/UNICAMP

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Sensor de permissividade por microondas

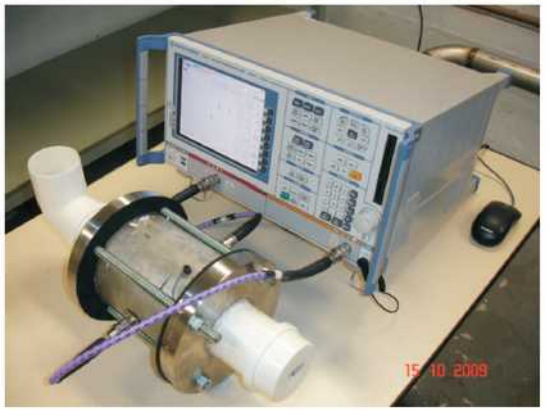
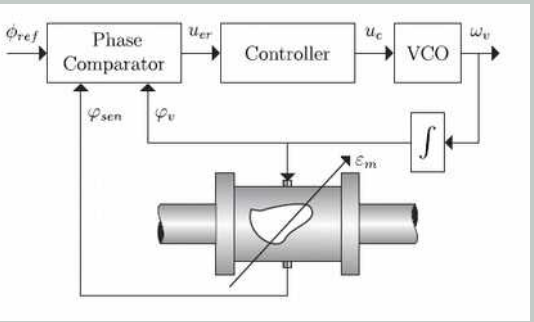
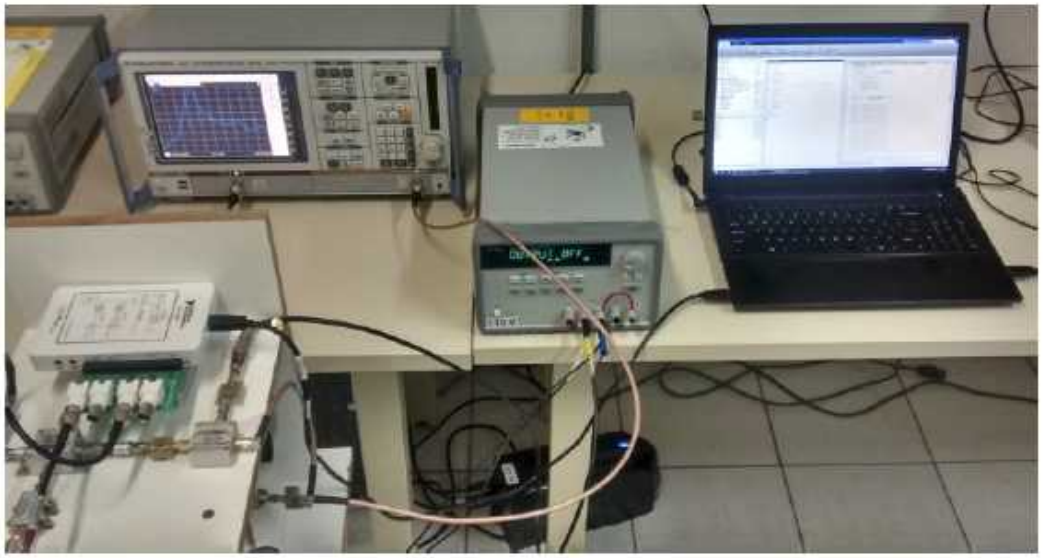


Figura 6.1: Protótipo desenvolvido para experimentos, conectado ao analisador de rede.

