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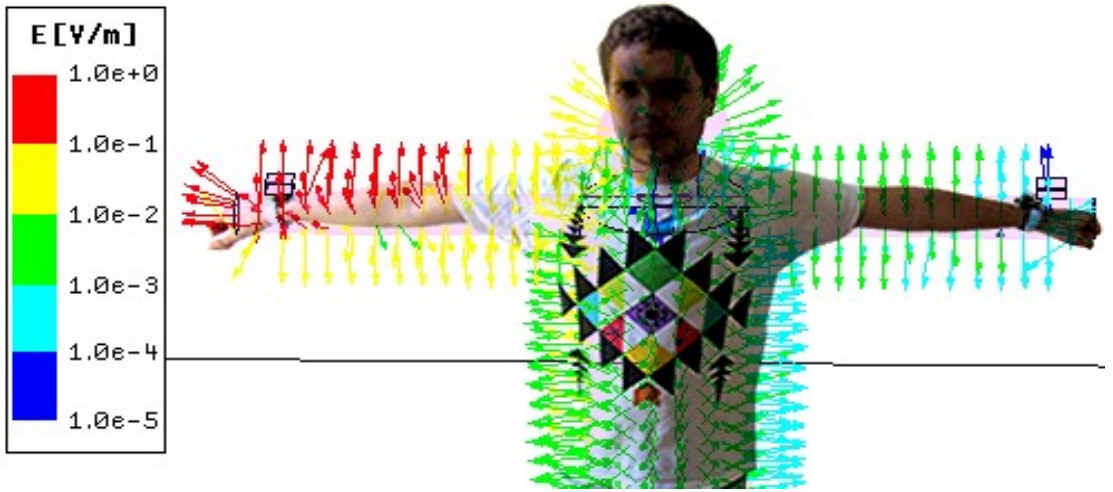
Biological Signals Communication System through the Human Body



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FCT

Fundação para a Ciência e a Tecnologia

MINISTÉRIO DA CIÊNCIA E DO ENSINO SUPERIOR

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WBANs (Wireless Body Area Networks)

Wireless Personal (/Body) Area Networks potential use:

- **Connect Personal Devices**
- **Secure User-Machine Communication**
- **Monitor Biological Signals** (Healthcare Systems)

- Resource/Application constraints:
- **Low Power / High Security**
- **High Coexisting Capability**

(Lots of PANs working in a Small Area, like an Auditorium / a Bus)

Why Capacitive Coupling?

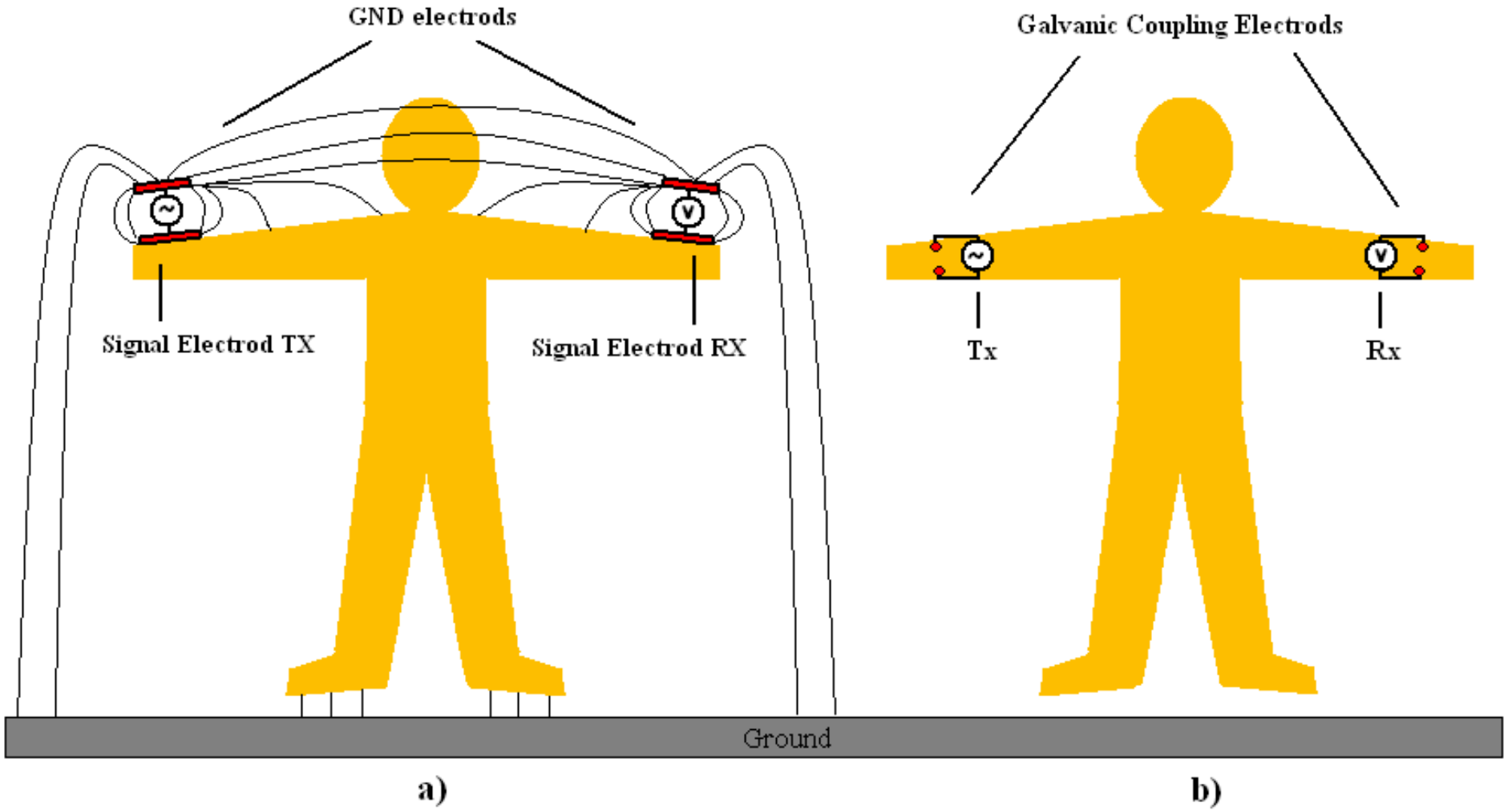
Wireless Body Area Networks requirements:

