Behavioral Modeling and System conference
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Battery lifetime modeling for a 2.45GHz cochlear implant application

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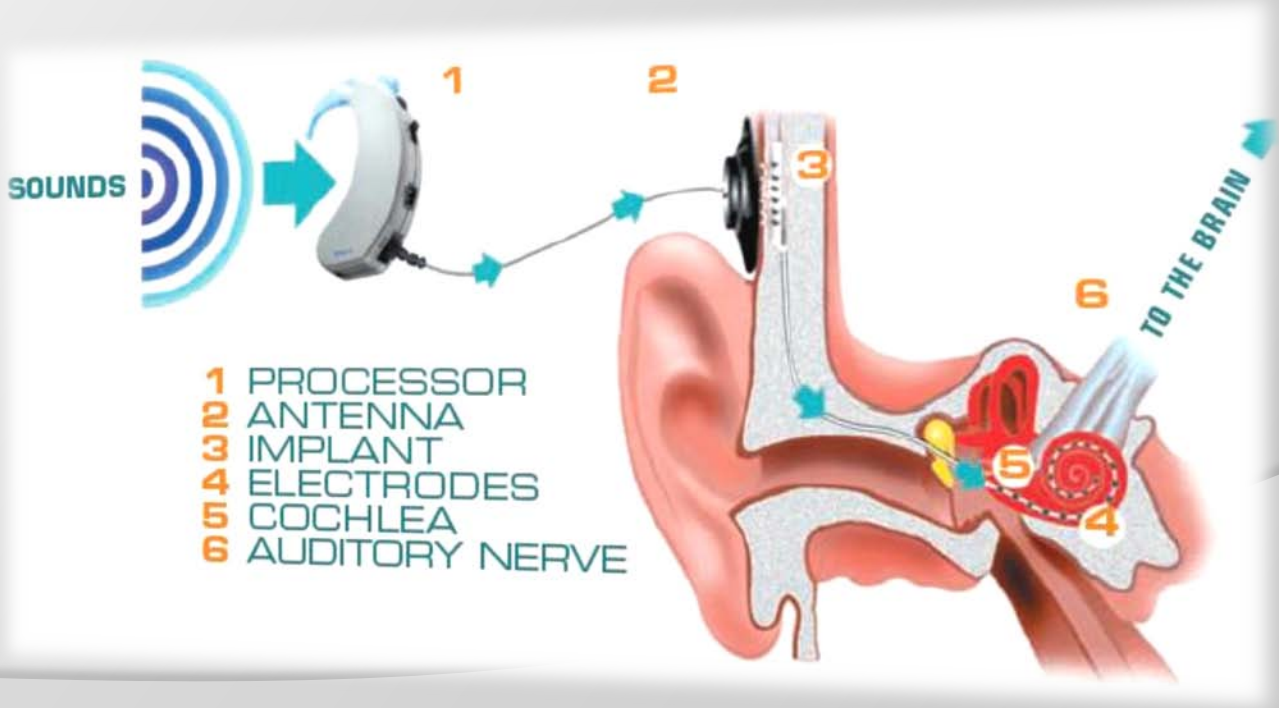
Outlines

- Introduction
- Communication for cochlear implant
- Modeling
  - Heterogeneous Simulation Framework
  - Channel and Antenna Modeling and simulation
  - Transmitter Modeling
- Implementation and Simulation Results
- Conclusion

