Main objective and summary of the project

The number of people with life-style related health issues and diseases has been growing significantly the last few years. At the same time the relative share of elderly people in the population is increasing creating a demand for new solutions and technology to maximize quality-of-life and at the same time minimizing costs for the global society. This project will focus on developing integrated CMOS technology for new sensor that will both simplify the everyday life and reduce the cost related to continuous monitoring of elderly or people at risk in their own homes.

The overall framework for the PhD project is an advanced 3D multichannel UWB microwave sensor operating in the frequency band between 6.0 GHz to 10 GHz and that may be easily integrated in private homes or care units. This device will be mounted in the ceiling similar to movement sensors or fire alarms and will have the ability to not only perform localization of people and their movement patterns, but also measure respiration and heartrate in real-time. The framework project will involve several partners both from academia and industry including a group of PhDs.

The specific objective for this specific PhD project is to address CMOS design challenges related to significantly reducing power consumption and at the same time increase robustness against WiFi compared to existing systems. The project may both address front-end RF components and system architecture depending on the candidate qualifications and interests.

Project background and scientific basis

The positions will be part of an ongoing research collaboration involving the Nanoelectronics group, the strategic initiatives MEDIMA (http://www.mn.uio.no/ifi/english/research/groups/medima/) and LATICE (http://www.mn.uio.no/geo/english/research/groups/latice/index.html), Imperial College London, Norwegian Defense Research Establishment and the Norwegian technology company Novelda AS (www.xethru.com) through the granted RCN research project WellSafe addressing new sensor technology for smart homes, assisted living and home based care. Advanced radar sensor technology has been a topic for research within the research group for the last 15 years and this research has also resulted in commercial product development [1].

The scientific basis for the project is a novel UWB radar transceiver with direct RF sampling [2]. The architecture is based on CTBV [3] design methodology moving design challenges
from the amplitude domain to the time-domain. Measuring vital-signs and performing high-accuracy imaging have already been demonstrated [4], [5]. Depending on the received signal strength, this methodology may however impose an overhead in terms of energy dissipation due to the need for many iterations to resolve the required RX signal accuracy. The application in mind will require a system with several transmit (TX)- and receive (RX) channels to enable full 3D sensing. Still the total size of the sensor needs to be kept small and at the same time battery operation should be feasible. This will require very small antennas and the project is already exploring the possibility of using new materials to meet these requirements [6]. In current products, the radar raw data is processed locally to extract the required application data. This is a relatively energy demanding process which will scale further with the increased number of channels when expanding to 3D. The hypothesis is that a better solution is to perform limited processing locally in the sensor and move the main application processing to the cloud which also opens for combining data from several sensors / rooms to increase overall quality of information. Cloud streaming will however require co-location of a high bandwidth communication channel and the radar sensor. Currently 5GHz WiFi would be the natural choice since such infrastructure is widely available and do not require costly physical infrastructure. In the future 5G is also a candidate. The challenge is however that the upper 5 GHz WiFi bands are very close to the frequency band used by the UWB radar sensor. Although the current design is relatively robust against interference, the SNR will reduce for high power close-band interference. It is assumed that this challenge must be solved by combining more aggressive filtering in the RX front-end with architecture level measures and at the same time maintain in-band signal quality.

Research questions and scientific challenges

The key research questions to address is related to the ability to minimize the energy used per sensing operation and how to minimize the sensitivity to interference from external noise sources like WiFi, where the later also relates strongly to energy efficiency since interference may require more samples to obtain sufficient data integrity. More specifically 1) How can the overall energy efficiency of the CMOS radar sensor be improved for the given use-case? and 2) How can the system be made more robust against out-of-band interferers?

Scientific method

Certain hypotheses with respect to methodology and approach on how to address the challenges have been established. The candidate may use these as starting points, but need to validate and / or challenge them through a combination of analysis, high-level modeling, transistor-level simulation and experiments in the lab or actual use-case. Matlab or Python are normally used for system-level modeling while Cadence in combination with the relevant Process Design Kit (PDK) will be the design / simulation platform. The Nanoelectronics group has well equipped laboratory facilities to accommodate all required experiments including anechoic chamber and RF test equipment.
Ethics

The project deals with technology, humans and social science. The research and future products will follow rules and guidelines on this type of research in terms of ethical perspectives, especially on anonymity when storing of research data and findings. The ethical main vision for the project is that each human involved in the project shall feel included in the research activities and research group.

Project timeline

The position will be for three years, alternatively four years including 25% teaching obligations. We will plan for a research stay abroad during this period.

Applicant Background and Competence

Applicants must hold a Master’s degree or equivalent in microelectronics, electrical engineering or similar disciplines.

Candidates should have experience in at least one of the following subjects: Full custom analog-/mixed-signal CMOS integrated circuit design, CMOS RF circuit design, CMOS UWB circuit design.

Literature references

Short CVs of contact persons

**Dag T. Wisland** received the M.Sc. and Dr.Scient. degrees in electrical engineering from the University of Oslo, Norway in 1996 and 2003 respectively. He is currently a Professor at the Nanoelectronics group at the University of Oslo. From 2004 to 2008 Wisland was heading the Nanoelectronics research group at the University of Oslo. Dr. Wisland was a co-founder of the semiconductor company Novelda and was CEO from 2004 to 2013 when he took position as CTO. His present research interests include low power analog/mixed-signal CMOS design, Ultra Wideband radio (UWB), and design of ADC/DAC with a particular focus on Delta-Sigma data converters. In his research Wisland has focused on conceptually new methods and topologies combined with low-power design. Dr. Wisland is a member of IEEE and serves as a TC member of the IEEE CAS society Analog Signal Processing (ASP) and Biomedical Circuits and Systems (BIOCAS) technical committees and has authored or co-authored several scientific publications and been the principal investigator / project manager for several international research projects.

**Tor Sverre Lande**, F-IEEE, NTVA, is a professor in the Microelectronic at Dept. of Informatics, Univ. of Oslo as well as visiting professor at Institute of Biomedical Engineering, Imperial College, London, UK. His primary research is related to microelectronics, both digital and analog. Research fields are Neuromorphic Engineering, analog signal processing, subthreshold circuit and system design, biomedical circuits and systems, RF CMOS, pulsed radio (UWB) and radar systems. He is the author or co-author of more than 150 scientific publications with chapters in three books. He is serving as an associate editor of several scientific journals and as guest editor for several IEEE journals. He is/has been a technical committee member of several international conferences and has served as reviewer for a number of international technical journals. He has served as Technical Program Chair for several international conferences (ISCAS 2003 in Bangkok, NORCHIP, BioCAS2004, BIOCAS2006, BioCAS2010, ISCAS 2011). In 2006 he was appointed Distinguished Lecturer of the IEEE Circuits and Systems Society (CAS) and elected member of CAS Board of Governors. He served as CAS Vice-President of Conferences (2011-2013). He is also the founding Editor-in-Chief of *IEEE Transactions on Biomedical Circuits and Systems* (2007-2010).