- **Low Power Consumption**
- **High Security**

Capacitive Coupling Characteristics:

- **Reactive Field**
  (Consumption: Receiver Electronics + Physical Losses (no radiation))
- **Low / Sharp Range**
  (Electric Field of dipole decay with d^{-3})

Capacitive Coupling vs Galvanic Coupling

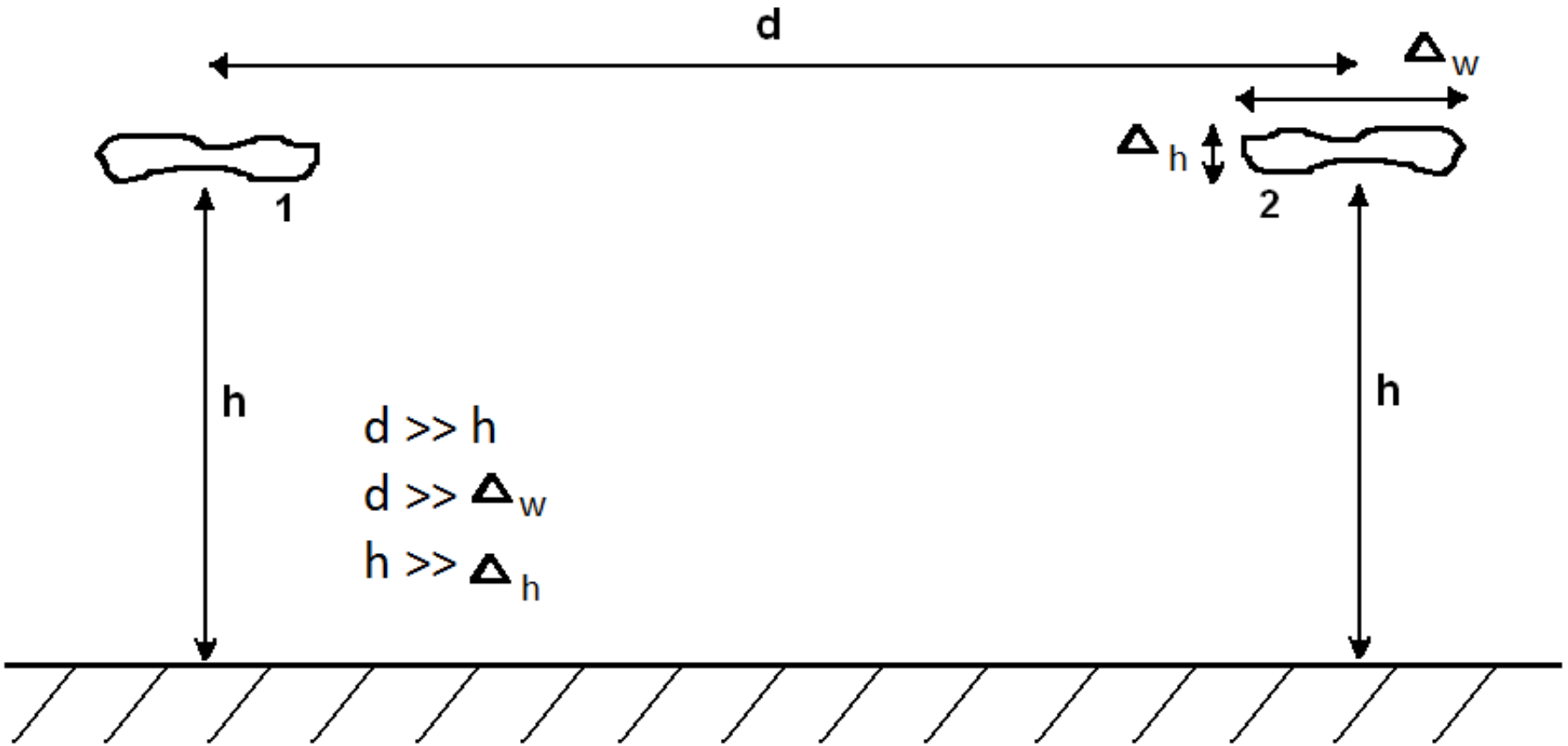


Capacitive Coupling Advantages:

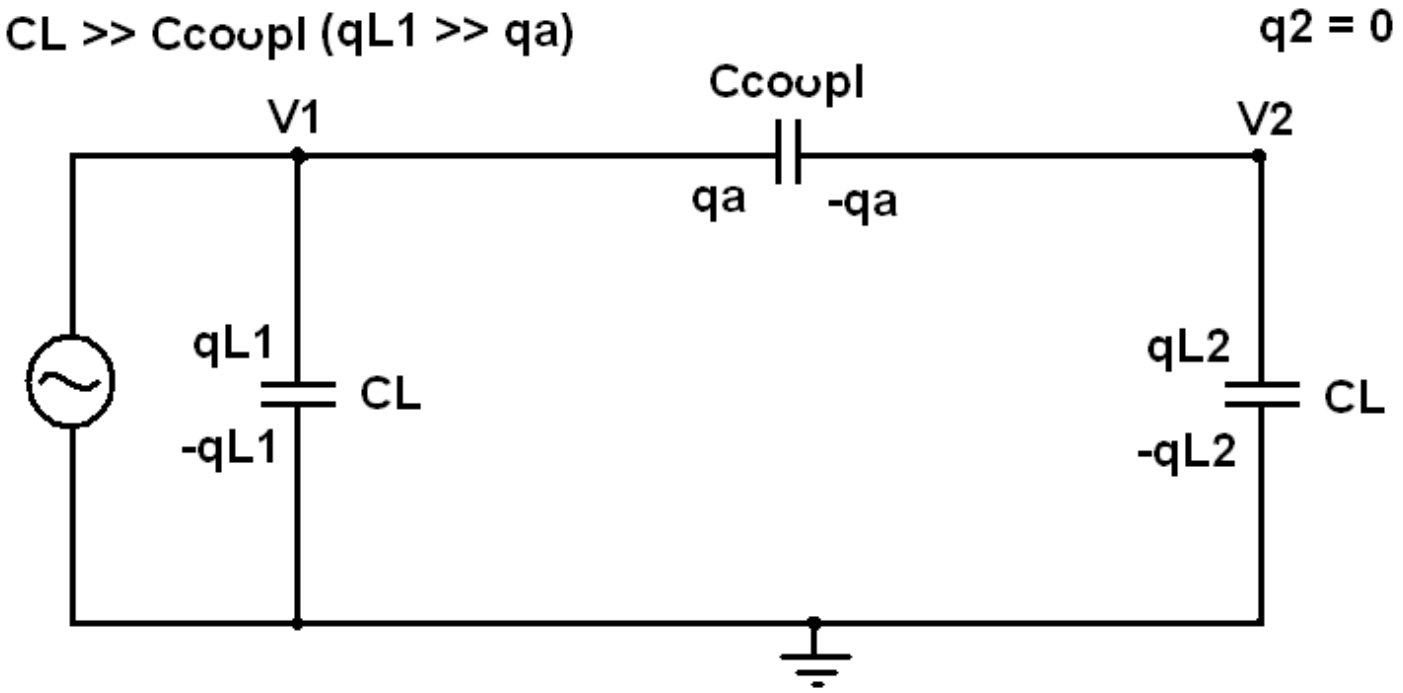
- No need of *Conductive Electrodes*
- *Less invasive* and better expected performance to *User to User* and *User to Machine* communication (important fields for communication on the surface and proximity of body).

Simplified System

(body/connecting conductor as a perfect ground plane)



Equivalent Circuit / Theoretical Results



(C_transceiver)

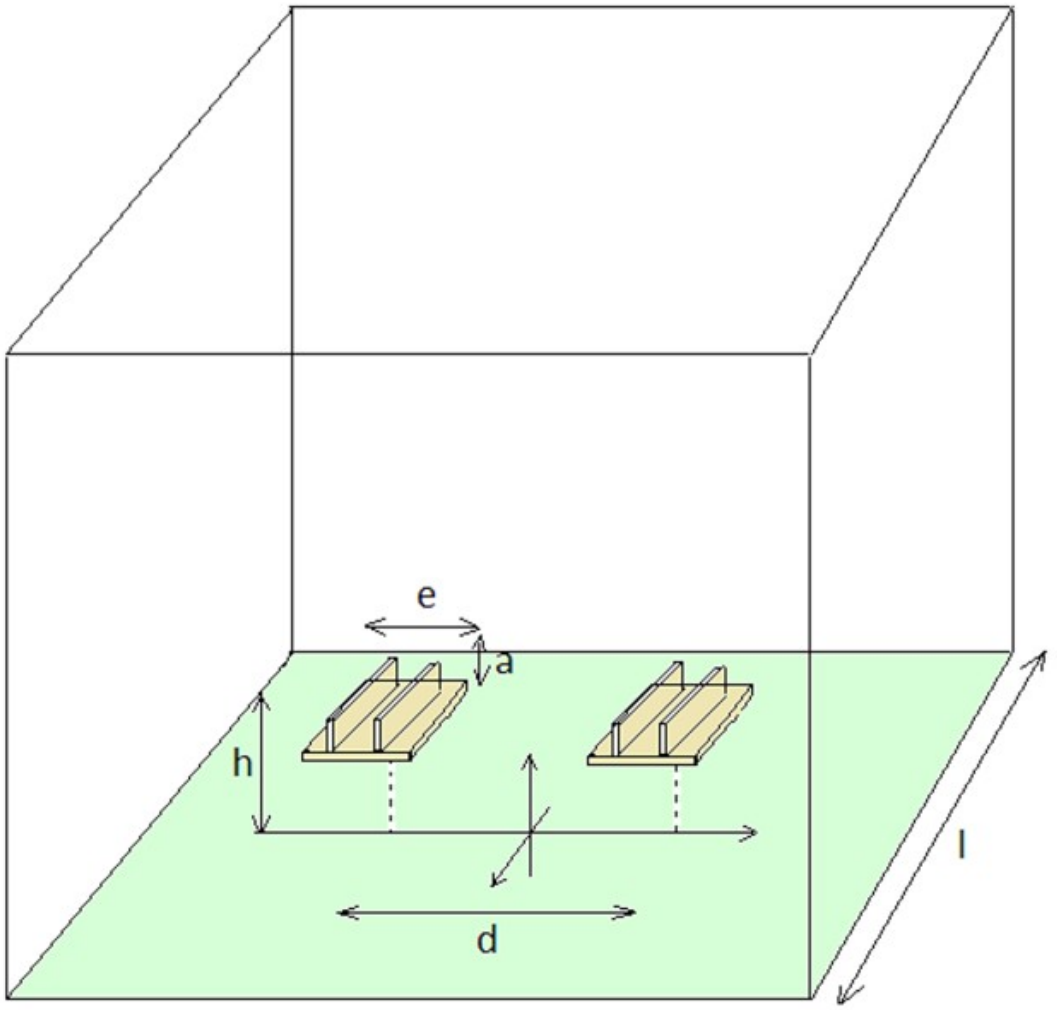
$$\frac{C_{coupl}}{C_L} \simeq 2 \cdot k_e \cdot C_L \cdot \left(\frac{(h)^2}{(d)^3} \right)$$