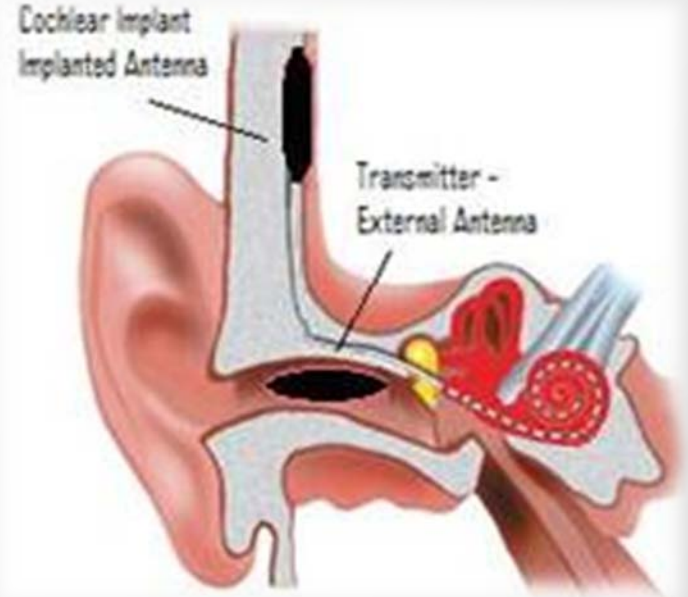
Introduction

- Severe to Profound Deafness
- Current cochlear implant: inductive system
- Visible and unattractive

