Electronic Mode Stirring for Improved Backscatter Communication Link Margin in a Reverberant Cavity Animal Cage Environment

Sara Reyes[1], James Rosenthal[1], Alexandra Pike[2], Matthew S. Reynolds[1]

[1] Electrical & Computer Engineering, University of Washington, Seattle, WA, USA [2] Science Department, Juanita High School, Kirkland, WA, USA

Introduction

Backscatter communication has the potential to enable multi-day neural plasticity experiments in non-human primate (NHP) models (Fig. 1) requiring wireless brain-computer interfaces (BCIs) with a high rate uplink and minimal power consumption [1,2]. However, wireless backscatter uplinks suffer from an unfavorable link budget due to the two-way path loss incurred by the externally-provided carrier wave. As a result, backscatter communication systems often face negative link margin in dense multipath environments, such as the reverberant cavity observed inside a metal animal cages [3,4]. **To overcome the unfavorable channel within a metal cage, we present the use of electronic mode stirring as a means of improving channel loss statistics in the 915 MHz and 2.4 GHz industrial, scientific, and medical (ISM) frequency bands.**

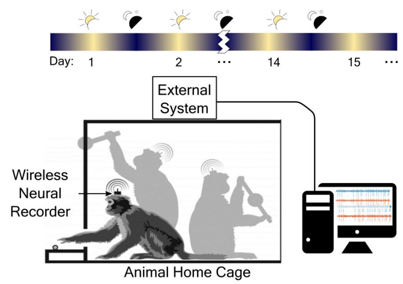


Fig 1: Example use of wireless backscatter communication for neural recording from a freely moving NHP in its home cage environment

Methods

When an electromagnetic wave traveling in a medium encounters a change in impedance, some energy of the wave is reflected. Leveraging this phenomena, it is possible to implement electronic mode-stirring in a cage by selectively changing the impedance presented to small form factor antennas mounted inside a reverberant environment [5]. We tested electronic mode stirring by using four mode stirring assemblies (Fig 2) in both the 915 MHz and the 2.4 GHz ISM bands. We measured the channel transfer function at discrete locations in the cage using a vector network analyzer (VNA) with port 1 connected to the BCI antenna and port 2 connected to the Cage Antenna serving as the receive antenna. At each location, we measured all possible switch configurations (16 in total) and compared the channel transfer function to the measurements within the cage without any mode stirring assemblies (control case).

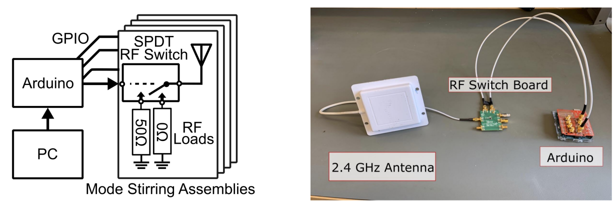


Fig. 2: (left) Block diagram of the mode stirring assemblies controlled by an Arduino, (right) Photo of a 2.4 GHz mode stirring assembly. Four total assemblies were used, controlled by a single Arduino and PC.

Experimental Results in the 2.4 GHz Band

Table I: Summary of mean insertion loss measurements with and without mode stirring in the 915 MHz and 2.4 GHz ISM bands

Frequency Band	Mean Insertion Loss (dB) across all locations: No Mode Stirring	Mode Stirring	Improvement w/ Mode Stirring
915 MHz ISM	26.60	25.85	+ 1.21
2.4 GHz ISM	28.60	27.84	+ 0.76

Conclusion

Electronic mode-stirring is a promising approach to improve the communication link margin for wireless BCIs using backscatter uplinks. Using this technique, we observed reductions in the worst-case and mean insertion loss for both the 915 MHz and 2.4 GHz ISM bands. The observed benefits would be double for backscatter communication systems where the external carrier wave travels round trip. These benefits could enable longer duration BCI experiments in freely moving animals within their home cage.

References

[1] R. Eaton, et al., "Operant conditioning of neural activity in freely behaving monkeys with intracranial reinforcement," Journal of Neurophysiology, vol. 117, pp. 1112, 2017.
[2] J. Rosenthal, et al., "A 6.25 Mbps, 12.4 pJ/bit DQPSK backscatter wireless uplink for the NeuroDisc brain-computer interface," in Proc. 2018 IEEE Biomed. Circuits Syst. Conf. (BioCAS), Oct 2018, pp. 1–4.
[3] A. Sharma, et al., "Wideband UHF DQPSK Backscatter Communication in Reverberant Cavity Animal Cage Environments," in IEEE Trans. Ant. Prop., vol. 67, no. 8, pp. 5002-5011, Aug. 2019.
[4] J. Rosenthal, et al., "A 1 Mbps 158 pJ/bit Bluetooth Low Energy (BLE) compatible backscatter communication uplink for wireless neural recording in an animal cage environment," in 2019 IEEE Int'l Conf. on RFID (RFID), 2019, pp. 1–6.
[5] S. Y. Park et al., "Intelligent reflecting surface-aided phase-shift backscatter communication," in 2020 14th Int'l Conf. Ubiq. Info. Mgmt. and Comm. (IMCOM), 2020, pp. 1-5

Mode Stirring System and Example Results

a

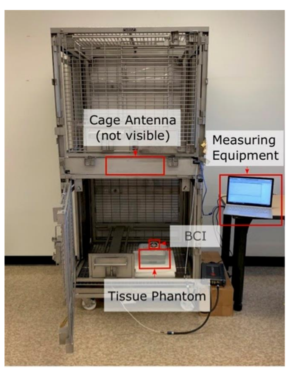
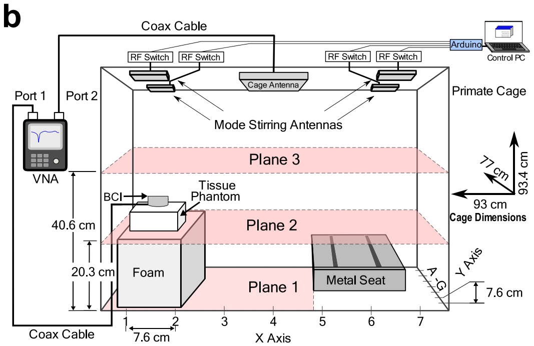


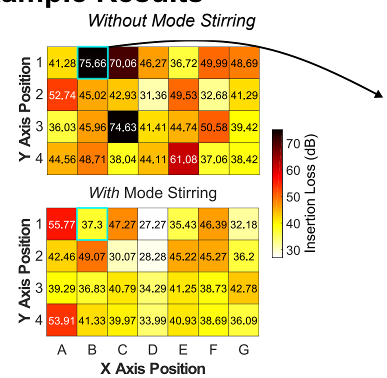
Photo of the NHP cage and measurement setup

b



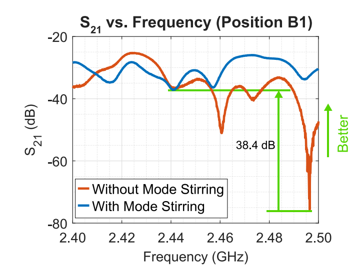
Block diagram of the cage and measurement setup

c



Heatmaps of worst-case measurements from Plane 1 in the 2.4 GHz ISM band

d



Note: Insertion Loss = $-S_{21}$

Plot of insertion loss measurements with and without mode stirring at position B1 in Plane 1

CENTER for NEUROTECHNOLOGY
a National Science Foundation Engineering Research Center