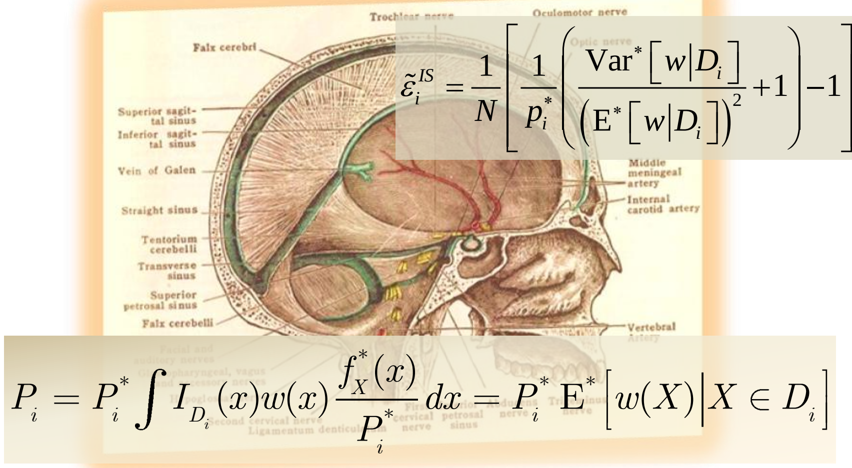
hSITE
Healthcare Support through Information Technology Enhancements



$$\tilde{\varepsilon}_i^{IS} = \frac{1}{N}\left[\frac{1}{p_i^*}\left(\frac{\mathrm{Var}^*\left[w|D_i\right]}{\left(\mathrm{E}^*\left[w|D_i\right]\right)^2}+1\right)-1\right]$$

$$P_i = P_i^* \int I_{D_i}(x)w(x)\frac{f_X^*(x)}{P_i^*}dx = P_i^*\,\mathrm{E}^*\left[w(X)\middle|X \in D_i\right]$$

Math and Skulls

the fundamental and the practical

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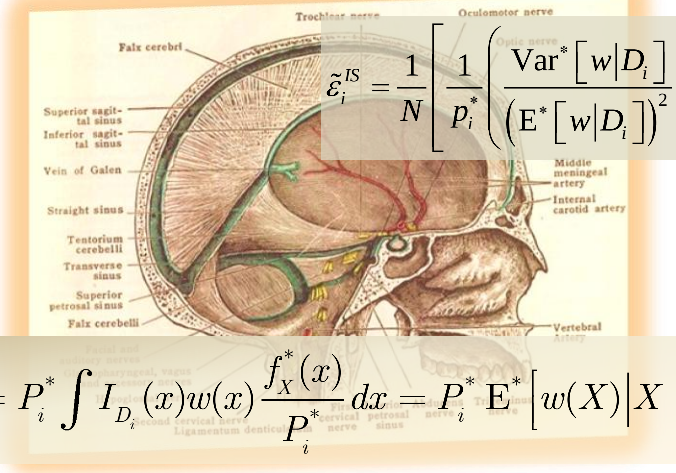
Outline



$$\tilde{\varepsilon}_i^{IS} = \frac{1}{N}\left[\frac{1}{p_i^*}\left(\frac{\mathrm{Var}^*\left[w \middle| D_i\right]}{\left(\mathrm{E}^*\left[w \middle| D_i\right]\right)^2}+1\right)-1\right]$$

$$P_i = P_i^* \int I_{D_i}(x)\, w(x)\, \frac{f_X^*(x)}{P_i^*}\, dx = P_i^*\, \mathrm{E}^*\left[w(X) \middle| X \in D_i\right]$$

- Math
  - Simulation tools for statistical analysis
  - Adaptive importance sampling
  - Convergence of Markov Chain Monte Carlo & Parallelization Multicanonical Monte Carlo
- Skulls
  - Low-power impulse radio telemetry for neuroscience applications
  - Antennas designed to operate within the skull