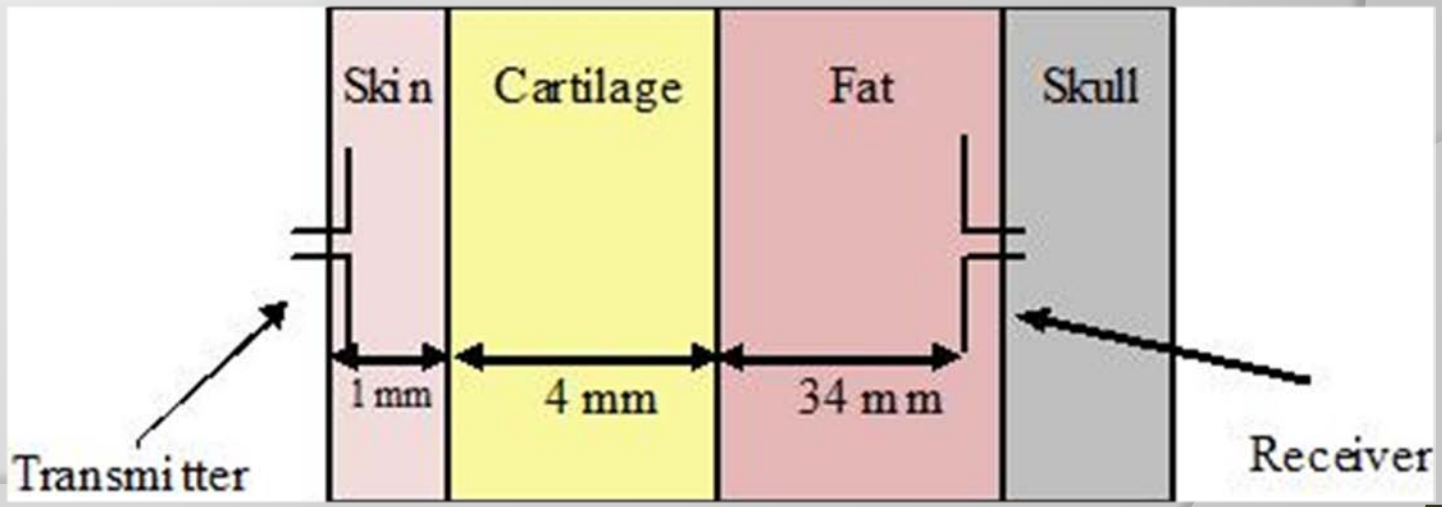


Communication for cochlear implant

Communication for cochlear implant



Equivalent Channel



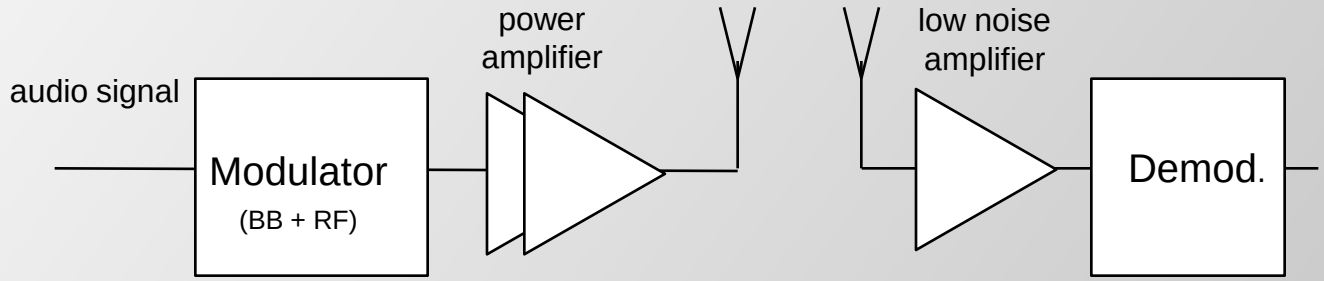
Communication for cochlear implant

- Wire connection not allowed for biomedical application => RF system
- Integration of the emitter within ear canal
  - Small Battery: low power
  - Miniature antenna
- 2.45 GHz: Good tradeoff between antenna efficiency and transmission losses

Modeling

Modeling

- Schematic:



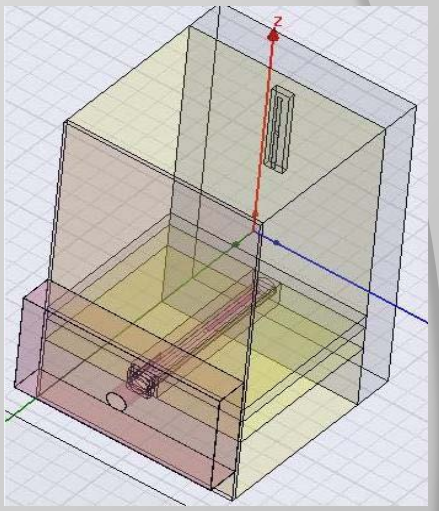
- Analog architecture fixed
- LNA sensitivity
- Transmission losses depend on patient anatomy
  - Variation of transmitted power
- Critical points: PA and Propagation Channel

