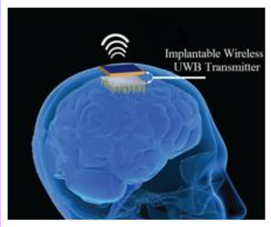
Realistic Modeling of the Biological Channel for Implantable Wireless UWB Neural Recording Systems

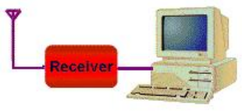
Main issues of the proposed realistic modeling

Several emerging medical applications require that a miniature data acquisition device be implanted into the head to extract and wirelessly communicate brain activity to other devices. Designing a reliable communication link for such an application requires a realistic model of the surrounding biological tissues.

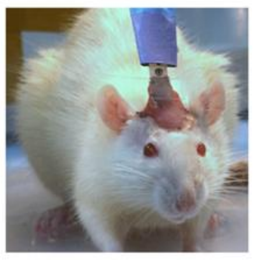
- **Characterizing and modeling the biological medium as a communication channel in the UWB frequency band in HFSS software.**
- **In the modeled medium of body in HFSS, Designing implantable UWB monopole microstrip antenna as transmitter antenna and another monopole as receiver antenna.**
- **Discussing 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.**



Patient



External Receiver



Animal Research

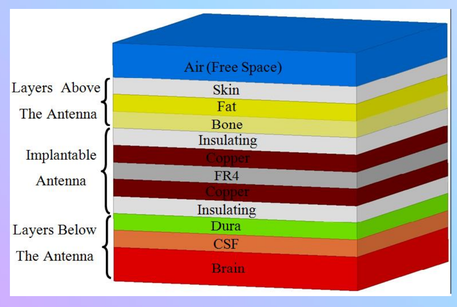
Assistive Technology

Channel Modeling And Simulation

➢ ***The antenna design inside body is different of free space!!***

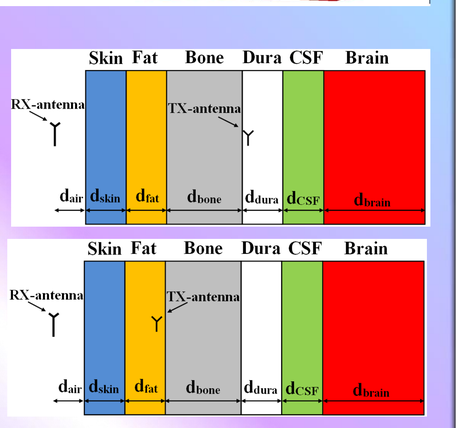
- ***Multi-Layer Model of tissues defined for HFSS software***

  - **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.**

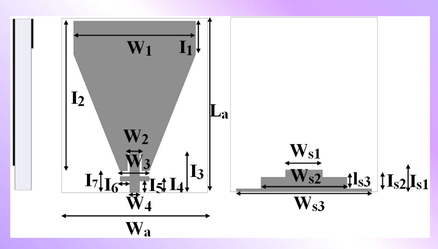


- ***Antenna Design***

The implantable UWB antenna must have specific requirements :

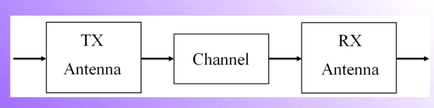
- **it is restricted to small dimensions.**
- **it must be biocompatible.**
- **it needs to be electrically insulated from the body.**

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.



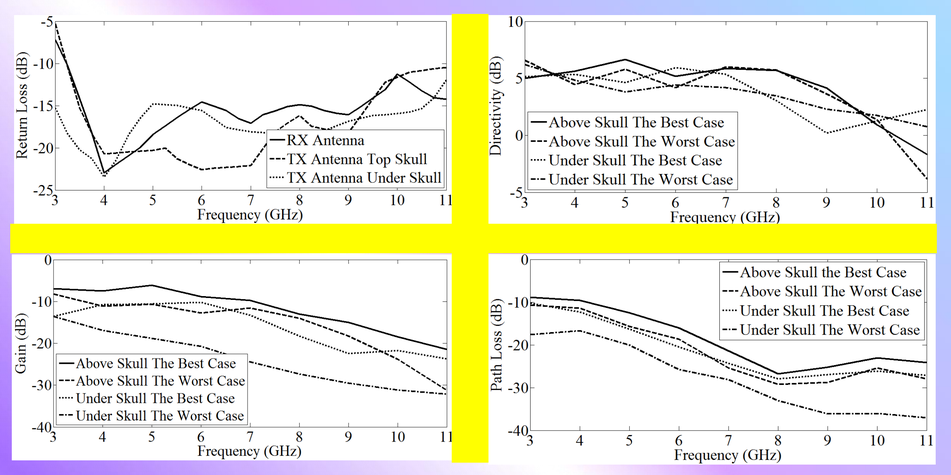
- **The worse case and the best case:**

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

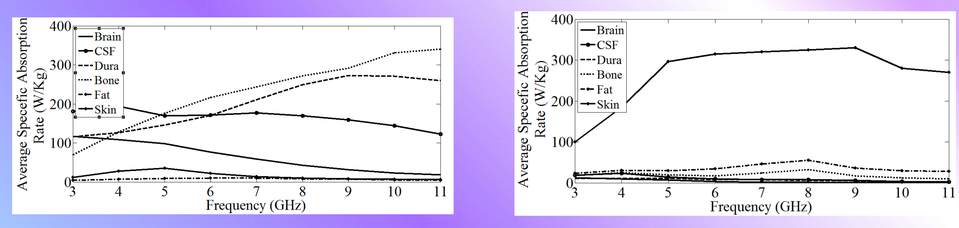
- ***Acceptable Performance for UWB Antenna***

  - **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 around 320 W/kg. These ASARs are much higher than the regulated ANSI limitation of 1.6 W/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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Reference:
1) Hadi Bahrami, Benoit Gosselin, and Leslie A. Rusch, "Design of a Miniaturized UWB Antenna Optimized for Implantable Neural Recording Systems", accepted for NEWCAS Conference in Montreal, Canada.
2) Hadi Bahrami, Benoit Gosselin, and Leslie A. Rusch," Realistic Modeling of the Biological Channel for the Design of Implantable Wireless UWB Communication Systems", submitted for The 34th Annual International Conference of EMBC in San Diego, California, USA.