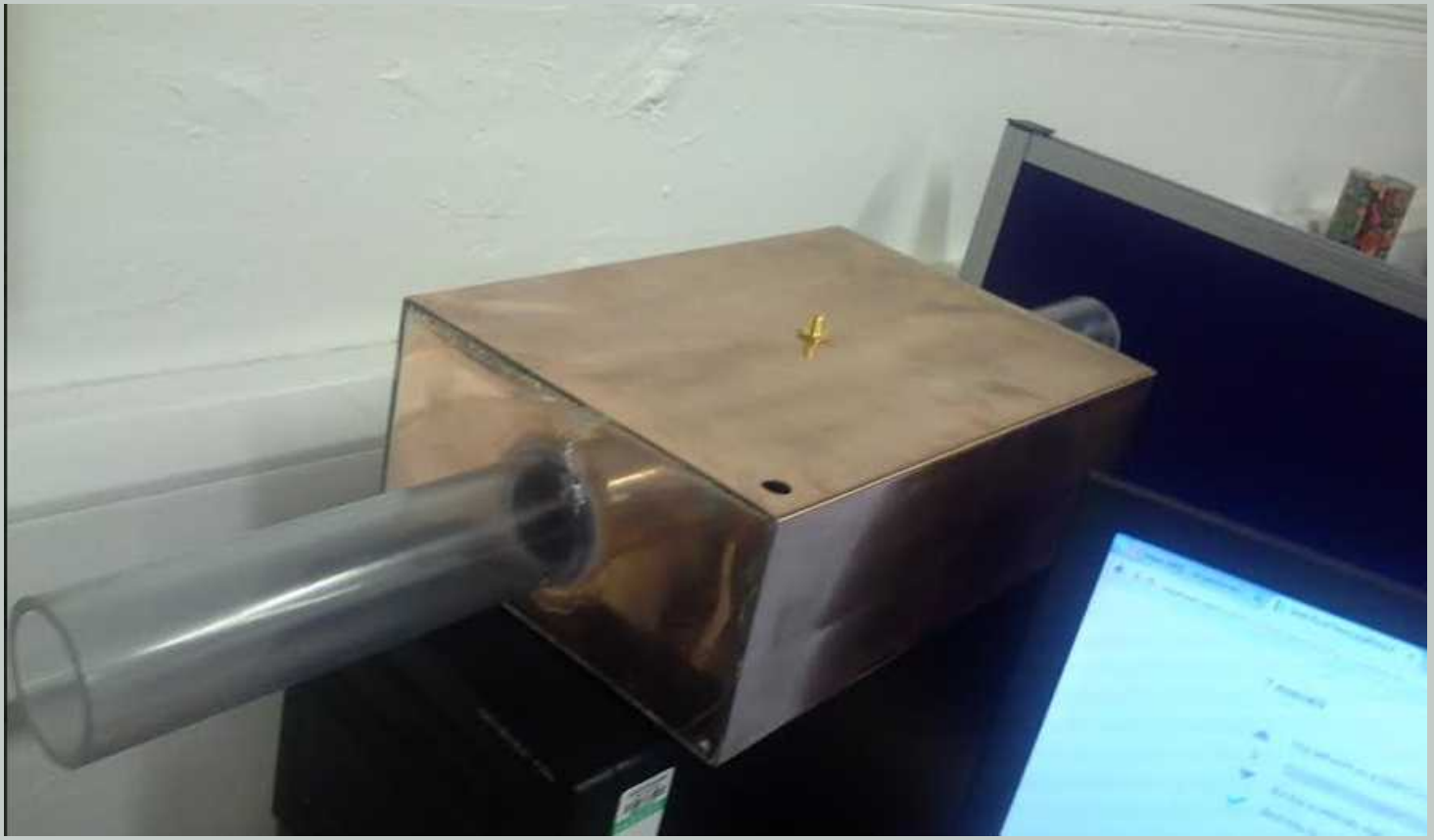




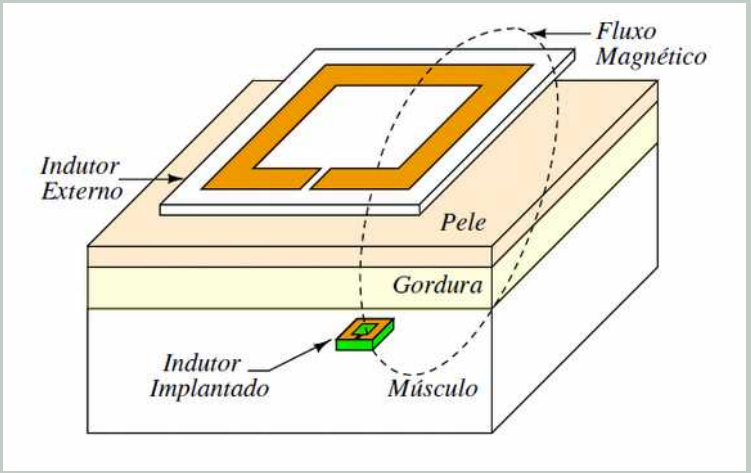