$$\frac{V2}{V1} = \frac{Ccoupl}{CL + C_{transceiver}}$$

Simulations
(Layout in HFSS and STAP)

HFSS – 3D Full Wave Electromagnetic Simulator

STAP – Electrostatic Simulator with Static Coupling Capacitances Extraction



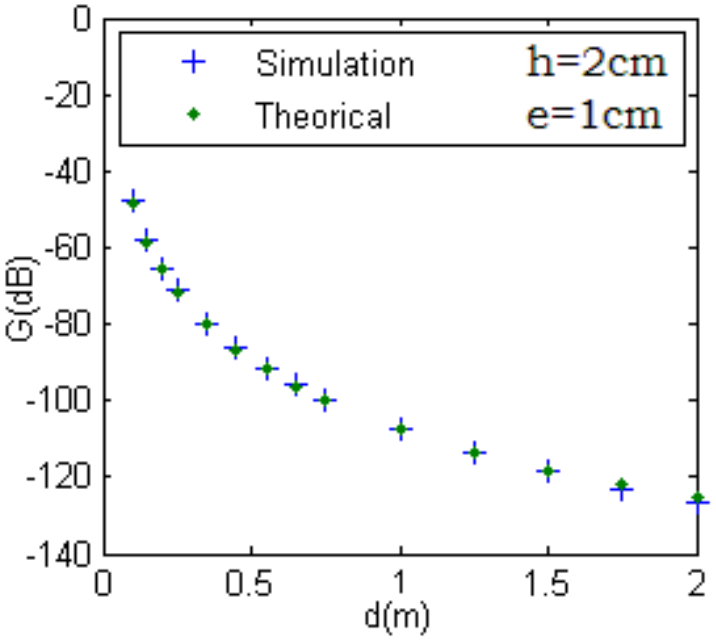
Legend:

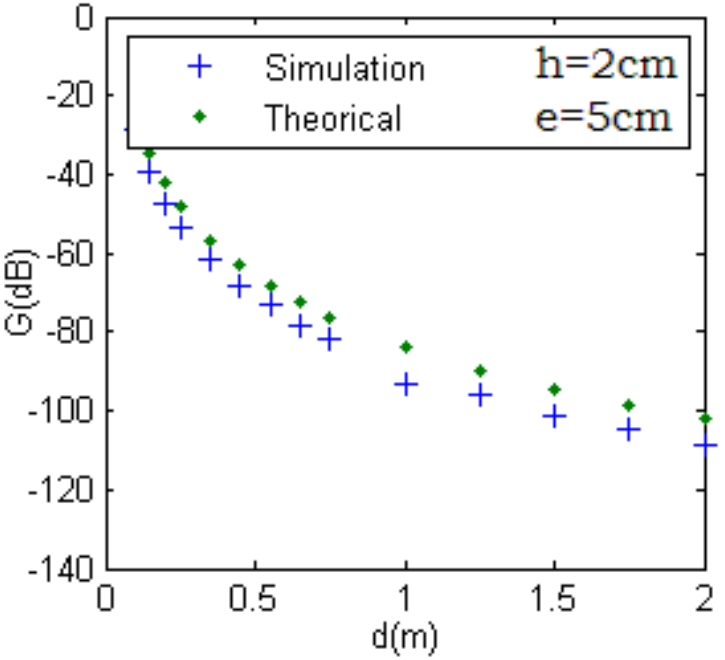
e - electrode's width
a - wings' height
h - electrode's height
l_{fc} - faraday cage width
f - frequency

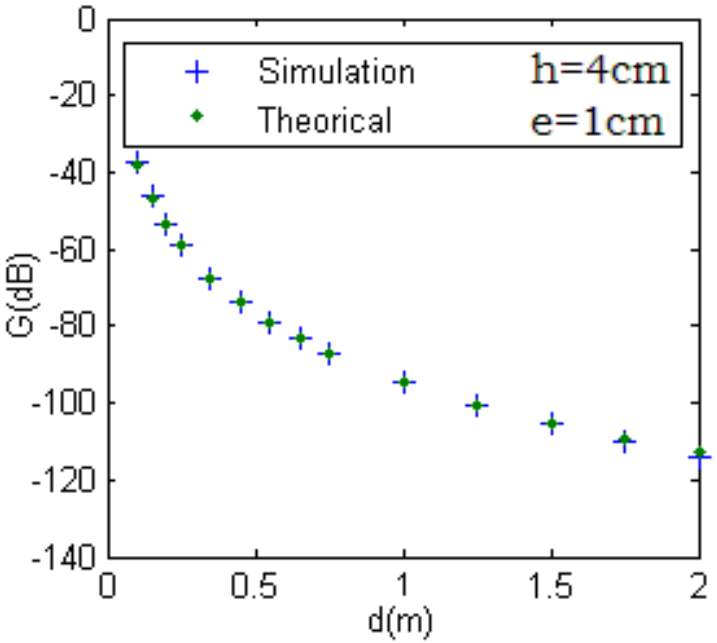
Channel Gain (dB) (f=10MHz)

