ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium
for Informatics and Mathematics

Scientific Report

First name / Family name	Pritam Bose
Nationality	Indian
Name of the *Host Organisation*	Norwegian University of Science and Technology (NTNU)
First Name / family name of the *Scientific Coordinator*	Ilangko Balasingham
Period of the fellowship	01/02/2020 to 31/01/2021

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The growth and extensible research in active implantable medical devices (AIMDs) have provided the opportunity for continuous and remote monitoring of patients with chronic illness. But the major technological challenge is that most of the implants operate on batteries with limited durability. It is difficult to replace these implants as human tissues grow around them and re-quires surgeries for their removal, which are costly and stressful for the patients. Moreover, battery replacement surgeries require hospital stays which is an additional risk in this era of pandemics like COVID-19. So, the sustainability and eventual fate of implantable medical devices depends on its capability forlong-term use.

Most of the AIMDs are equipped with wireless communication systems for data transfer, device monitoring and reprogramming. In this regard, we proposed that energy harvesting from radio frequency (RF) signals for a wireless communication system provides a new paradigm called Simultaneous Wireless Information and Power Transmission (SWIPT)that can allow the wireless implant nodes to recharge their batteries from the RF data signals.

In the literature, SWIPT has been studied for in-door and outdoor environment and has investigated transmission of high energy levels with large antenna dimensions for harvesting energy. There have been no studies in the literature for investigating SWIPT within the human body. My research project has explored and untaped the potential of SWIPT for the human body environment.
The major outcomes of the project includes: 1) preliminary energy-capacity function and the end-to-end analytical model of SWIPT for deep implants; 2) hardware design of SWIPT for implant communication systems; and 3) feasibility of the novel SWIPT architecture for medical implant technology by in-vitro liquid phantom models. The new fundamental knowledge developed from this project could be applied to multiple other domains. The results obtained from the project is very positive and will be further studied in the future for practical implementations.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

"A comparative analysis of radio frequency WIPT v/s Backscatter WIPT for medical implant technology"
Pritam Bose, Ali Khaleghi, Jacob Bergsland and Ilangko Balasingham
IEEE Journal of Selected Topics in Signal Processing (under preparation)

"The use of active implantable medical devices (AIMDs) has increased rapidly in the recent years due to their usefulness in diagnostic and therapeutic purposes of different critical disorders and diseases. The major technological challenge for these devices is that they are constrained by the battery power and it requires surgeries to replace the batteries for deeply implanted AIMDs. Thus, to increase the longevity of these devices, we have conducted research on two different methods for wireless information and power transfer (WIPT). Our first approach has been radio frequency WIPT (RF-WIPT) which uses radio frequency for communication and power transfer. Our second approach has been human body backscatter WIPT (BS-WIPT) which uses the low power backscatter technology for communication and power transfer. In this paper, we have presented a comparative analysis of both these methods in terms of signal and system models, prototype design and our experimental results. The experiments have been conducted in three different models – computational human models, liquid phantom models and living animal models. Our initial results have shown that the backscatter method could lead to battery-free sensing and communication whereas the RF method could lead to charging the implant battery from a long distance and through ambient RF signals. The initial results have been very promising and, in this paper, we have pointed out the directions that are promising for future research in this domain."

"Effects of Cardiac Channel Variability on Data Transmission for Future Leadless Pacemaker"
Pritam Bose, Ali Khaleghi, Jacob Bergsland and Ilangko Balasingham
IEEE Transactions on Biomedical Engineering (under preparation)

"The radio frequency cardiac channel model varies significantly based on the cardiac movements during the cardiac cycle. In our previous research, we found out these variations based on computational human models and liquid phantom experiments. In this paper, we found out these variations by placing small capsule pacemakers inside the cardiac chambers of living pig. These variations were then compared with the current state of the heart using 3d accelerometer, ECG, LVP and X-rays. The results shows that the received RF signal strength and BER varies linearly with the accelerometer and ECG. These results will help us to find the optimum time-period for communication between the capsules as well as reduce the energy consumption of the multi-node leadless cardiac pacemaker technology."

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

In January 2021, I gave a talk at the online seminar titled "**Turn challenges into success stories"** organised by Ovesco Endoscopy, Germany. The link for the seminar is https://www.youtube.com/watch?v=USITeERWl2g&feature=youtu.be&ab_channel=OvescoEndoscopyAG

IV – RESEARCH EXCHANGE PROGRAMME (REP)

I have done the Research Exchange Program at Simula Labs, Norway under the supervision of Dr. Hermengild Arevalo. The one week research program from Jan 18-25, 2021 focused on computational modelling of heart to predict cardiac arrhythmias. Apart from the scientific discussions and research work, I participated in several meetings with them and schedule is mentioned below:

Jan 18 - Computational Physiology Department meeting. Scientific presentation by Hector Martinez-Navarro (~30 minutes) followed by round table updates.

Jan 21 - Arevalo group meeting. Presentations by 3 PhD students on their respective projects

Jan 25 - Computational Physiology Department meeting. Presentation by me on my Postdoc work.