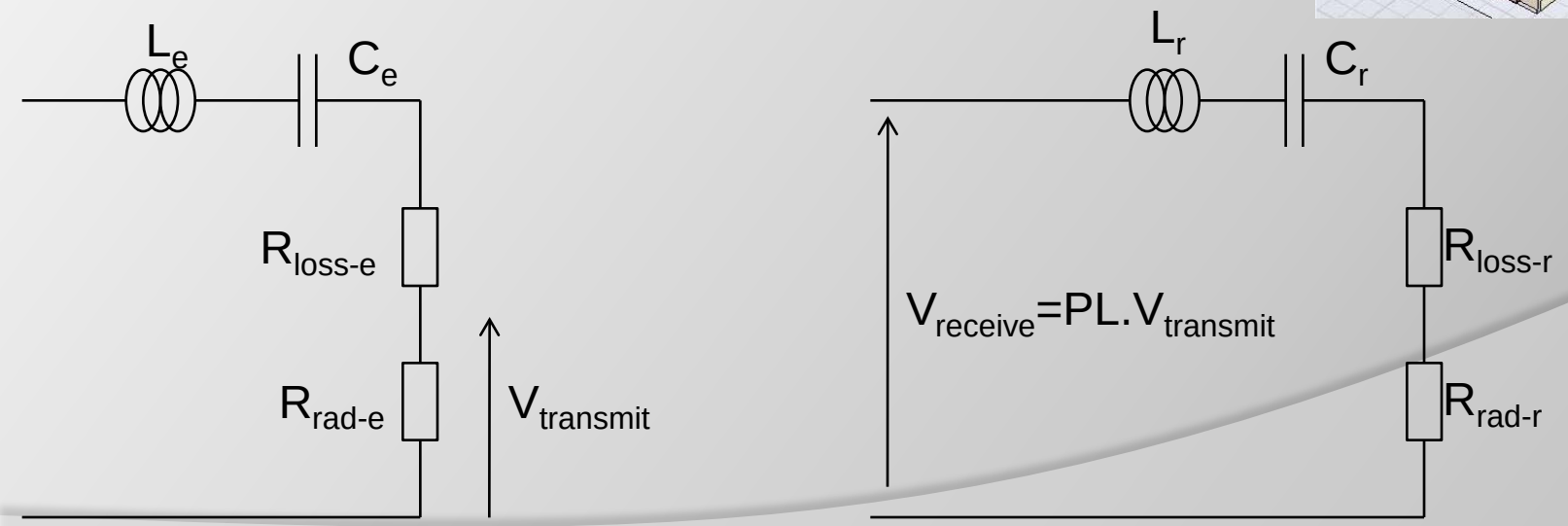
Modeling Heterogeneous Framework

- Analog and RF simulation:
  - Electrical using SPICE simulator
- Antennas and Channel:
  - Electromagnetic simulator : Ansoft HFSS
- Battery Lifetime model on Simulink

Modeling
Antenna and Channel Modeling

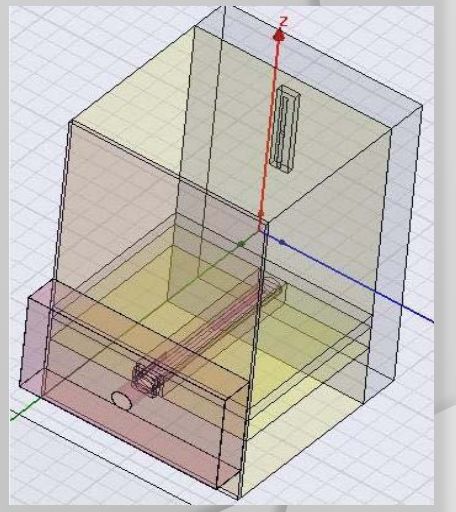
- Electromagnetic Simulation of the propagation channel
- Extraction of the equivalent circuit





Modeling
Simulation Issues

- Electromagnetic simulation:
  - Using sophisticated head phantom:
    1 week on a 2.8GHz Core2Duo 4GB RAM
  - Using equivalent medium phantom:
    1 day on a 2.8GHz Core2Duo 4GB RAM



- Analytical model:

$$\varepsilon_{eq} = \frac{\varepsilon_{skin}.t_{skin} + \varepsilon_{fat}.t_{fat} + \varepsilon_{cart}.t_{cart}}{t_{skin} + t_{fat} + t_{cart}}$$

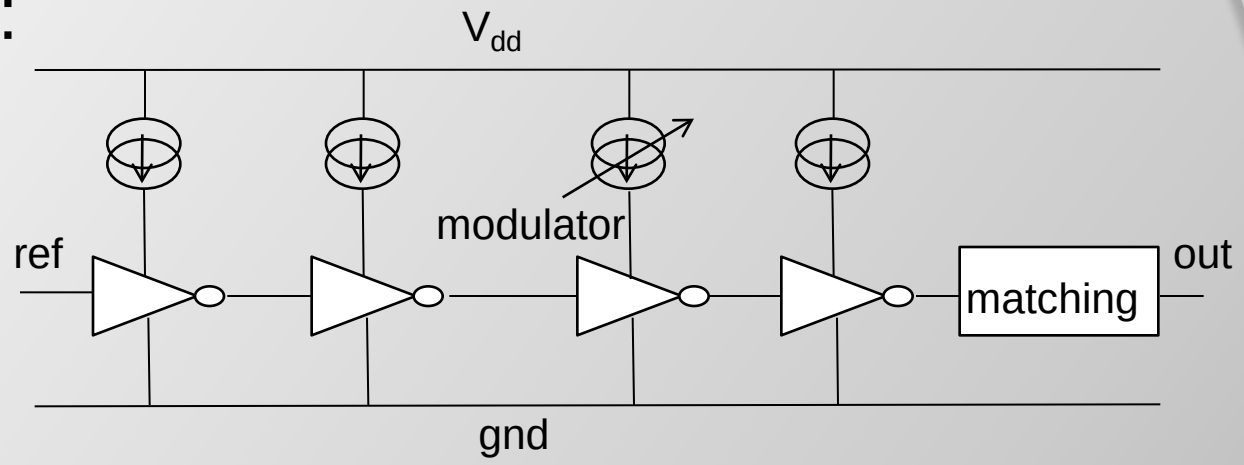
$$PL = \left(\frac{\lambda_m}{4\pi D}\right).\exp\left(-\frac{D}{\delta_{eq}}\right)$$