(b)

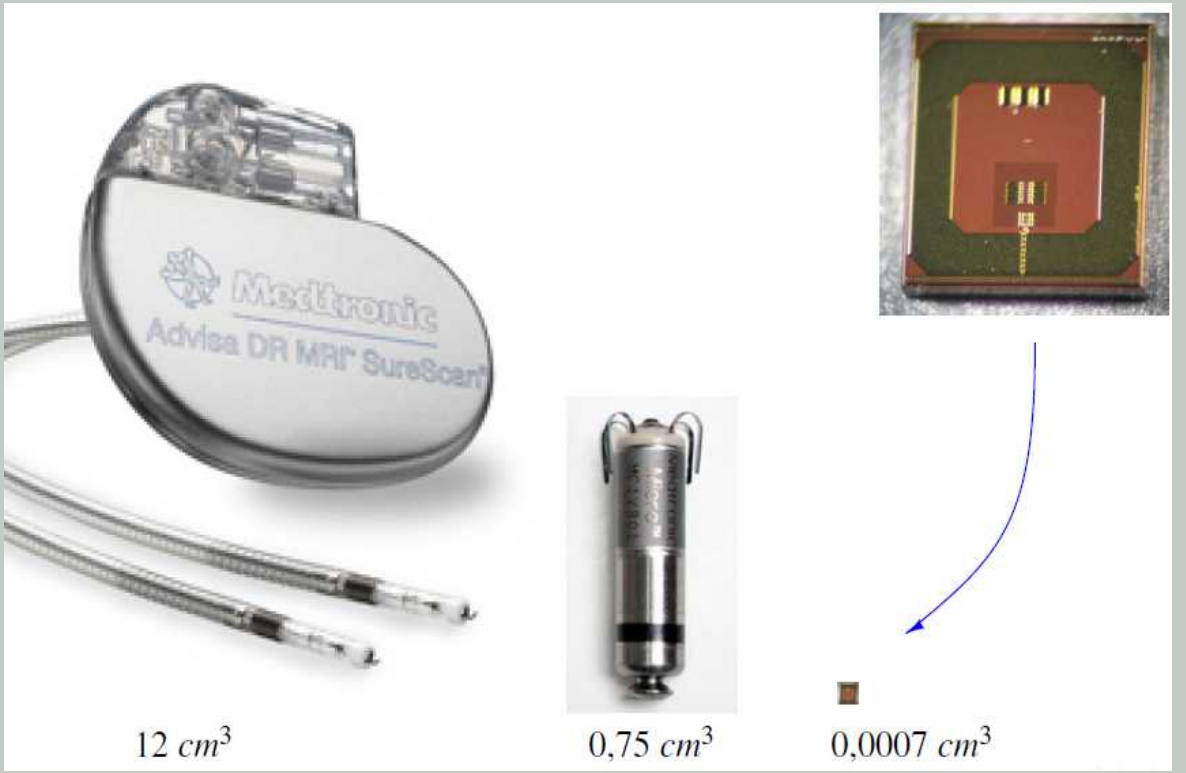
(c)

