Summary for MTT-S Graduate Fellowship for Medical Applications

Xiaotian Du

Prior to this project, ultra-wideband electrical sensing of a single live cell has been developed in the efforts of capturing the impedance spectroscopy of a cell based on a single-shell model. β-dispersion in the cell dielectric spectrum has been captured by an 2R2C equivalent circuit of four nondispersive elements, namely the membrane resistance, membrane capacitance, cytoplasm resistance and cytoplasm capacitance. This makes the 2R2C equivalent circuit model a very compact and relatively precise cell model to use, though the cytoplasm properties here include the contributions of all intra-cellular structures such as organelles and nucleus.

In this project, standing on the shoulder of the single-shell model, the double-shell model of a single-cell has been developed in terms of impedance spectroscopy. With the help of the double-shell theory, 4R4C equivalent circuit simulations, and ultra-wideband single-cell measurements from 9 kHz to 9 GHz, resistance and capacitance of nuclear envelope and nucleoplasm have been extracted. The extracted parameters are in general agreement with the calculated order-of-magnitudes and the literature values. After adding another four impedance parameters, the dielectric spectrum of the whole cell can even be better described with the 4R4C equivalent circuit model. And this is important as we can simultaneously obtain both cellular and intra-cellular dielectric properties with the ultra-wideband measurements in a fast, compact and label-free pattern.

With the collaboration of the National Institute of Standards and Technology (NIST), we designed new chips at NIST in Boulder, CO, including microfluidic chips that can better cooperate liquid calibrations, and a packaged device that makes another step towards a more integrated and commercialized application. In the efforts of making the entire setup more automated, several machine learning and deep learning algorithms are proposed and under trial as potential candidates to accomplish automatic cell-trapping detection and real-time big data analysis in the future. With the help of ultra-wideband electrical sensing and artificial intelligence, hopefully a flow cytometry with higher throughput and accuracy can be achieved to contribute to the cancer diagnostics in the future. And this is another important step to move forward this research project a bit further from lab to the industry applications.

Publications resulting in part from the fellowship project work:

[1] X. Du, C. Ladegard, X. Ma, X. Cheng and J. C. M. Hwang, "Broadband Electrical Sensing of Nucleus Size in a Live Cell From 900 Hz to 40 GHz," *2020 IEEE MTT-S International Microwave Biomedical Conference (IMBioC)*, 2020, pp. 1-4, doi: 10.1109/IMBIoC47321.2020.9385023.

[2] Ma X, Du X, Li L, Ladegard C, Cheng X, Hwang JCM. Broadband Electrical Sensing of a Live Biological Cell with In Situ Single-Connection Calibration. *Sensors*. 2020; 20(14):3844. https://doi.org/10.3390/s20143844

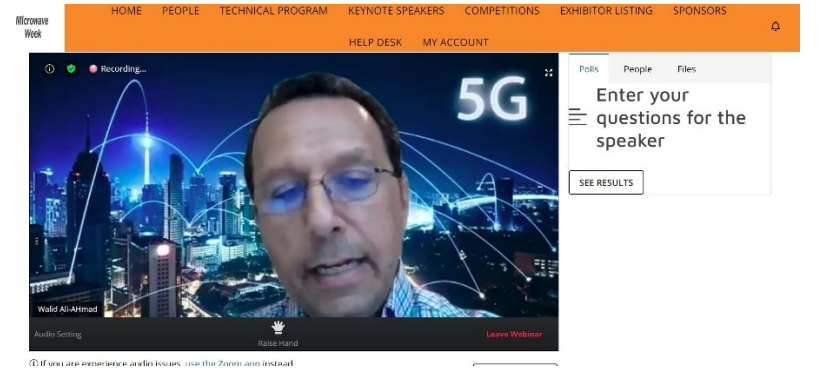
[3] Caroline Ladegard, Niccolo Pini, Xiaotian Du, Marco Farina, James M Hwang, Tiziana Pietrangelo, Xuanhong Cheng, " Broadband Electrical Impedance as a Novel Characterization of Oxidative Stress in Single L6 Skeletal Muscle Cells", *Journal on biosensors and bioelectronics,* Submitted for publication.