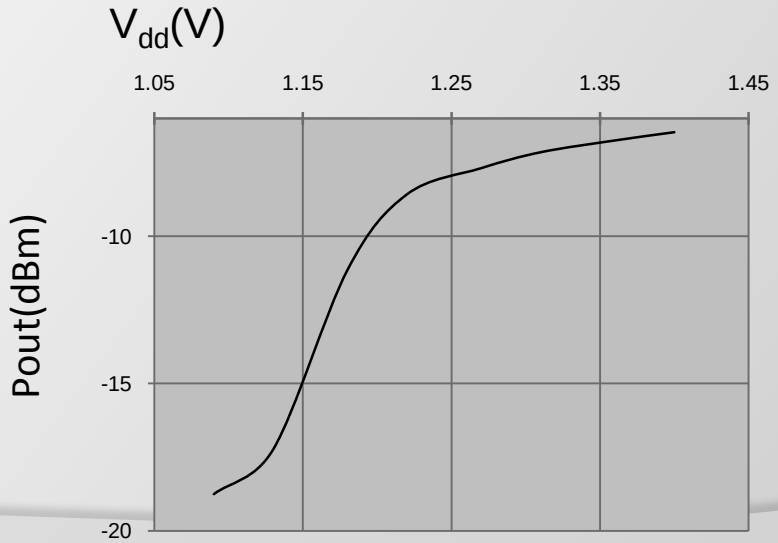
Modeling
Simulation Issues

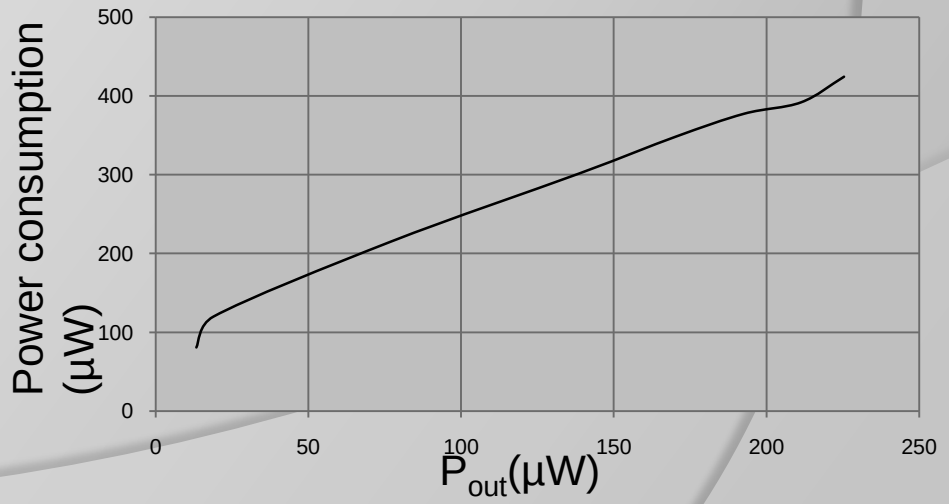
- Typical attenuation in transmission channel: 25 dB
- LNA Sensitivity: - 55 dBm (internal design)
- Losses due to antennas efficencies: - 15 dB
- Typical Transmitted Power: -15 dBm
- Channel Variation => Transmitted Power and Battery Lifetime Variations

Modeling
Transmitter Modeling

- PA Tuning:

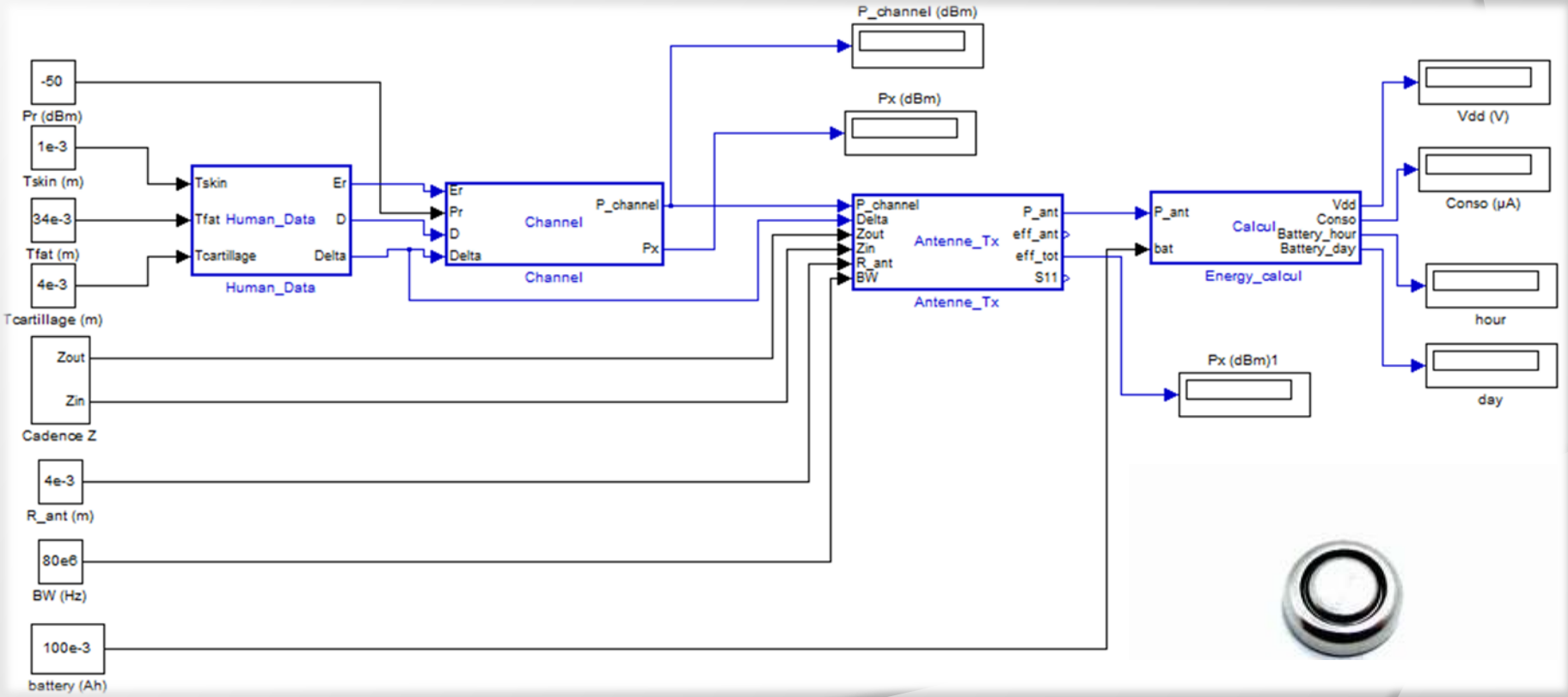






Modeling Implementation

- Battery Lifetime estimation:
- Using Simulink (also implementable in any simulator)



Results

Results

- Battery Lifetime estimation according to channel variations :

	T_{skin} (mm)	T_{cart} (mm)	T_{fat} (mm)	Loss (dB)
Best	**0.5**	**2**	**20**	**19.4**
Typical	**1**	**4**	**34**	**25.5**
worst	**2**	**6**	**50**	**30.4**

	Pt (µW)	P_{PA} (µW)	P_{tot} (µW)	Lifetime (days)
Best	**10**	**96**	**396**	**12**
Typical	**30**	**139**	**439**	**11**
Worst	**100**	**250**	**550**	**9**