Research Team

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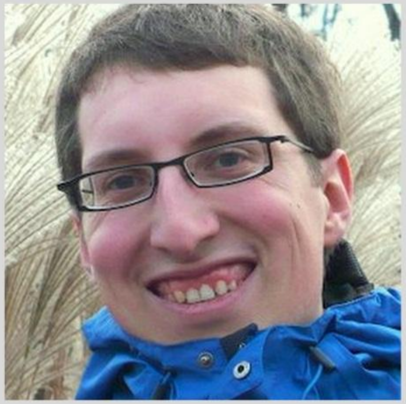
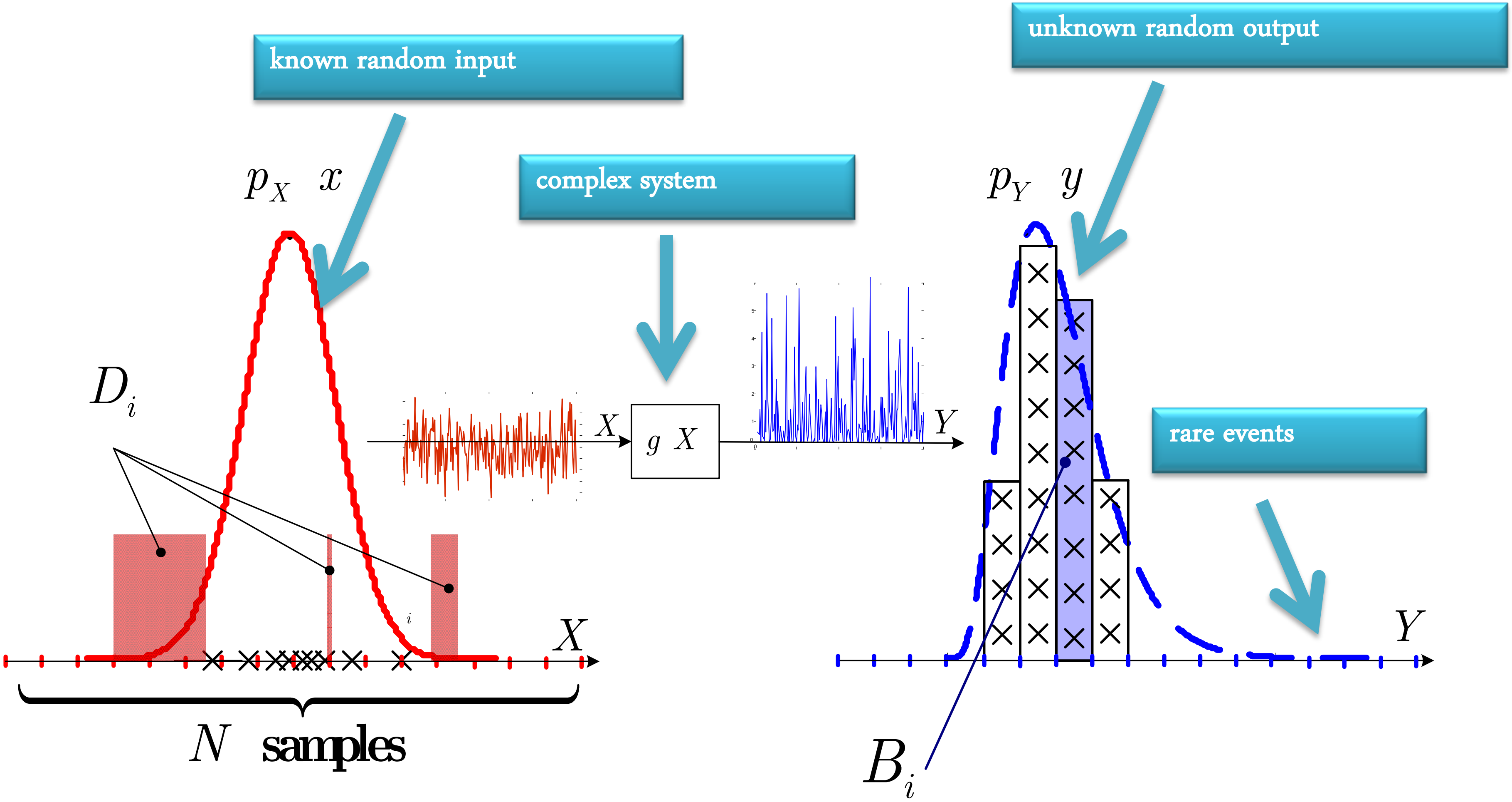
Ph.D. candidate

Hadi Bahrami
Ph.D. candidate



Charles Brunet
MSc student

Problem Statement



known random input

complex system

unknown random output

rare events

Simulating Rare Events

- Analytical solutions: fast but not generalizable
- Traditional Monte Carlo
  - Extremely general approach
  - Computationally inefficient
    - 10^{12} samples to reach 10^{-10} BER
- Importance Sampling
  - Somewhere in between on complexity
  - Not at all general
- Multicanonical Monte Carlo
  - Adaptive importance sampling