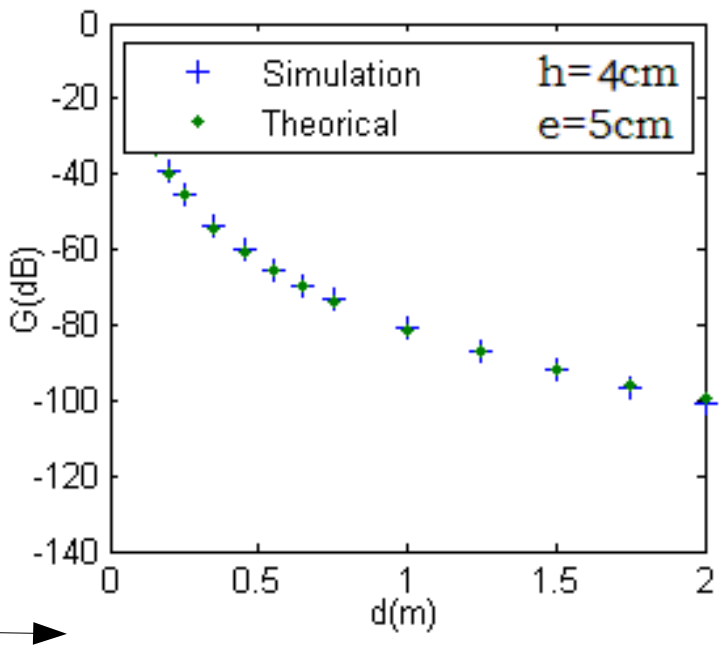
(**Theoretical Voltage Gain** prediction using averaged simulated CL *vs* **Simulated Voltage Gain**)

