# Advances in Implantable and Wearable Antennas for Wireless Brain-Machine Interface Systems

Elham Moradi(1), Karoliina Koski(1), Toni Björninen(1), Rikky Muller(2), Peter Ledochowitsch(2), Lauri Sydänheimo(1), Elad Alon(2), Michel M. Maharbiz(2), Jan M. Rabaey(2), Leena Ukkonen(1), Yahya Rahmat-Samii* (3)
(1) Department of Electronics and Communications Engineering,
Tampere University of Technology, Tampere, Finland
(2) Department of Electrical Engineering and Computer Science,
University of California, Berkeley, USA
(3) Department of Electrical Engineering,
University of California, Los Angeles, USA

The goal of brain-machine interface (BMI) is to convert thought into action and sensation into perception. This novel technology holds the potential to revolutionize healthcare and neurorehabilitation. A major challenge in translating BMIs to the patient population is the lack of clinically viable implantable devices that will last a lifetime. To achieve this, wirelessly addressable battery-free implants are a must: there can be no transcranial feedthrough for wires or batteries which require replacement.

The on-body antenna, which powers and communicates with the implant needs to be designed simultaneously for maximal link power efficiency (G) and low specific absorption (SAR) and should be comfortable to wear. To achieve this, we studied for the first time the implementation of a 2-segmented loop antenna (regular loop split into two segments joined through capacitance), which provides a compelling SAR – link power efficiency -ratio, using electro-textiles.

For the implant, we studied two antennas. Firstly, a thin and flexible 6.5x6.5 $mm^2$ (Fig. 1a) loop integrating a high-density grid of electrodes for 64-channel electrocorticography (ECoG) recordings. While conforming to the U.S. FCC SAR limit of 1.6 W/kg, it provided 470 μW at 380 mV to the implant when coupled to a metallic 5-segmented loop (G = −16.5 dB). Secondly, we studied an extremely small 1 $mm^3$ cubic implant (Fig. 1b), where a loop is formed on the cube surfaces. When coupled to a metallic 2-segmented loop (G = −23.3 dB), it provided 107 μW at 133 mV to the implant. In the conference presentation, we will compare simulation results from flat and spherical multilayered tissue models for metallic and electro-textile transmit antennas and present measurements in a liquid body phantom and in biological environment (Fig. 1 c-d).

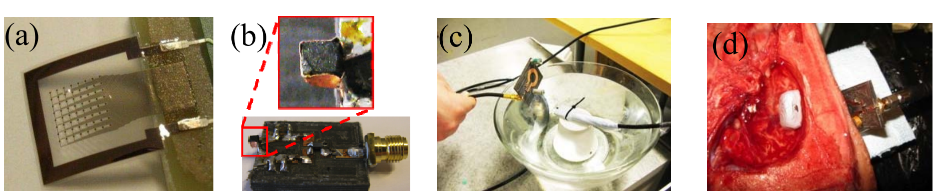


**Figure 1. ECoG loop (a), cubic loop (b), measurement in a liquid phantom (c) and head of a pig (d).**