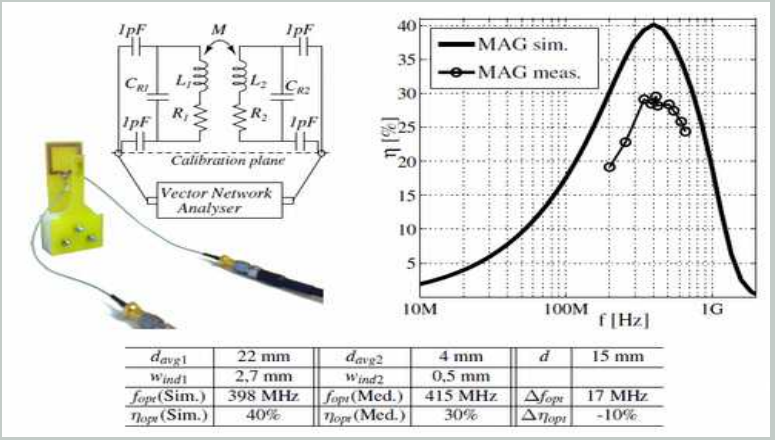
Sensor measured



Chip para alimentar implantes miniaturizados

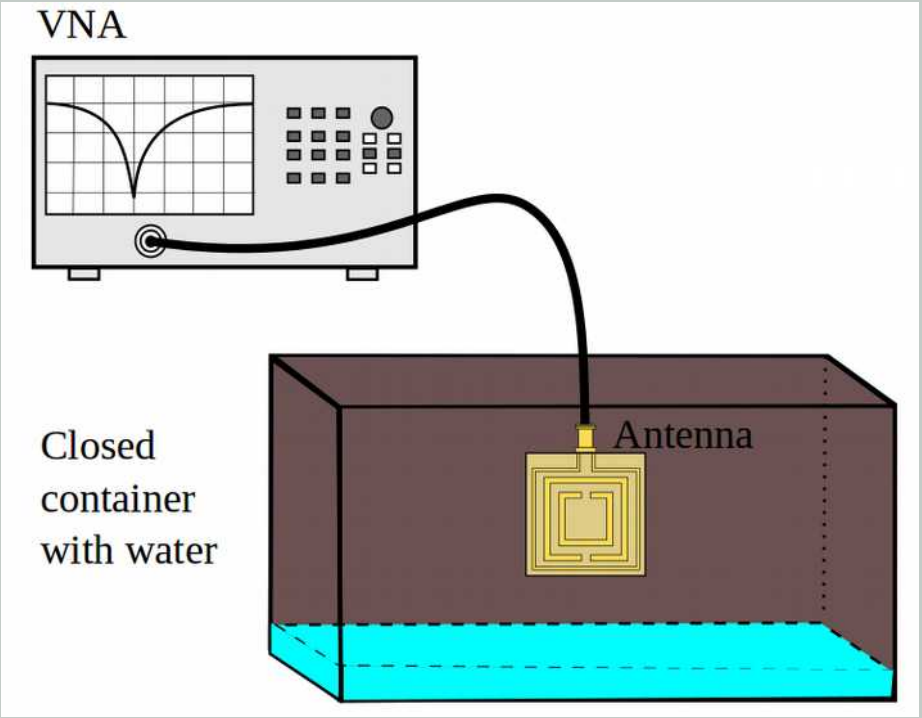


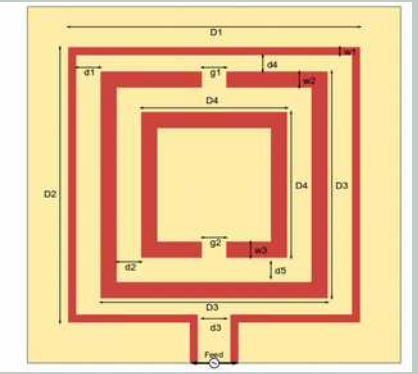


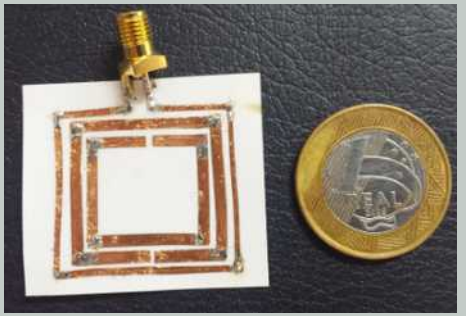