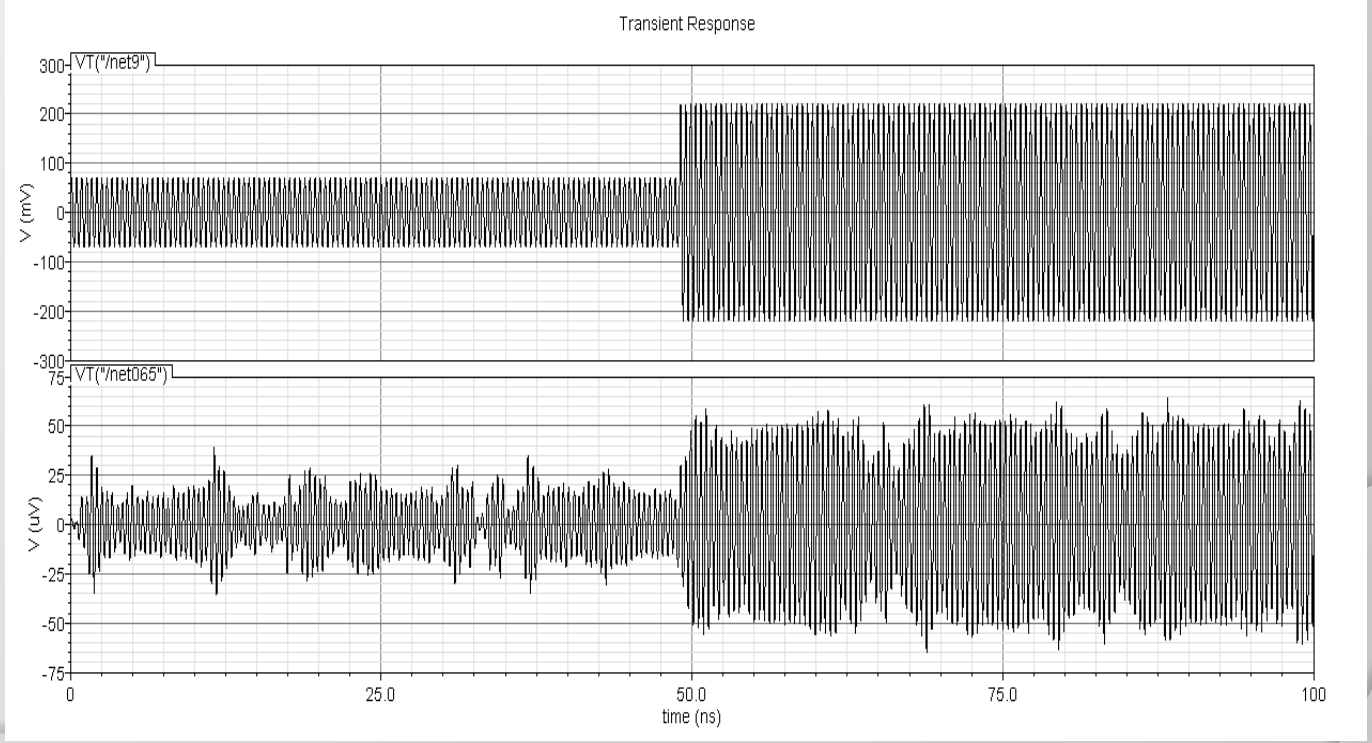
Results

- Battery Lifetime estimation according to other variations :
- Typical => 3% efficiency ; adaptation @ -20 dB

	Pt (µW)	P_{PA} (µW)	P_{tot} (µW)	Lifetime (days)
Typical	**30**	**139**	**439**	**11**
Antenna adaptation @ - 10 dB	**33**	**144**	**444**	**10.8**
Antenna adaptation @ - 6 dB	**36**	**148**	**448**	**10.7**
Antenna Efficiency x2	**15**	**115**	**415**	**11.5**

Channel noise modeling and simulation

- Worst Case
- ASK modulation: P_1/P_0 = 0 dBm /- 10 dBm
- *Noise Channel (WIFI interference): 20 dBm @ 3m*



Conclusion

- Channel losses are very important on biomedical transmission

- This model permit to:
  - Know the transmitted power necessary
  - Evaluate multiple modulation to find the better SNR
  - Optimise the bitrate with digital modulation

Thank you for your attention.

Any Questions ?