instantaneous

Analytical

10^6 samples

MMC

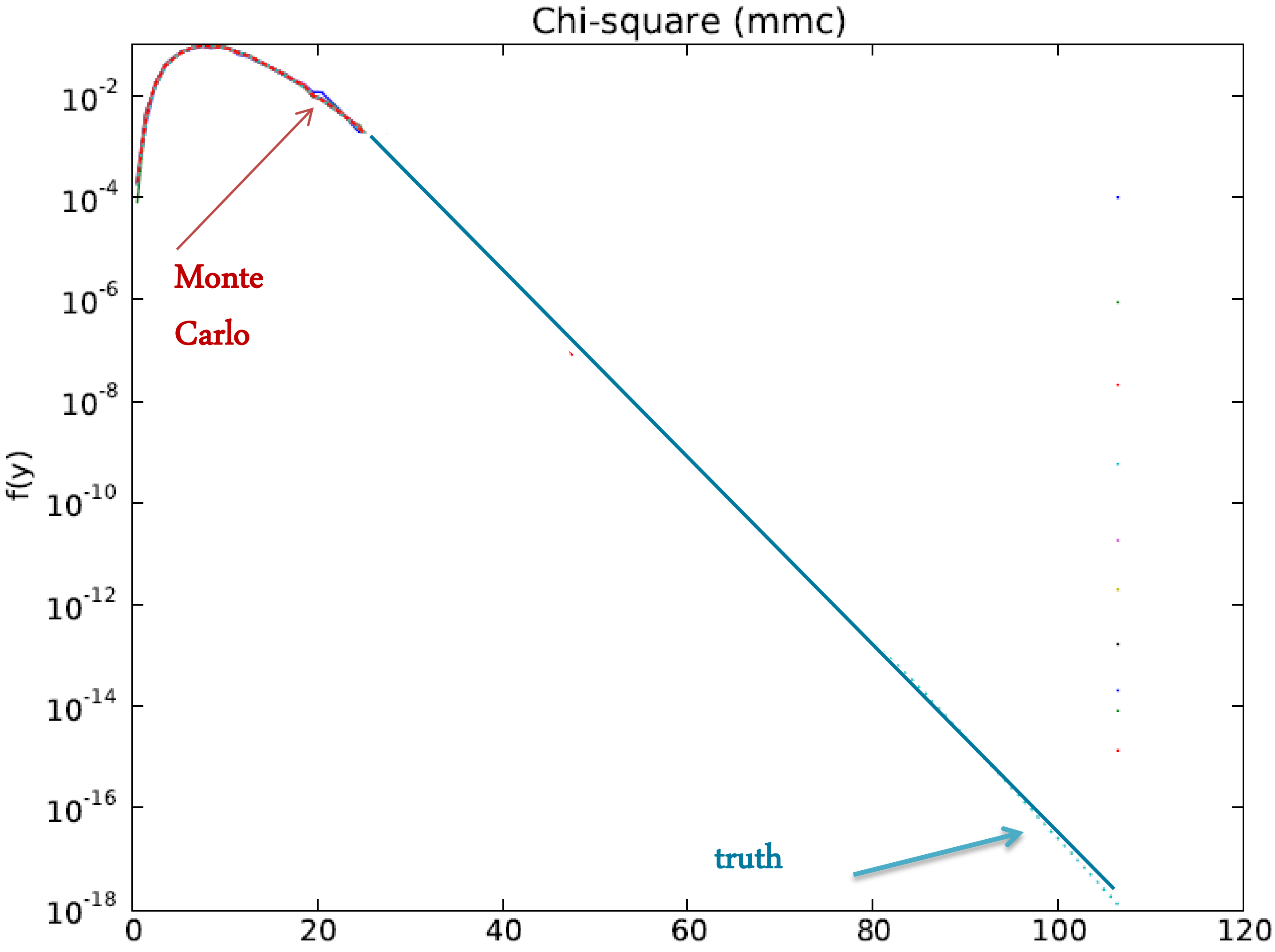
general

10^{12} samples

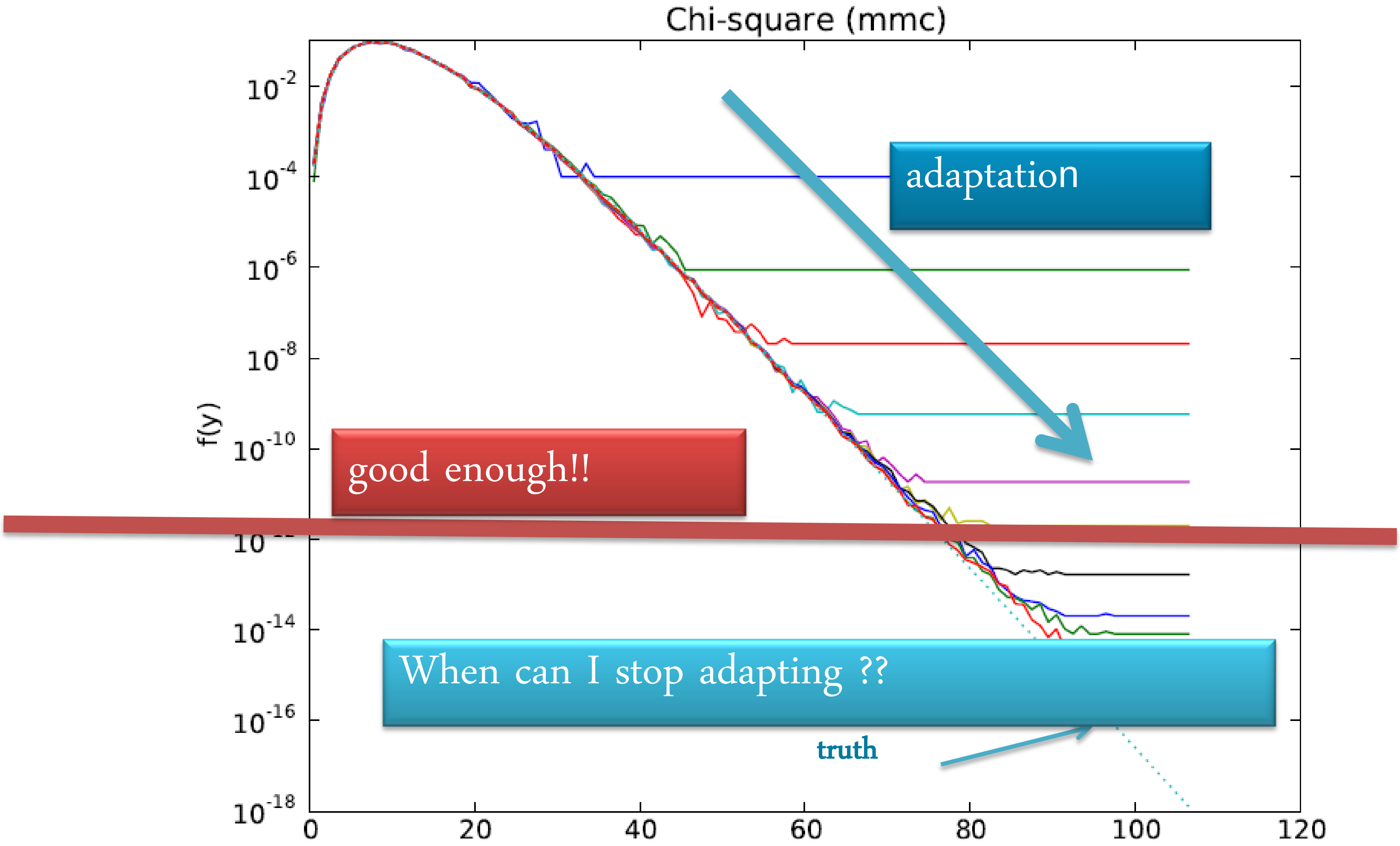
MC

general

Toy Problem


Chi-square (mmc)
f(y)
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
10^-14
10^-16
10^-18
0
20
40
60
80
100
120
Monte
Carlo
truth