Higher Electrode Height



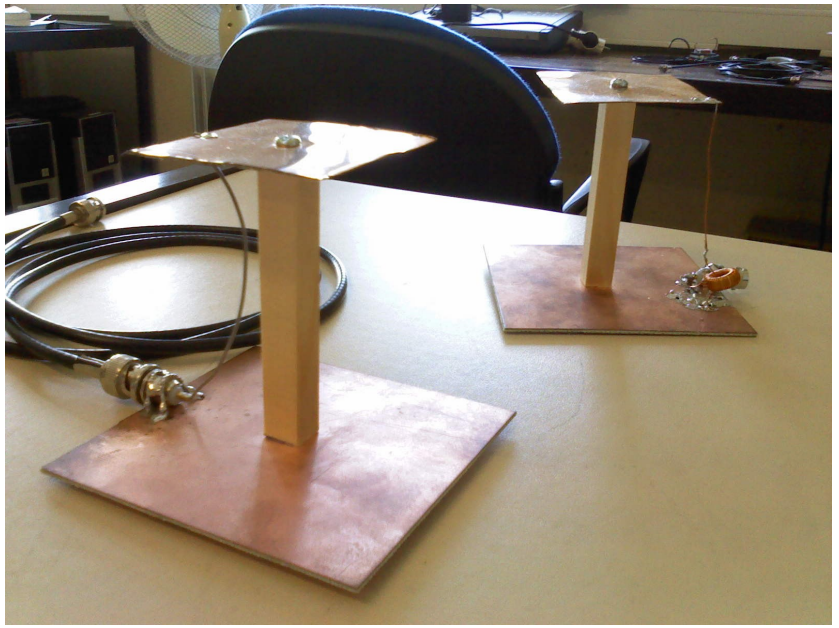


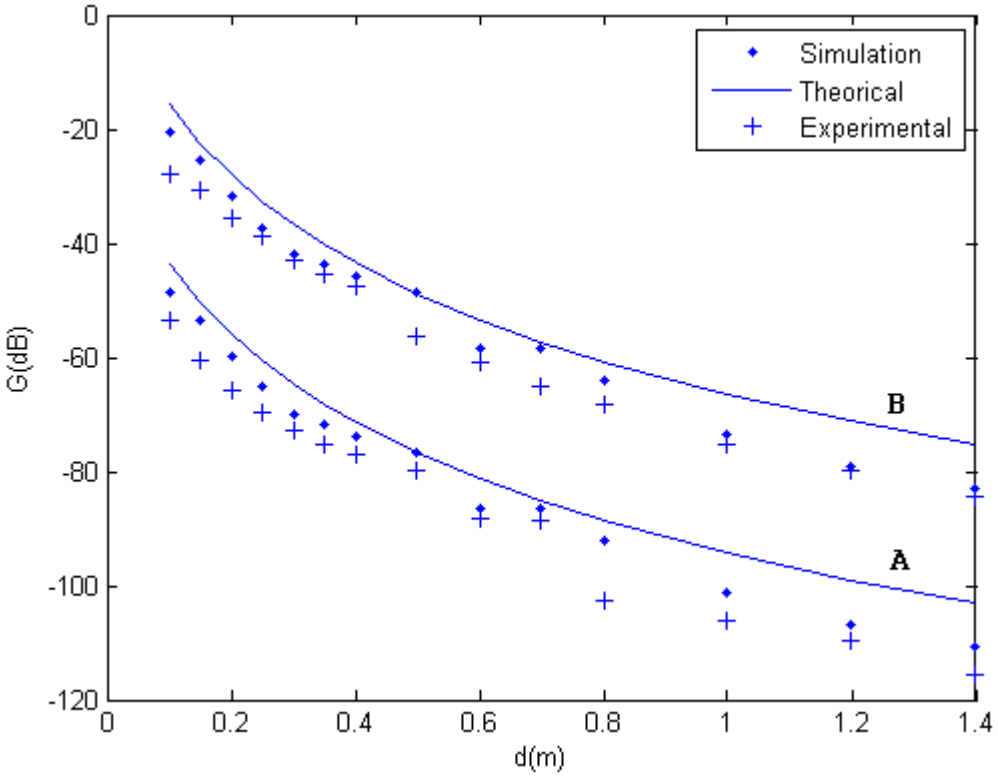




Higher Electrode Size

Practical Experiment
(inside a Faraday Cage)



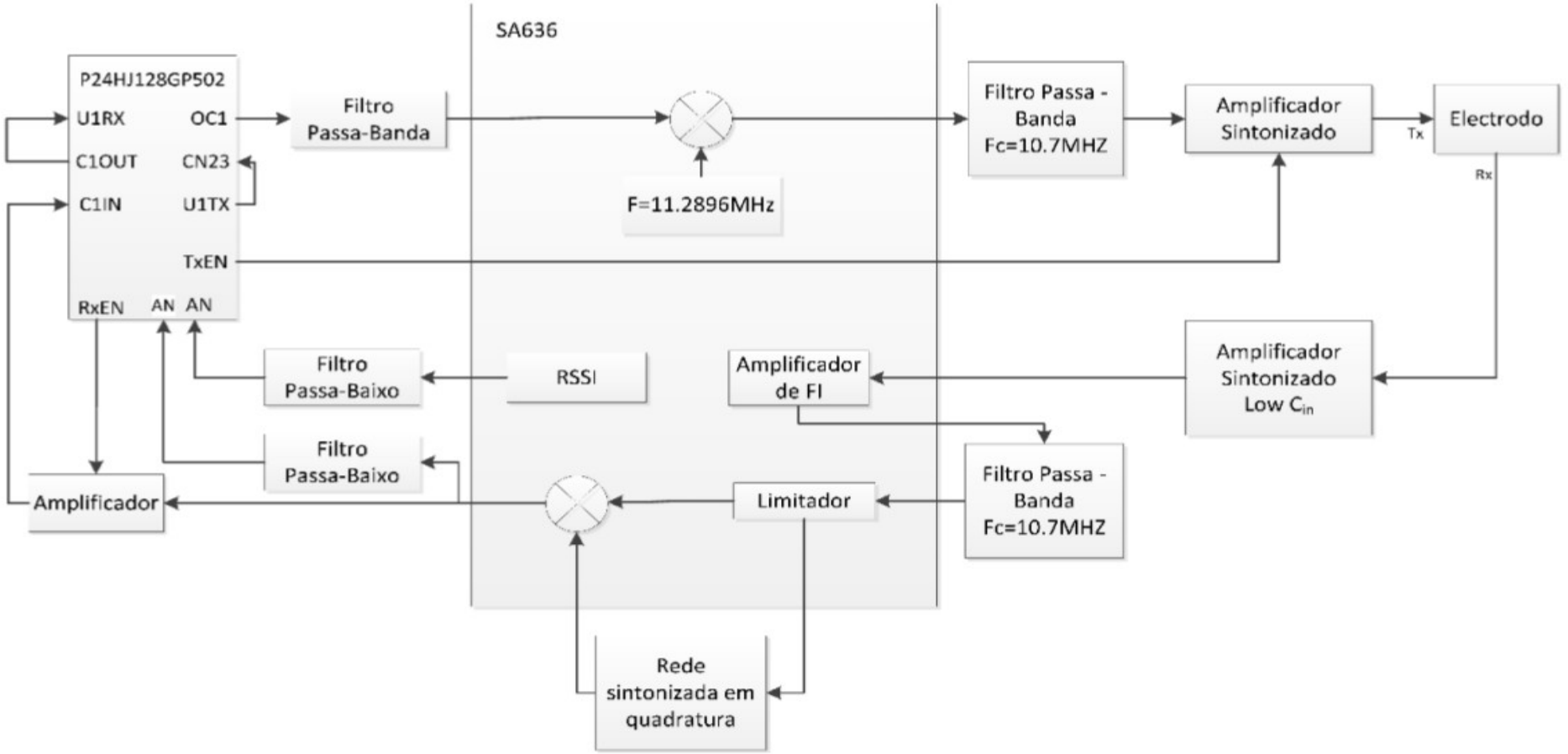


Legend:

Frequency = 12.4MHz

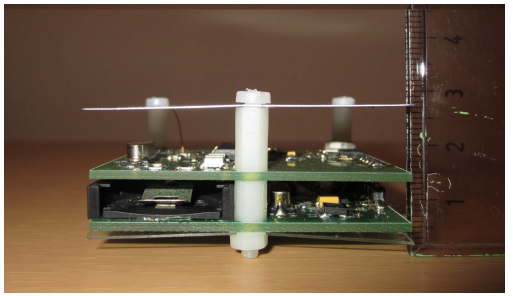
A unbuffered receiver electrode – CL external = 200pF
B buffered receiver electrode – CL external = 3pF

