

Session L – Electrical Engineering (Alphabetical)

Stability and Performance of Digital Spectrometers for Wideband Radiometers

Eythan Familier

Mentors: Sander Weinreb and Glenn Jones

Caltech is in charge of the development of a wideband microwave radiometer for a 34-meter radio-telescope, the second dish of the Goldstone Apple Valley Radio Telescope (GAVRT). The large amount of data that needs to be processed in real time presents a challenge to the design of efficient spectrometers. We have simulated and tested different designs in the lab, and we have tested thoroughly the radiometer and the spectrometer of the system. This enabled us to characterize the frequency response and to quantify the nonlinearities of the spectrometer. We have measured the stability of the radiometer and of the whole system using Allan variance tests. We have written a software spectrometer to compare the system's stability and performance against theoretical results. In addition, we have written software algorithms to eliminate radio frequency interference to obtain sensitive astronomical measurements in the presence of interfering signals.

Electrical, Thermal, and Mechanical Characterizations of Implantable Parylene-coated Microelectrodes and Microcables for Neural Prosthesis

Adi Wijaya Gani

Mentors: Yu-Chong Tai and Ray Huang

Neural prosthesis is an artificial system that substitutes motor or sensory functions which have been damaged by injuries or diseases. Implantable parylene-coated microelectrodes and microcables were previously developed in the lab to extract and manipulate nerve signals for neural prosthesis. A comprehensive characterization of the microelectrode and microcable is crucial to determine their electrical sensitivity and specificity, durability, and implant duration. For the microelectrode, electrical characterization is done by determining the right microelectrode opening area that gives optimal Signal-to-Noise Ratio (SNR), because a more-sensitive microelectrode (lower impedance) derogates its specificity (stronger noise), vice-versa. This relationship is also theoretically analyzed using an electrode-electrolyte interface circuit model. For the microcable, thermal characterization is done by individually soaking the microcable in 60°C, 90°C, and 125°C saline. To raise the saline temperature up beyond its boiling point, a modified pressure-cooker is utilized. Mechanical characterization of the microcable is done collectively by cyclic bending and twisting to determine its mechanical properties, such as Young's Modulus, strength, and S/N-curve.

Neural Signal Sensing with Platinum Black Electroplated Electrodes

Suyao Ji

Mentors: Yu-Chong Tai and Ray Huang

Neural signal detecting using electrodes is of paramount importance in biomedical applications. On one hand, an electrode with larger exposed area has lower impedance to avoid cell damage. On the other hand, high specificity of the electrodes requires each electrode to have a small cross-section area to record single neurons with high signal-to-noise ratio (SNR). Platinum black by nature has a highly irregular structure that can greatly enhance the contact area of a coated electrode. The methodology of Platinum black electroplating is used in this work to provide a rough electrode contact surface to reduce the electrode impedance without changing its cross-section area. Thus, electrodes with low impedance and high SNR can be achieved at the same time by using this technique. Furthermore, laser annealing then consolidates the platinum black to the electrodes to improve the reliability of platinum black electrodes and extend their lifetime in bodies.

Multivalued Stochastic Relay Circuits

David T Lee

Mentor: Jehoshua Bruck

Can we design circuits that can generate specified random variables? Motivated by this question, we study stochastic relay circuits: circuits whose relay switches don't exist in a set state, but have a probability distribution over all the states. Previous work focused on designing networks and examining the expressibility and robustness for two-state relay circuits. We extended this work by generalizing the boolean relay circuits to allow multiple values, replacing the logical 'and' and 'or' with 'min' and 'max' respectively. In studying these circuits, we found a duality property and designed algorithms for constructing rational probability distributions. We extend the previous robustness result to these constructions and finally design a universal probability generator for the 3-state case which maps input

bits to arbitrary 3-state probability distributions. Potential applications exist in the analysis and design of biological systems.

Fly Eyes as a Template for Antireflective Microlenses

Jasmine Sears

Mentors: Changhuei Yang and Ying Min Wang

Microlenses have many commercial and experimental applications. Plano-convex microlenses as small as 6 μ m in diameter can currently be fabricated in two-dimensional arrays containing hundreds of lenses; however, the transmittance of these microlenses is outperformed by microlenses found in the compound eyes of many insects. The lenses of some insects, such as the common housefly (*M. domestica*), have tapered surface features with heights and bases of approximately 200nm, less than half the wavelength of visible light. These features greatly reduce the amount of light reflected at the surface of the lens, thus increasing the amount of light transmitted through the lens. The goal of this project was to develop a cheap, fast, uncomplicated procedure for fabricating antireflective microlenses by using fly eyes as an imprint lithography template. Polydimethylsiloxane was used for both the molds and microlens replicas. The resulting microlenses have consistent focal lengths and small spot sizes, and appear to have fly-lens surface structures when viewed under a scanning electron microscope. These lenses demonstrate the feasibility of using insect eyes to fabricate antireflective microlens arrays, and further research may lead to lenses suitable for commercial applications.

Biomolecular Spectroscopy: Designing Low-cost, Portable Biosensors in CMOS

Constantine Sideris

Mentors: Ali Hajimiri and Hua Wang

Bioimaging is one the most important fields in biology today. On the macroscopic scale, imaging can be done with traditional optical microscopes. However the increasing need for viewing and studying smaller structures such as individual DNA strands, RNA, or proteins has led to the development of various other imaging and spectroscopy techniques capable of much higher magnification and resolution than the optical microscope. To this day, the most common alternative approach is fluorescent spectroscopy. Although fluorescent spectroscopy has been well refined and can be used to resolve very small structures tagged with specific fluorescent markers, it has various major disadvantages, namely: cost and size. Our goal is to design and realize an alternative biosensing system which can sense the presence (and location to some extent) of microscopic ferromagnetic beads which are biocompatible and can easily be tagged to strands of DNA and RNA. The system essentially presents a "lab-on-a-chip" environment which solves both of the space and cost issues presented. We have currently already fabricated and measured the performance of the first version of the sensor. Our results were very satisfactory, indicating sensitivity very close to our initial simulations and a low noise floor. We were able to resolve individual magnetic beads with diameters as small as a single micron. Currently, we are researching ways to improve our sensing scheme even further. Our main focus is to improve the design and layout of the sensor itself, which is a planar on-chip inductor. We are also designing methods for preparing the chip surface for bioprobe structures to be bound to it. These include specific chemistries which specifically bind to the silicon dioxide top layer of the chip as well as PDMS channels and structures to route solutions to the appropriate locations on-chip.