Toy Problem



adaptation

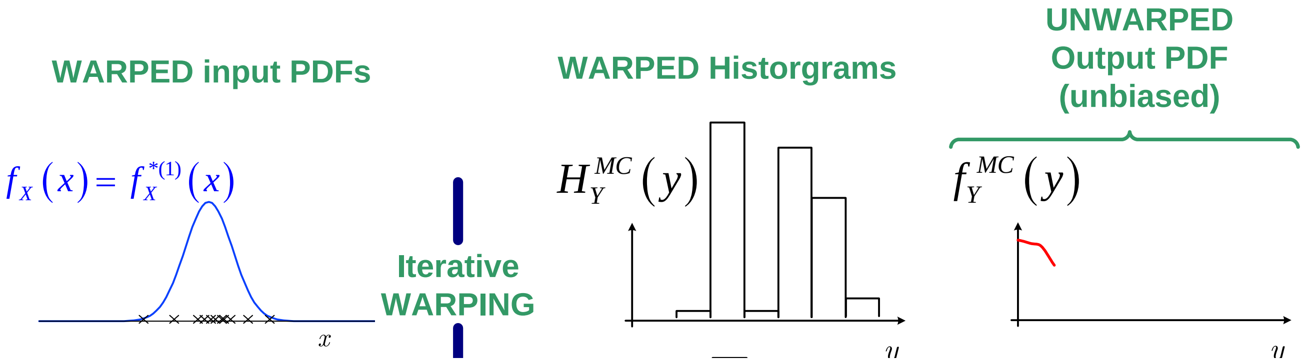
good enough!!

When can I stop adapting ??

truth

Adaptation

Multicanonical Monte Carlo (MMC)



WARPED input PDFs

$f_X(x) = f_X^{*(1)}(x)$

Iterative WARPING

WARPED Historgrams

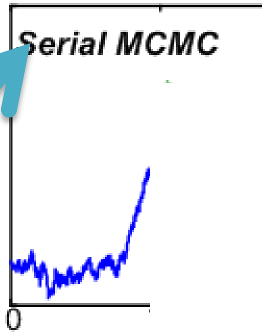
$H_Y^{MC}(y)$

UNWARPED Output PDF (unbiased)

$f_Y^{MC}(y)$

“weird” distributions

Parallelization of MMC



great for “weird” distributions!

Given multiple uncertainties on convergence, how to capture efficiency of parallelization???

