Wireless Galvanic transmission through neural tissue via modulation of a carrier signal by a passive probe

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1 Background

Existing neural recording technologies require an electrode adjoined to a skull-attached headstage or held fixed relative to a head-fixed animal. This wire limits applications of in-vivo recording due to the damage and displacement it causes. For example, recording from fragile structures such as spinal cord are particularly challenging. Wireless communication from the recording site (the ***probe***, in or near the cell(s)) to the signal processing stages (the ***headstage*** or ***waystation***) would permit recordings from fragile or moving structures, and could potentially simplify intracellular recordings from freely moving animals. Available prototypes of wireless biomedical probes require DC power or a large inductor as an antenna for a radio transceiver, producing excessive heating and limiting miniaturization. Capitalizing on the highly conductive nature of the body, intra-body based signal transmission is a potential low-power, safe, and miniaturizable alternative [1]. We have already proven the viability of using the brain as a transmission channel for carrier signals [2]. At high-frequencies (100kHz to 10MHz), this technology does not interfere with neural firing, transmitting microwatt-level signals at distances as large as 15mm through live rat brain, using 50µm-diameter Pt wire electrodes [2].

2 Methods

Here we describe a simple device with the potential to become a next-generation biomedical sensor. The key concept is to place a passive probe in line between the source of carrier signal and ground, while the voltage along an alternate path between the source and receiver is measured. This is a voltage-divider circuit dependent on the impedance of the path through the passive probe. A high-frequency alternating current is sent from the source which provides the carrier signal for the probe. By changing the probe's impedance at the carrier frequency, AM (amplitude modulated) signals are created in both branches of the circuit which can be detected by a standard AM receiver.

3 Results

We tested a passive resonant RLC circuit with voltage-variable capacitance. A biopotential of sufficient voltage across the probe changes the capacitance of this circuit, which changes its resonant frequency [3,4]. Probes were built out of discrete passive components (BB202 variable-capacitance diodes, low-profile µH inductors, and 100µm PtIr electrodes). The carrier signal was transmitted at MHz frequencies with an Agilent 33120A waveform generator. AM signals were demodulated with a commercially-available radio receiver (WiNRADiO G313i). SPICE models and tests in 0.9% physiological saline demonstrated that mV voltage and nA current modulating inputs to the RLC circuit produced detectable AM signals. *In-vivo* tests through anesthetized rat brain reliably transmitted modulating signals as small as $10mV_{rms}$. The carrier was transmitted through electrodes placed just under the skull, however, previous experiments have successfully transmitted larger carrier signals from brain to extracranial, subcutaneous electrodes [2]. Modeling suggests possible increases in sensitivity by consideration of the built-in potential of the variable-capacitance diode, and control of the spacing and orientation of the probe electrodes. Modulated passive resonance can also be achieved with a transistor and an intrinsic oscillator, using the intrinsic capacitance of the transistor as the voltage-variable element.

Because many probes can communicate with a single waystation using frequency sharing, it will be possible to record from multiple probes simultaneously. These probes should cause less damage and should allow parallel simultaneous recording from multiple structures, since they are not physically tied to a headstage. Finally, the probes should remain where they are deployed and move with the tissue, which would enable recording from fragile structures (such as spinal cord) during behavior.

References

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