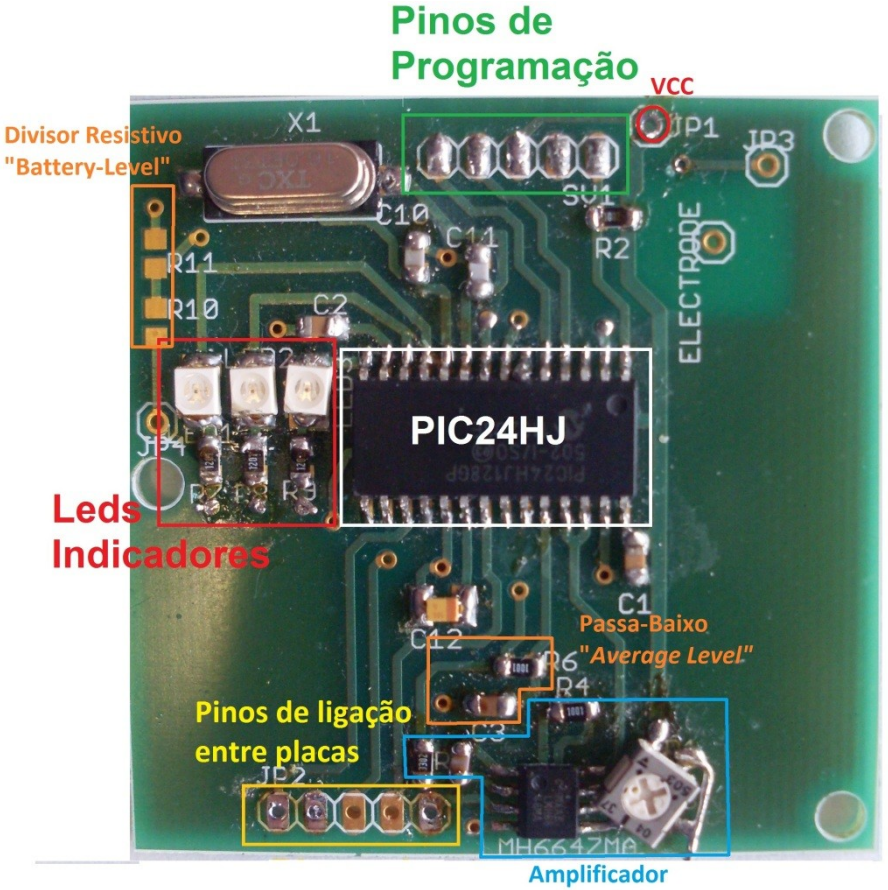
Transceiver architecture (FSK, fo = 10.7MHz, 100Kbits/s)

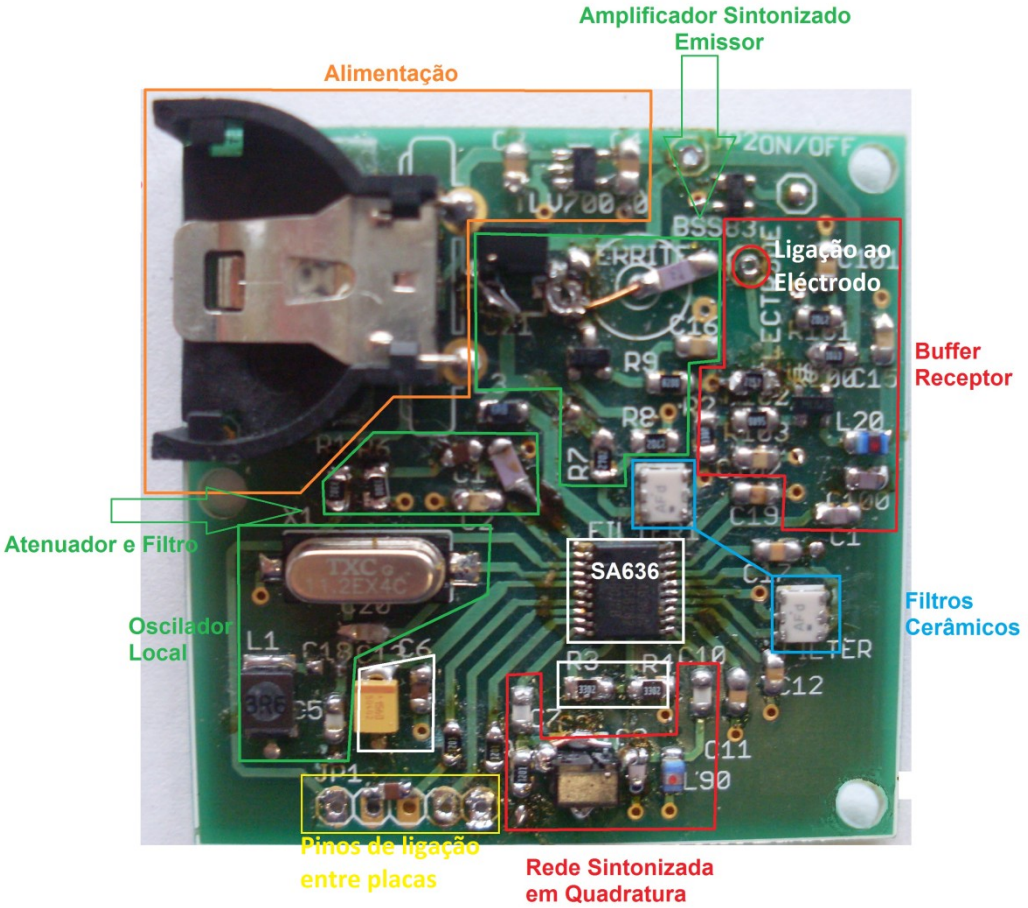


A low frequency FSK is generated by a uC and then translated (frequency up-conversion) to 10.7MHz. The buffered received signal (2pF input buffer) is amplified, filtered with a high selectivity ceramic filter (BW=280KHz) and demodulated by a Quadrature Detector. Both the emitter and receiver circuits are connected to the tunned electrode emitter circuit. By this way (when turned off) the emitter doesn't load the receiver signal.