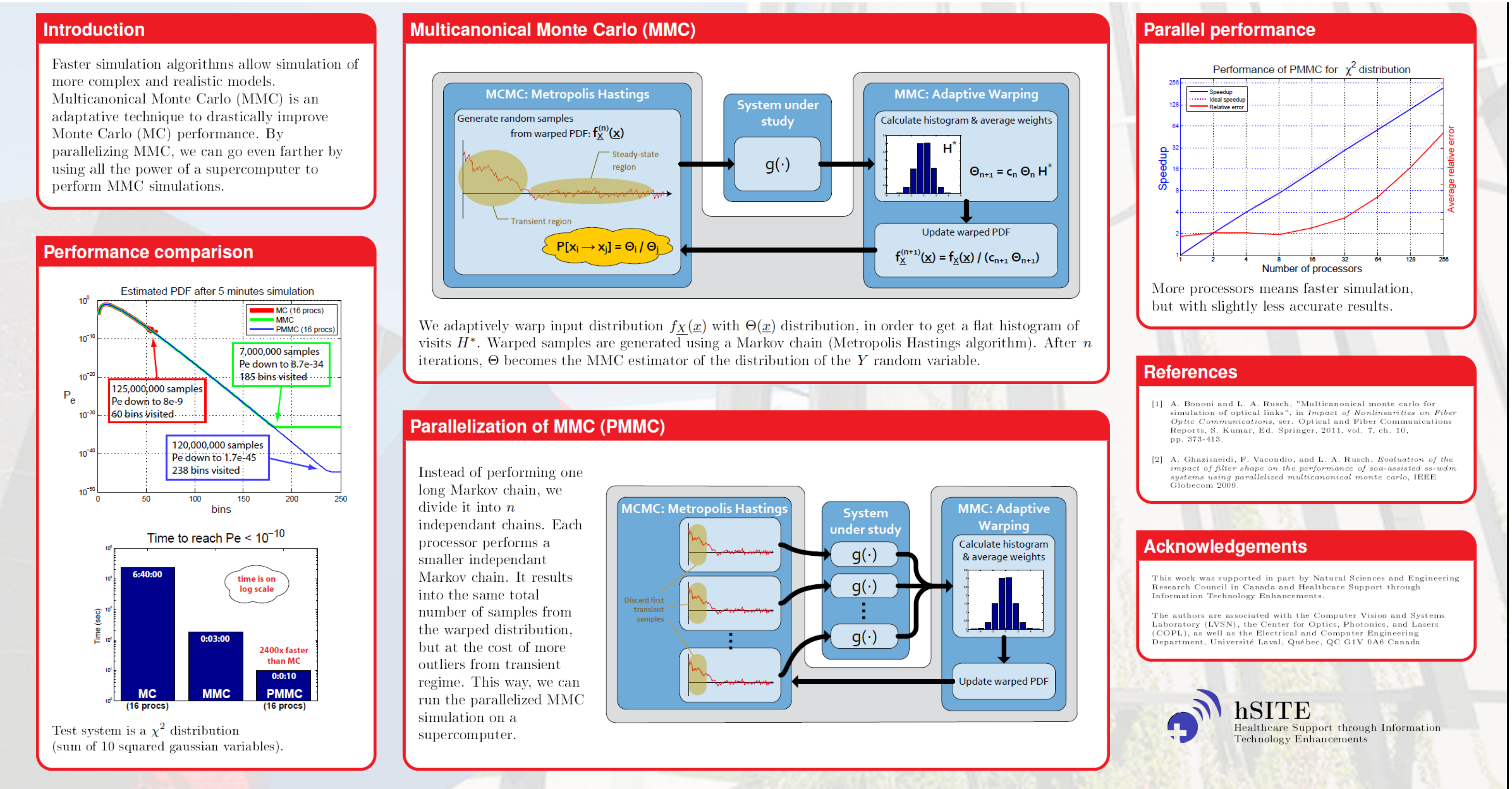
Challenges

- Capturing convergence
  - When you know the right answer
  - When “truth” is NOT known

- Quantifying Efficiency
  - When you know the right answer
  - How results vary with the system under test

Poster

- Charles Brunet



Introduction

Faster simulation algorithms allow simulation of more complex and realistic models. Multicanonical Monte Carlo (MMC) is an adaptative technique to drastically improve Monte Carlo (MC) performance. By parallelizing MMC, we can go even farther by using all the power of a supercomputer to perform MMC simulations.

Performance comparison

Test system is a χ^2 distribution (sum of 10 squared gaussian variables).

Multicanonical Monte Carlo (MMC)

We adaptively warp input distribution $f_X(x)$ with $\Theta(x)$ distribution, in order to get a flat histogram of visits H^*. Warped samples are generated using a Markov chain (Metropolis Hastings algorithm). After n iterations, Θ becomes the MMC estimator of the distribution of the Y random variable.

Parallelization of MMC (PMMC)

Instead of performing one long Markov chain, we divide it into n independant chains. Each processor performs a smaller independant Markov chain. It results into the same total number of samples from the warped distribution, but at the cost of more outliers from transient regime. This way, we can run the parallelized MMC simulation on a supercomputer.

Parallel performance

More processors means faster simulation, but with slightly less accurate results.

References

[1] A. Bononi and L. A. Rusch, "Multicanonical monte carlo for simulation of optical links", in *Impact of Nonlinearities on Fiber Optic Communications*, ser. Optical and Fiber Communications Reports, S. Kumar, Ed. Springer, 2011, vol. 7, ch. 10, pp. 373-413.

[2] A. Ghazisaeidi, F. Vacondio, and L. A. Rusch, *Evaluation of the impact of filter shape on the performance of soa-assisted ss-wdm systems using parallelized multicanonical monte carlo*, IEEE Globecom 2009.

Acknowledgements

This work was supported in part by Natural Sciences and Engineering Research Council in Canada and Healthcare Support through Information Technology Enhancements.

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Background

- *Proceedings of the IEEE*

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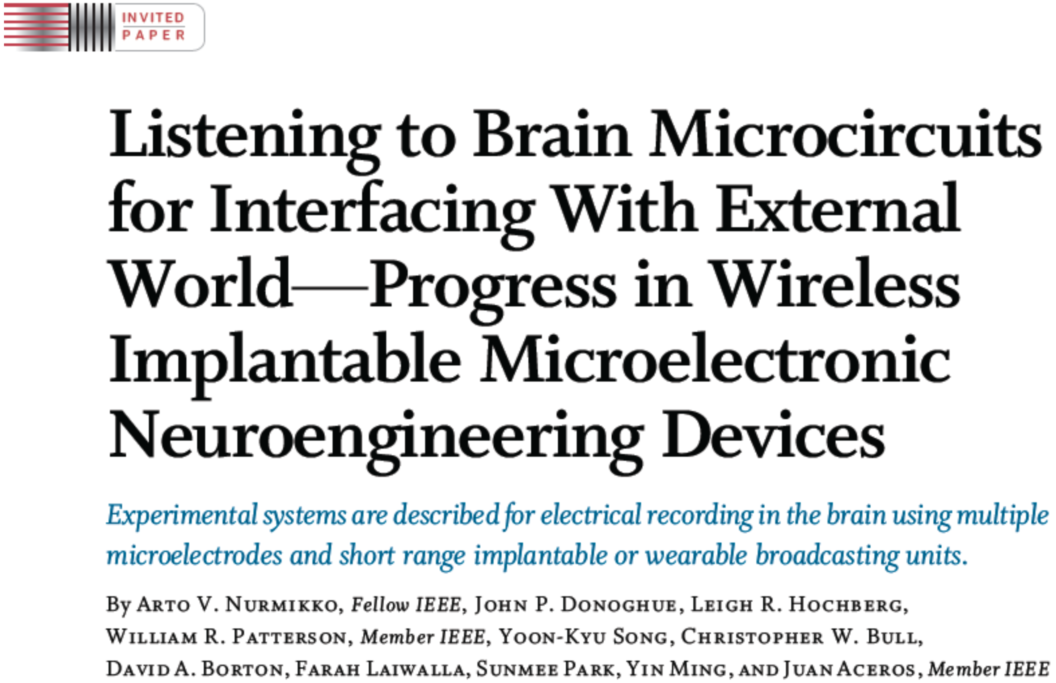
pp. 375-388



INVITED PAPER

Listening to Brain Microcircuits for Interfacing With External World—Progress in Wireless Implantable Microelectronic Neuroengineering Devices

Experimental systems are described for electrical recording in the brain using multiple microelectrodes and short range implantable or wearable broadcasting units.