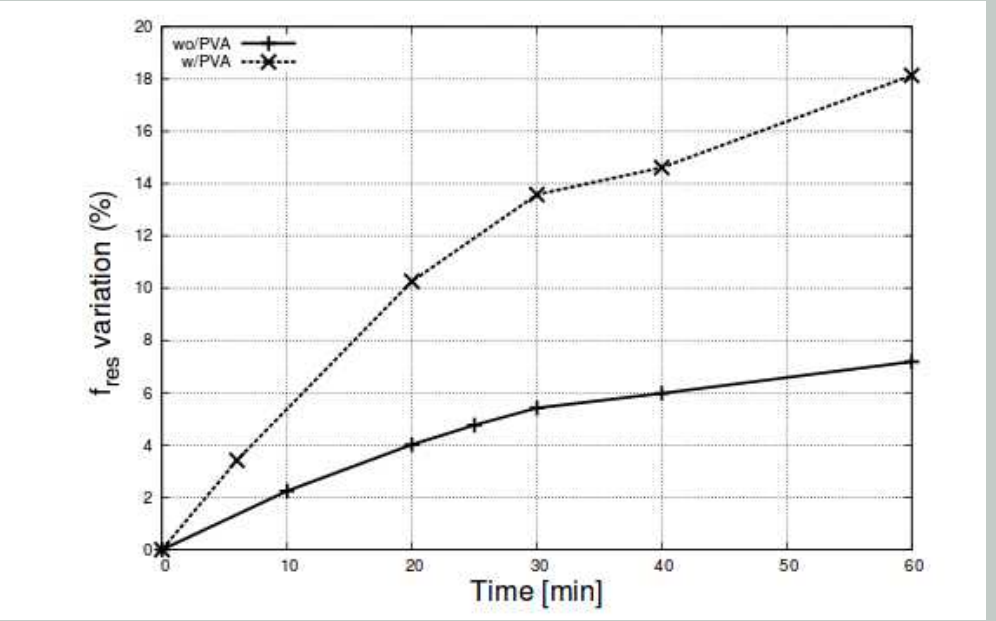
d_{avg1}	22 mm	d_{avg2}	4 mm	d	15 mm
w_{ind1}	2,7 mm	w_{ind2}	0,5 mm		
f_{opt}(Sim.)	398 MHz	f_{opt}(Med.)	415 MHz	Δf_{opt}	17 MHz
η_{opt}(Sim.)	40%	η_{opt}(Med.)	30%	$\Delta\eta_{opt}$	-10%

