Broadband Wireless Neural Recording System for Freely Moving Subjects

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A miniaturized head-mounted wireless neural recording device was developed for untethered freely moving laboratory animal research and future human clinical use. The device simultaneously provides 96-channel of broadband neural data at 20kSps/ch from an array of intracortical microelectrode arrays (MEA) along with 3 channels of xyz accelerometer signals. These signals were wirelessly transmitted by an ultralow power RF transmitter ASIC with tunable frequency from 3GHz to 4GHz driving a miniature fractal chip antenna. The entire wireless neural recording device was implemented on two custom designed printed circuit boards. A custom designed polyoxymethylene (POM) enclosure was developed to house the electronics while taking the considerations of system miniaturization, electromagnetic compatibility (EMC) safety, and sterilization compatibility for both animal and human clinical applications. The entire system is powered by a 1.2Ahr 3.6V Li-SOCl₂ 1/2AA primary battery at 17mA and runs for more than 2 days. A custom 3-4GHz super heterodyne receiver was also designed to receive the wireless signal and directly interface with either custom or commercial neural signal processors for multi-channel broadband neural recording. In order to enhance the fidelity of the wireless data telemetry and truly enable wireless neural recording for freely moving test subjects, spatial diversity based single input multiple output (SIMO) wireless channel topology was implemented to reduce the multipath fading effect in a rich scattering environment. The SIMO technique improves the stability of the wireless link considerably with minimum system complexity and low power dissipation on the transmitter side, at the cost of reasonably increased complexity at the receiver side where power and size are less constrained.

As part of a potential roadmap for regulatory approval as a clinical device, this head-mounted device was specifically designed for, but not limited to, interfacing with the 510k approved NeuroPort™ MEA, as shown in the figure. As is, the wireless neural interface that incorporates the compact head-mounted device and the SIMO receiver described here is expected to significantly enrich non-human primate research, such as studies for freely moving monkeys. Verification and validation of the system have first been conducted on bench, and then in vivo on tethered non-human primates in chair while performing a center-out task. Furthermore, factor analysis was applied to multichannel neural recordings in the leg area of primary motor cortex to expose dynamics during unconstrained, tether-free locomotion on a treadmill and overground. In conjunction with wireless electromyography and motion capture technologies, we found that neural states extracted from cortical signals correlated with muscle synergies and leg kinematics across tasks and speeds. Finally, using this wireless recording system, we conducted 24-hour constant recordings of neural modulation from the hand area of the ventral premotor cortex (PMv) in freely behaving non-human primates in their home cages. This wireless recording device enables neurophysiological studies that were previously impossible under tethered conditions, such as sleep-wake pattern and unconstrained locomotion on cortical neural dynamics.