By Arto V. Nurmikko, *Fellow IEEE*, John P. Donoghue, Leigh R. Hochberg, William R. Patterson, *Member IEEE*, Yoon-Kyu Song, Christopher W. Bull, David A. Borton, Farah Laiwalla, Sunmee Park, Yin Ming, and Juan Aceros, *Member IEEE*

Research Trends

- High density sensors
  - 100 per array
  - Single neural cell resolution
  - 100 signals to capture & transmit
- Tethered vs. untethered

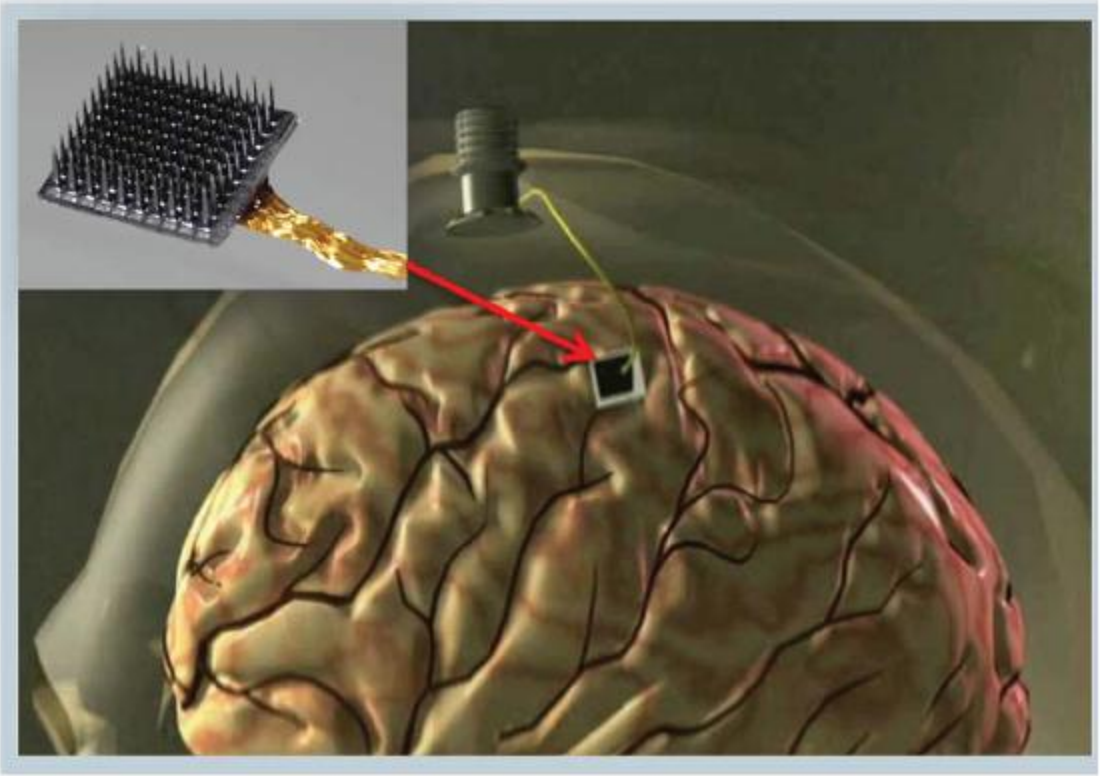
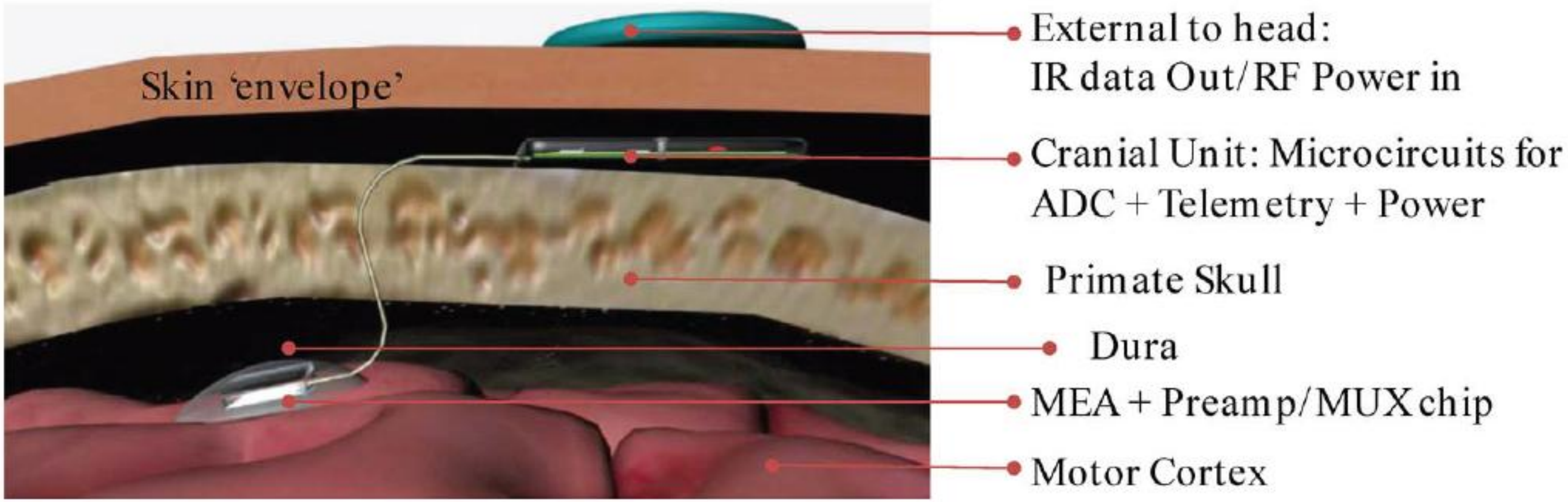