Sensores em substratos orgânicos



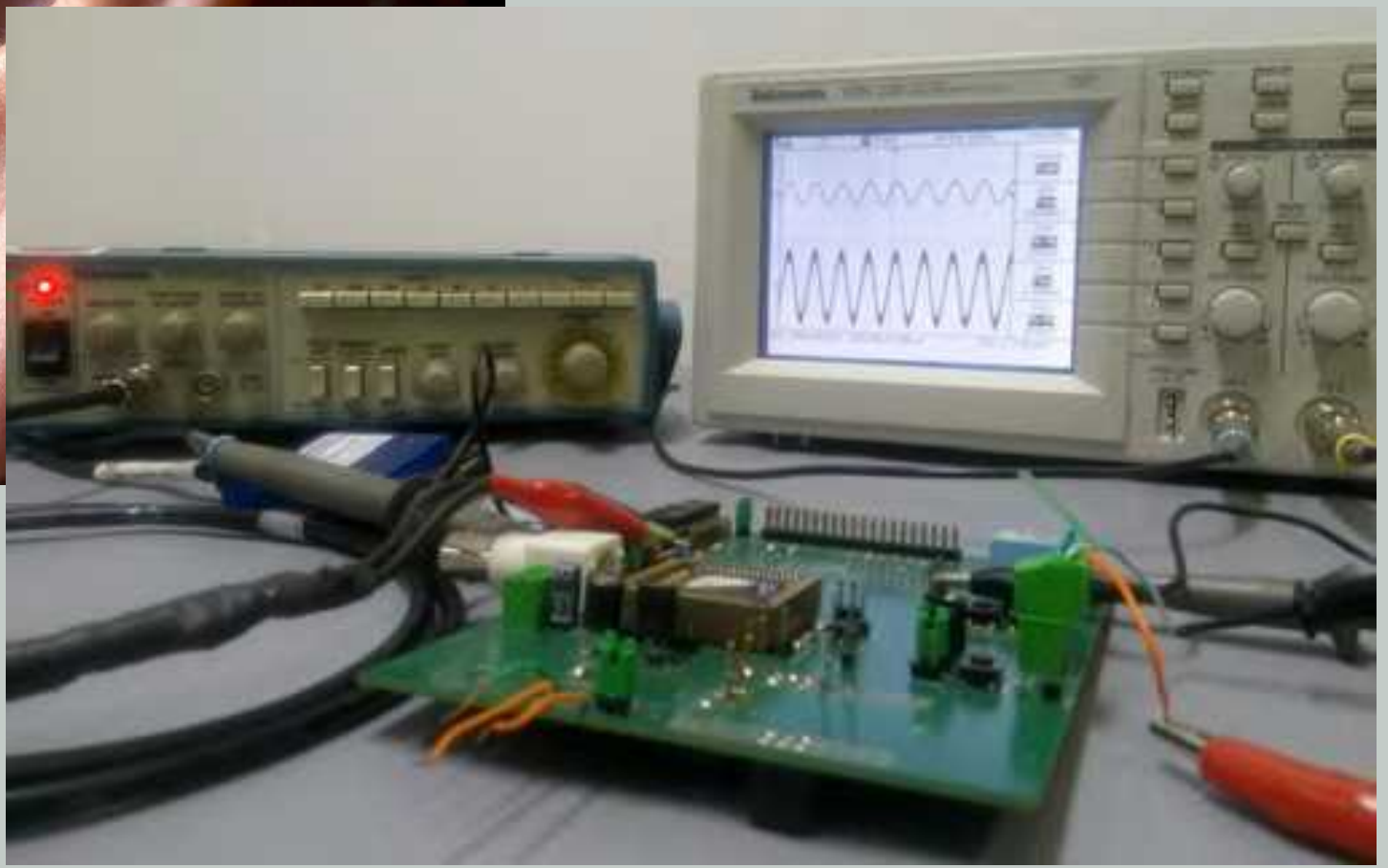




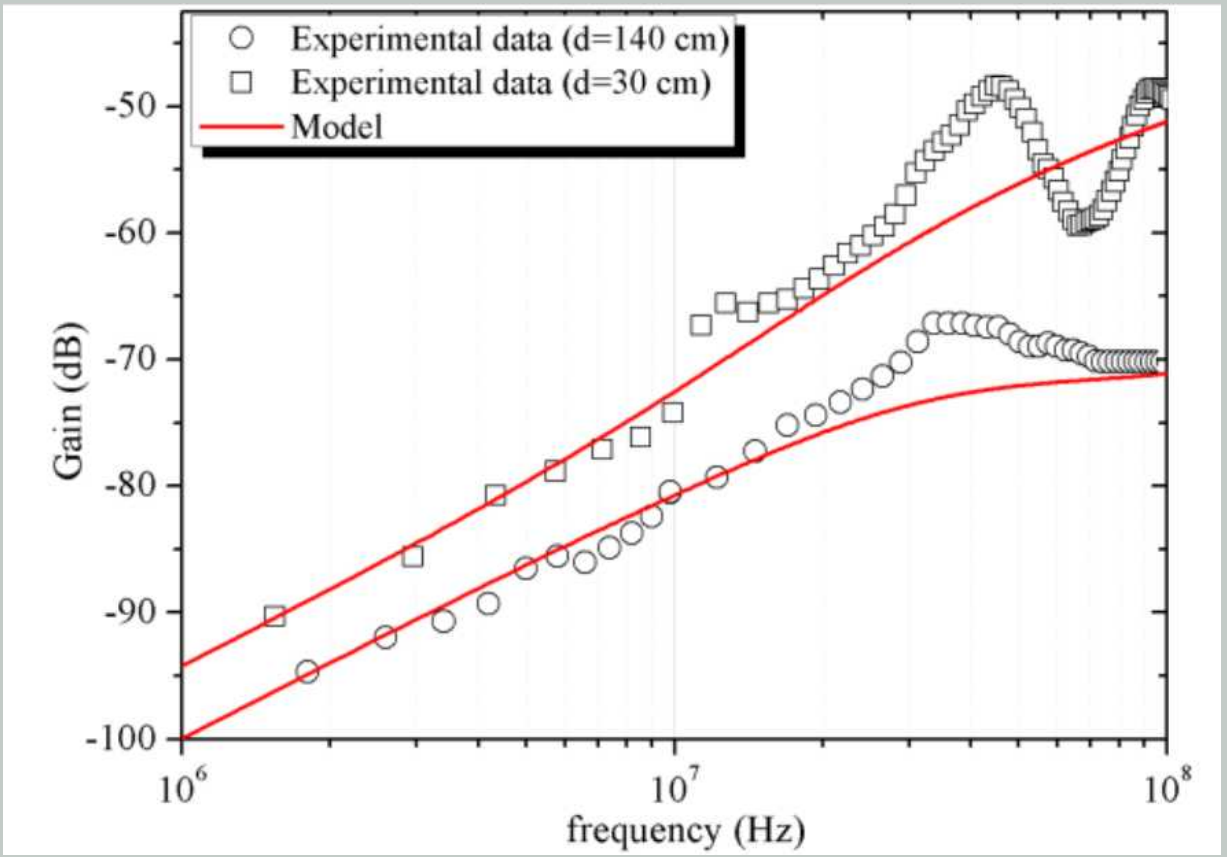


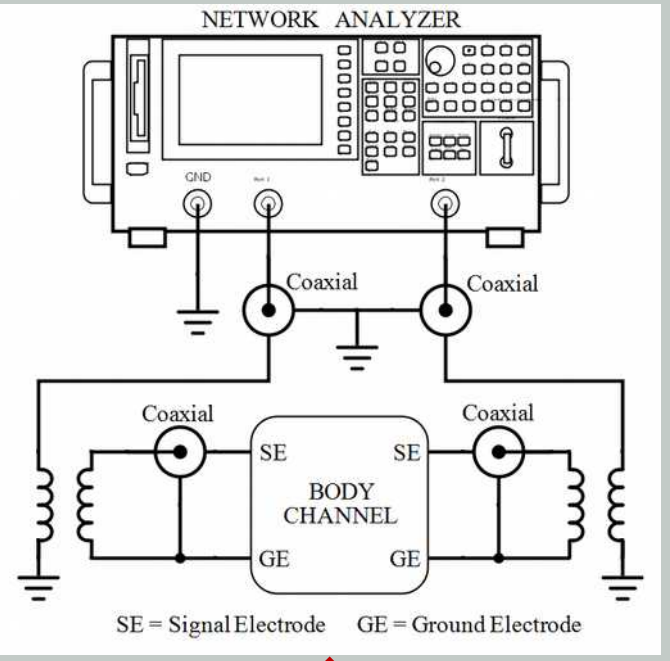
Chip para aparelhos auditivos

- Parceria com empresas



Comunicação intra-corporal





Calibration Procedure to Remove the Balun Effects on HBC Channel Measurements

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