A Wideband Low-frequency Near-field Measurement System for Detecting Electromagnetic Emission from Biological Cells

Menglou Rao*, S. Mohammad Amjadi, and Kamal Sarabandi
The University of Michigan, Ann Arbor, MI 48109

The existence of intra- and inter-cell electromagnetic signaling has been studied for decades. With recent advances in technology and modeling, our EM cell model based on electromechanical coupled system of oscillators suggests that there can be electromagnetic signaling occurring at frequencies below 1 MHz. However, measuring very weak electromagnetic radiation at low frequencies is extremely challenging due to the presence of various interference sources. Aside from some natural electromagnetic radiation, the man-made radiation from high-power transmission lines, electrical equipment, radiolocation stations and other communication systems are typically much stronger and can easily corrupt the signals under detection. For biosensing applications where signal level is close to the noise floor, a sensitive measurement system with low noise figure and high amplification capability is of great importance.

This work presents a near-field capacitive coupling measurement system for collecting electromagnetic emission from biological cells from 10 kHz to 1MHz. The system consists of a capacitive sensor, a signal amplification circuitry and an oscilloscope. The capacitive sensor is a specially designed interdigital capacitor on which bio-cells are grown. It is used to effectively couple the signals generated from bio-cells to the circuit input. The amplification circuit is composed of a number of parallel fixed and tunable capacitors, a 1:10 transformer and a two-stage high-gain low-noise operational amplifier (op-amp). The amplification process can be divided into three stages: at the first stage, the capacitors and the primary winding of the transformer form an LC tank and boost the current by a factor of Q (quality factor of the LC tank) at resonance. The resonant frequency of the tank can be adjusted by tuning the values of the capacitors. At the second stage, the transformer amplifies the voltage dropped across the primary winding by its turn ratio. Finally, the signal is further amplified by the two-stage low-noise and high-gain op-amp. The amplification circuit is implemented and tested. It achieves a voltage gain of 104 dB at 100 kHz. The oscilloscope can be programmed to extract the data so that further measurement improvement can be realized through post processing. This system is regarded as a promising candidate for low-frequency bio-signal detection.