Fig. 1. *A silicon-based cortical microelectrode array (inset); implanted for intracortical neural microcircuit recording via a percutaneous connection to a skull mounted pedestal connector (main figure schematic).*

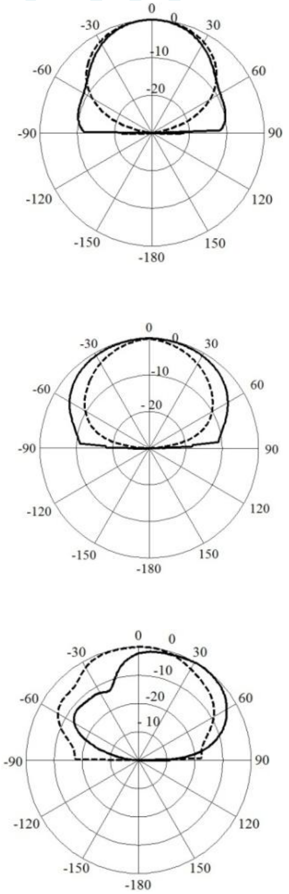
Antenna Placement

- Transition from infrared to radio signals
  - No ”line of sight” required
- Antenna instead of VCSELS
  - Ideally under skull
  - Under skin is a practical compromise



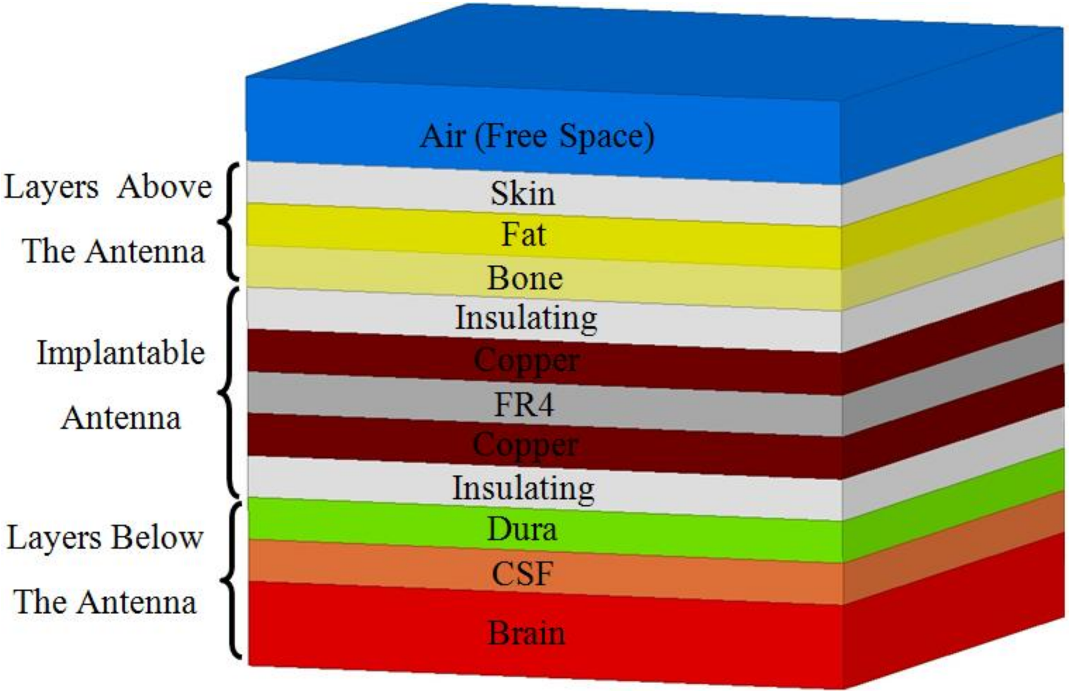
Antennas for the brain …

- Model the channel from inside skull to an outside body receiver
- Design antenna arrays for UWB transmissions
- Avoid tissue damage while increasing bit rate of transmissions

