

Inductive wireless power transfer for miniature rodent brain implants enabling untethered neural recordings

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Summary:

This work presents a compact inductive wireless power transfer system for miniature brain implants to be used in neural recordings of freely moving juvenile rat studies. The solution eliminates wired power connections and enables uninterrupted neural recording during natural sleep behavior. A multi-coil architecture combines a cage-embedded transmitter, an auxiliary compensation coil, and a lightweight head-mounted receiver. The system provides sustained spatially uniform power delivery under realistic misalignment conditions. Stable operation across the entire cage volume is experimentally demonstrated, facilitating long-term in vivo neuroscience experiments.

Keywords: wireless power transfer, inductive coupling, neural implants, biomedical sensors, smart cages

Background

Neural recording experiments in freely moving animals mostly rely on wired connections for power delivery and data transmission. In juvenile rat studies, implanted electrodes are fixed to the skull using dental cement and protected by a plastic head cap, while external cables restrict natural behavior and interfere with sleep patterns [1]. These constraints limit experimental validity and animal welfare.

The objective of this work is to deliver continuous wireless power to an existing miniature neural recording module incorporating an analogue front-end based on the Intan RHD2132 digital electrophysiology interface chip, an FPGA, a microcontroller with Bluetooth, power management unit, and supporting circuitry. The system is designed to operate under a strict head-mounted mass constraint of less than 5 g, while ensuring robust power delivery across unrestricted movement inside the cage.

Numerous studies have investigated inductive wireless power transfer for implantable systems using different coil geometries and circuit architectures. Representative approaches include the works of Jow et al. (2014) and Jia et al. (2016), which are summarized in the comparative table in the following [1], [2]. In both cases, flat planar coils are employed, making the power transfer

efficiency highly sensitive to angular misalignment between the transmitter and receiver.

Experimental methods and results

The proposed wireless power transfer system consists of three inductively coupled elements:

1. A helical rectangular transmitter coil is integrated into the animal cage and coupled to a driver coil to improve the effective quality factor.
2. An auxiliary coil is positioned beneath the cage floor to compensate for coupling degradation and eliminate identified power blind spots.
3. A compact two-part receiver coil mounted on top of the implant head cap with a total mass below 3 g.

The system operates at 6.78 MHz and is engineered to provide spatially robust power transfer across the animal's free-moving range. Coil geometries and resonant circuits were optimized to reduce impedance mismatch and maintain power transfer efficiency under lateral displacement and angular misalignment.

Experimental measurements were performed at 20 points within the cage in four heights: 0, 36, 56, and 101 mm at 0°, 45° and 90° angles. The results confirm stable power delivery throughout the cage volume. A maximum power transfer

efficiency of 12% and a peak delivered load of 19.6 mW were achieved, sufficient for continuous operation of the implant electronics. The inclusion of the auxiliary coil significantly improved spatial uniformity and reduced sensitivity to misalignment, enabling unrestricted animal movement without power dropout.

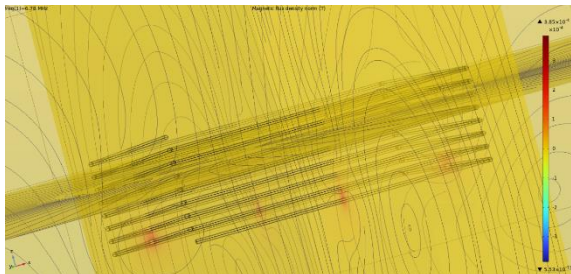


Fig. 1 Electromagnetic field distribution at 6.78 MHz obtained from 3D COMSOL simulations.

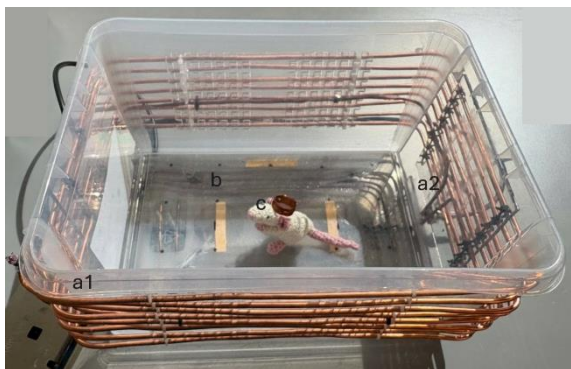


Fig. 2 System overview: (a1) cage-integrated helical transmitter coil, (a2) driver coil, (b) auxiliary coil below the cage floor, and (c) two-part receiver coil mounted on the implant cap.

Results

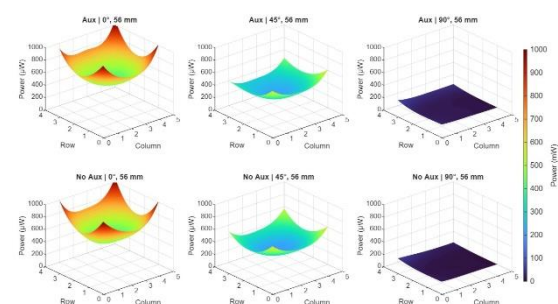


Fig. 3 Measured 3D power distribution inside the cage at a height of 56 mm at three angles with and without the auxiliary coil.

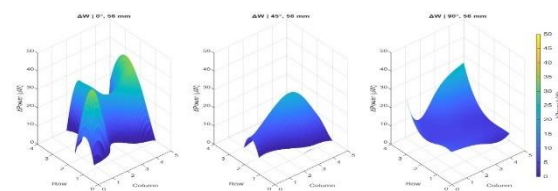


Fig. 4 Improved power distribution inside the cage at a height of 56 mm with the auxiliary coil.

Tab. 1: Comparison of previous work employing inductive links for free moving animals in neuroscience

Work	Year	PTE	PDL	Weight of head-piece (g)
[1]	2014	5.60%	20 mW	1.7 (wire only)
[2]	2016	14% on average	42 mW	5.1
[3]	2023	19.60%	1.93 W	< 7

Tab. 2: Parameters of the proposed coils

Coil	Inductance (μH)	Number of turns	Wire diameter (mm)
Tx	32	8	4.76
Aux	7	6	4
Rx	9	19	0.4

Conclusion

A compact inductive wireless power transfer system for miniature neural implants has been developed and experimentally validated. The proposed multi-coil architecture ensures robust and spatially uniform power delivery across the full cage volume, mitigating the effects of misalignment and animal movement. The achieved power levels are sufficient for continuous operation of the implant electronics, enabling fully untethered neural recordings. This approach represents a practical step towards long-term, behaviourally unconstrained in vivo studies in juvenile rodents, with potential for further optimisation in efficiency and integration.

References

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