A Multi-Channel Passive Brain Implant for Wireless Neuropotential Monitoring

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Deep brain neuropotential monitoring can significantly improve the well-being of individuals with epilepsy, Parkinson's, Alzheimer's, prosthetics, etc. Conventional neuropotential technologies employ intra-cranial wires that hinder lifestyle and comfort and are prone to infections. With this in mind, wireless brain implants are recently being explored. However, several challenges still need to be addressed before wireless brain implants can be employed in clinical settings, including 1) elimination of batteries that require replacement and/or recharging, 2) miniature footprint, 3) simplified electronics that generate minimal amounts of heat to the surrounding tissues, and 4) multi-channel operation.

Our recent work demonstrated a single-channel batteryless brain implant that addressed the first three of the aforementioned challenges (Lee et. al, IEEE AWPL, 2016). Our single-channel implant occupied a footprint of only 10mm×9mm, and was demonstrated to record neuropotentials as low as 20 μV_{pp} in *in-vitro* settings. This was an improvement of up to 25 times in sensitivity compared to previous works. In this work, we build on our previous accomplishments, and present a multi-channel passive wireless neuropotential monitoring system that addresses all four challenges mentioned above. Notably, this is the first ever implementation of a multi-channel brain implant with near zero power consumption.

The proposed multi-channel neuropotential system combines wireless RF backscattering techniques with an infrared-based implanted multiplexer to enable the desired functionality. System operation may be summarized as follows. First, an exterior interrogator sends a 2.4 GHz carrier along with an infrared signal towards the implant. The former serves to activate the implant, while the latter sequentially selects the desired channel where neuropotentials will be recorded from (f_{neuro}). Subsequently, mixing occurs within the implant using a very-low-loss Anti-Parallel-Diode-Pair (APDP) mixer to generate 4.8GHz$\pm f_{neuro}$. This signal is transmitted back to the exterior interrogator and eventually demodulated to obtain the desired neuropotentials. The same process is iteratively repeated, channel by channel.

A proof-of-concept multi-channel brain implant has already been designed and tested. At this stage, our implant occupies a miniature footprint of only 20mm×20mm, and integrates a 3-photodiode multiplexer that serves to implement 8 (2^3) channels. *In-vitro* testing has been performed using a multi-layer head phantom, demonstrating sensitivity as high as 20 μV_{pp} for all 8 channels. 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 link budget, as well as *in-vitro* measurement results.