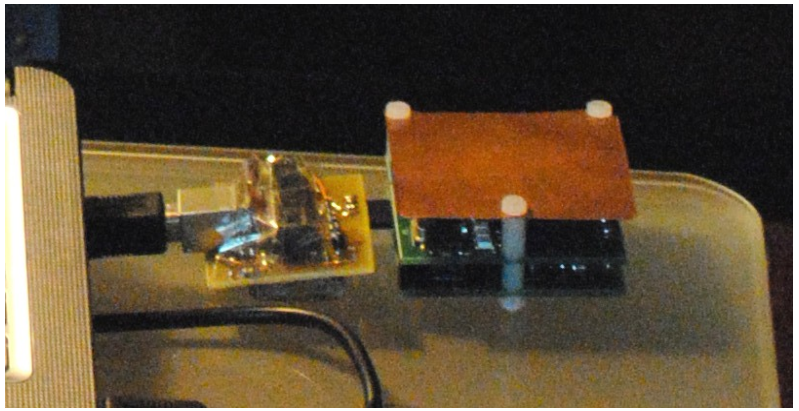
Layout (~3x5x5cm)

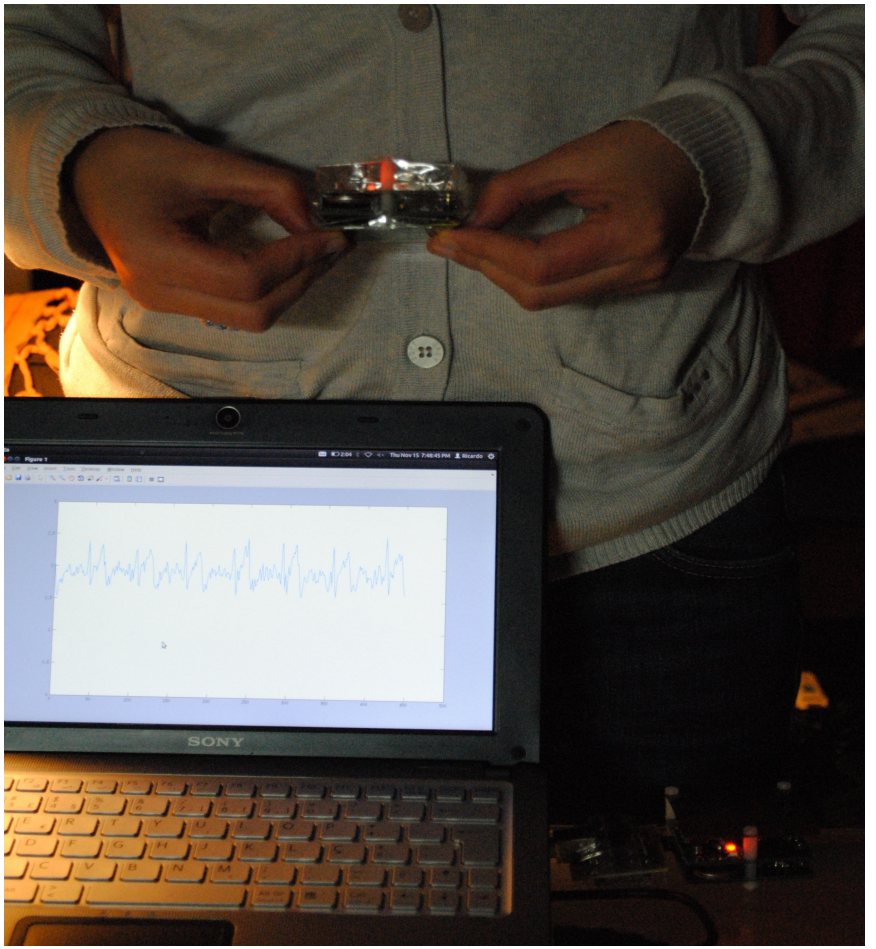






Results





Tests shown a full Human Body coverage. An ECG signal was seen in a portable device when a person touched a patient holding the transmitter with ECG sensing and the receiver, or the patient came close to the receiver.

Conclusions

- Our simple theoretical model has found significant coherence with simulations and with (not so idealistic) experimental setup results. The model can be used to predict the working range of capacitive coupled systems tested in controlled setup environment.

- Practical system showed that with 3x5x5cm transceiver is possible to communicate along the human body with a 100Kbit/s data-rate. User to user and user machine communications was demonstrated. Sharp ranges were reported and showed the inherent security of the system.

- In Future, reducing transceiver dimensions and increasing data-rate, implementing medium access and power control options (network architecture) are the next goals.

Thank You! / References

This work is supported by **FCT** - Fundação para a Ciência e Tecnologia, **Grant: SFRH BD 41808 2007**).

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