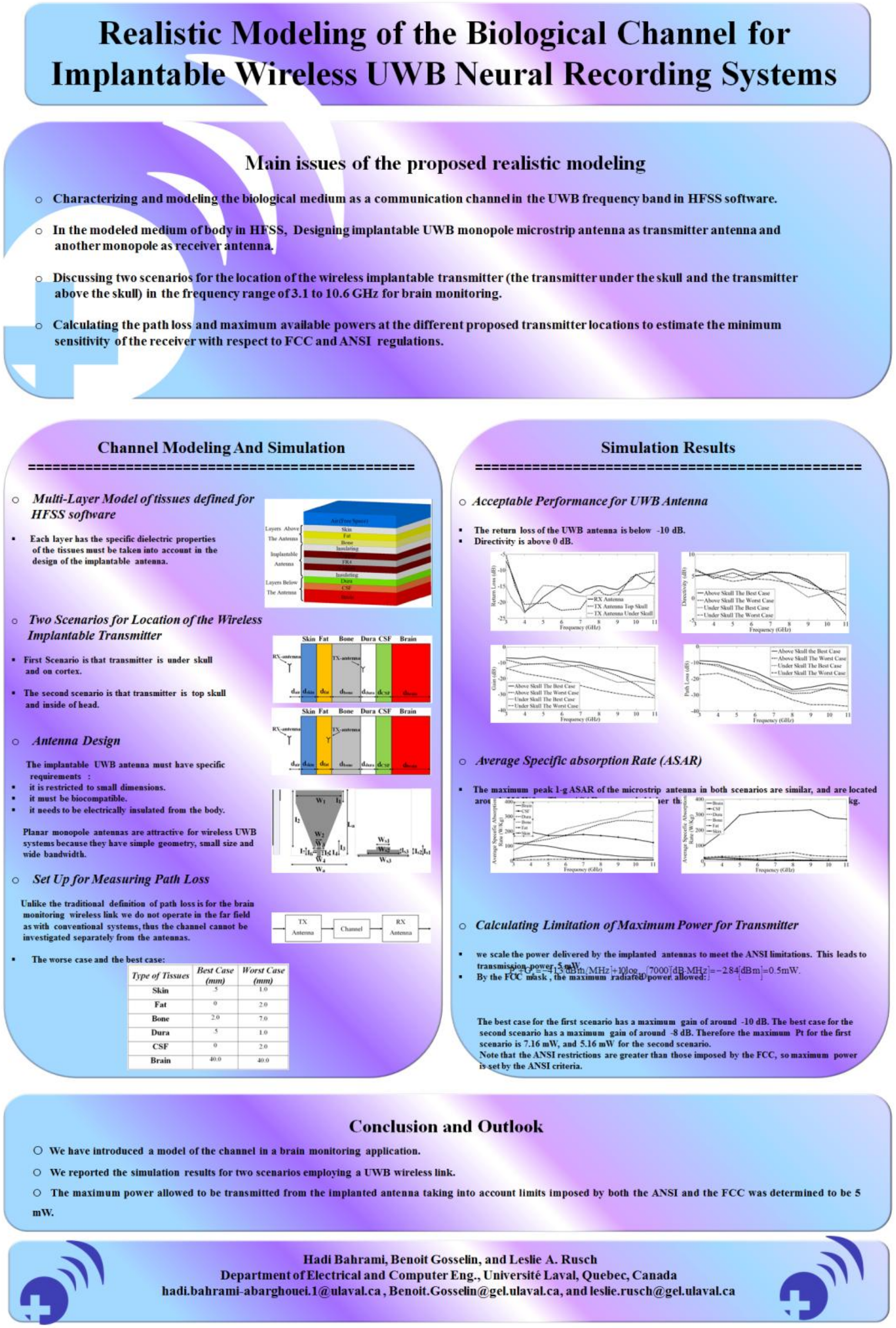


antenna performance

modeling RF propagation in the skull



Poster



Realistic Modeling of the Biological Channel for Implantable Wireless UWB Neural Recording Systems

Main issues of the proposed realistic modeling

- Characterizing and modeling the biological medium as a communication channel in the UWB frequency band in HFSS software.
- In the modeled medium of body in HFSS, Designing implantable UWB monopole microstrip antenna as transmitter antenna and another monopole as receiver antenna.
- Discussing two scenarios for the location of the wireless implantable transmitter (the transmitter under the skull and the transmitter above the skull) in the frequency range of 3.1 to 10.6 GHz for brain monitoring.
- Calculating the path loss and maximum available powers at the different proposed transmitter locations to estimate the minimum sensitivity of the receiver with respect to FCC and ANSI regulations.

Channel Modeling And Simulation

Multi-Layer Model of tissues defined for HFSS software

- Each layer has the specific dielectric properties of the tissues must be taken into account in the design of the implantable antenna.

Two Scenarios for Location of the Wireless Implantable Transmitter

- First Scenario is that transmitter is under skull and on cortex.
- The second scenario is that transmitter is top skull and inside of head.

Antenna Design

The implantable UWB antenna must have specific requirements :

- it is restricted to small dimensions.
- it must be biocompatible.
- it needs to be electrically insulated from the body.

Planar monopole antennas are attractive for wireless UWB systems because they have simple geometry, small size and wide bandwidth.

Set Up for Measuring Path Loss

Unlike the traditional definition of path loss is for the brain monitoring wireless link we do not operate in the far field as with conventional systems, thus the channel cannot be investigated separately from the antennas.

- The worse case and the best case:

Type of Tissues	Best Case (mm)	Worst Case (mm)
Skin	.5	1.0
Fat	0	2.0
Bone	2.0	7.0
Dura	.5	1.0
CSF	0	2.0
Brain	40.0	40.0

Simulation Results

Acceptable Performance for UWB Antenna

- The return loss of the UWB antenna is below -10 dB.
- Directivity is above 0 dB.

Average Specific absorption Rate (ASAR)

- The maximum peak 1-g ASAR of the microstrip antenna in both scenarios are similar, and are located aro [illegible] her th [illegible] kg.

Calculating Limitation of Maximum Power for Transmitter

- we scale the power delivered by the implanted antennas to meet the ANSI limitations. This leads to transmission power 5 mW.
- By the FCC mask , the maximum radiated power allowed:

$P_t + G_t = -41.3[\mathrm{dBm/MHz}] + 10\log_{10}[7000][\mathrm{dB{\cdot}MHz}] = -2.84[\mathrm{dBm}] = 0.5\mathrm{mW}.$

The best case for the first scenario has a maximum gain of around -10 dB. The best case for the second scenario has a maximum gain of around -8 dB. Therefore the maximum Pt for the first scenario is 7.16 mW, and 5.16 mW for the second scenario.
Note that the ANSI restrictions are greater than those imposed by the FCC, so maximum power is set by the ANSI criteria.

Conclusion and Outlook

- We have introduced a model of the channel in a brain monitoring application.
- We reported the simulation results for two scenarios employing a UWB wireless link.
- The maximum power allowed to be transmitted from the implanted antenna taking into account limits imposed by both the ANSI and the FCC was determined to be 5 mW.

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- Antenna design results (simulation)
  - under skull and on cortex
  - top skull and inside head