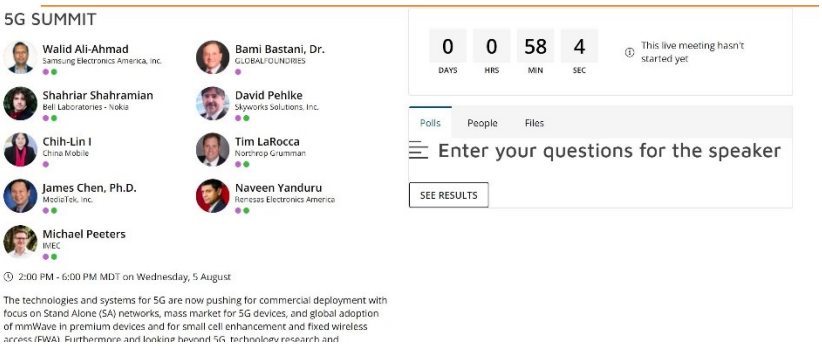
IMS2020 Impression

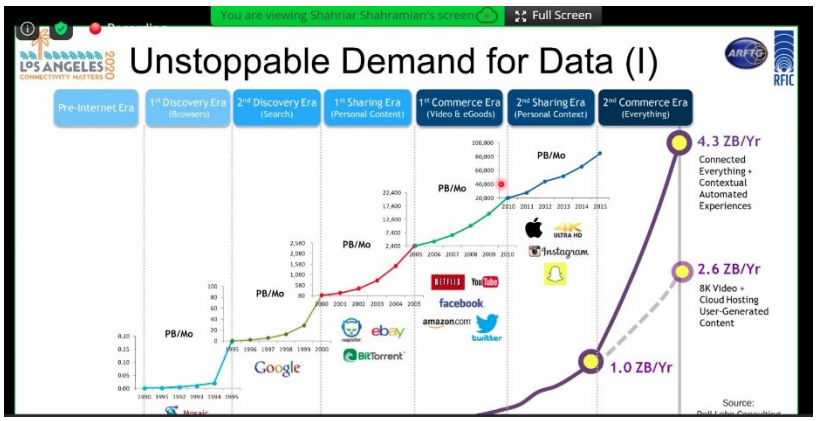
It was a pity that we didn't manage to have an in-person IMS2020 due to the COVID-19 pandemic, but the virtual event was still very impressive. The whole conference was well-organized and it was really surprising and amazing that the committee could make this transfer to a virtual event so efficiently in such short period of time while keeping its quality.

The conference provided the attendees with various state-of-the-art topics in the industry and many special events which were very helpful especially for the young engineers. The 5G Summit impressed me the most as one could obtain lots of cutting-edge information and technologies from many major players in the 5G industry. I've continuously attended IMS for a few years and the 5G Summit in IMS2020 was kept on a high level as those in the previous years even though it went virtual this time.

Overall, I obtained lots of helpful information and learned a lot from IMS2020. I really appreciate this opportunity to attend IMS2020. And congratulations on the success of the conference especially in such a challenging year.







Career Plan

After graduation of my PhD degree from Lehigh University, I will continue working in Prof. James Hwang's group at Cornell University as a postdoctoral research scientist on the same topic of ultra-wideband electrical sensing of nucleus in a biological cell. And there are still lots of interesting work to do in this topic. As for a long-term career plan, I'm open to opportunities in both academia and industry.

I think the MTT-S Graduate Fellowship was very helpful on my way of becoming an independent researcher. It not only helped me complete a project, but also made me realize that I'd be able to overcome many more challenges, and built up more confidence in myself to achieve more in my future career.