Fully-Passive Matching Between Wireless Brain Implants and High-Impedance Electrode Interfaces

Wei-Chuan Chen and Asimina Kiourti
Electrocience Laboratory, Electrical and Computer Eng. Dept.
The Ohio State University, Columbus, OH, 43212

Deep brain neuropotential monitoring is offering unprecedented opportunities for patients with epilepsy, Alzheimer's, Parkinson's, etc. Traditional neuro-sensing technologies employ intra-cranial wires that hinder lifestyle and comfort and are prone to infections. Wireless implants have been reported instead, but they require batteries for operation. As an alternative, we recently introduced a new class of wireless and fully-passive brain implants. Indeed, our latest work (Lee et. al, IEEE AWPL, 2016) demonstrated a single-channel batteryless brain implant that occupied a footprint of only $10mm \times 9mm$, and exhibited sensitivity as high as $20\mu Vpp$ in *in-vitro* settings. This was an improvement of up to 25 times in sensitivity compared to previous works.

However, the input impedance of our aforementioned implant was set to 50Ω so as to match the impedance of the function generator that emulated the brain neuropotentials. But impedances of real electrodes implanted into the human brain can be as high as $4K\Omega$ to $1M\Omega$. This mismatch between our 50Ω implant and the high-impedance electrode interface implies significant deterioration in sensitivity under realistic testing conditions. To address this challenge, we herewith present the first-ever fully-passive and wireless brain implant that is concurrently matched to its associated high-impedance electrode interface.

The proposed impedance-matched neuropotential system combines wireless RF backscattering techniques with a common-emitter NPN/PNP BJT pair (CE-BJT). First, an exterior interrogator sends a 2.4 GHz carrier towards the implant. The carrier signal is rectified by an implanted RF diode that generates a DC current to bias and turn on the CE-BJT. Subsequently, the neural signals pass through the CE-BJT and are mixed with the 2.4 GHz carrier (via the RF diode) to generate third-order mixing products at $4.8GHz \pm f_{neuro}$. The latter are then transmmited back to the exterior interrogator and demodulated to obtain the desired neuropotentials at f_{neuro}. Since the CE-BJT has much larger input impedance than the RF diode alone, it can boost the overall input impedance of the implant.

A proof-of-concept impedance-matched brain implant has already been fabricated and tested. At this stage, our implant occupies a footprint of only $40mm \times 40mm$, and integrates a common emitter NPN/PNP BJT pair. *In-vitro* testing has been performed using a multilayer head phantom, demonstrating that the impedance could be matched up to $56K\Omega$ while under $200\mu Vpp$ signal level. The exterior interrogator was placed right outside the scalp. In future, it will eventually be integrated into a hat/cap for unobtrusive operation. At the conference we will present further details on the system design and circuit analysis, as well as *in-vitro* measurement results.