

University of Oslo, Department of Informatics [Impact case #4]

Institution: University of Oslo
Administrative unit: Department of Informatics (IFI)
Title of case study: Low-cost miniaturized UWB antenna
Period when the underpinning research was undertaken: 2011 - 2021
Period when staff involved in the underpinning research were employed by the submitting institution: 2011 - 2024
Period when the impact occurred: 2020 - 2024

1. Summary of the impact

The WellSafe project funded through RCN NANO 2021 and related research efforts brought forward new and miniaturized Ultra-Wideband (UWB) antenna designs enabling UWB sensing in high-volume / low-cost consumer products. At the time of completion, the resulting design and corresponding radar module were the smallest reported globally and disrupted UWB antenna and module design for UWB sensor applications. The key challenges addressed were how to achieve directivity, minimize loss and at the same time make the antenna immune to its surroundings. The design was commercialized by the project owner Novelda AS and is currently deployed in high-volume consumer applications and further formed the basis for several UWB radar module products. These designs now serve as reference for UWB sensor module design across the global industry.

2. Underpinning research

During the RCN StorIKT project MELODY (2008-2011), the NANO group started exploring more system-level aspects beyond integrated circuit design especially focused on Ultra-Wideband radio transceivers. This included research on antennas and modules and as a result the group also established a new radio-lab with anechoic chamber when moving to IFI-2 in 2011 (Picolab). In the coming years, the group built expertise on RF/antenna design and characterization. This activity was headed by Professor Tor Sverre Lande and several PhD-students were involved. In the first phase, the research focused on biomedical applications of UWB sensing technology where near-field effects on antenna performance had significant impact and were studied in detail (References [1]-[3] below).

Later, the research expanded to also include through-air sensing for a wide range of applications. The common denominator was the high bandwidth (3.1 – 10.6 GHz) posing several design challenges compared to conventional narrow-band design. Several design-techniques were explored including 3D-printing of antennas and use of new materials (References [3]-[6] below). The research also involved collaboration with industry like the RCN-funded BIA projects UWBPOS and Ventricorder coordinated by Novelda AS. Kristian Kjelgård who is now an Associate Professor at the group was employed as a PhD-student and Post.Doc in these projects and later PhD-student Mathias Tømmer was also involved. In 2017, the group became partner in the RCN NANO-2021 project “WellSafe” (2017-2021) owned by Novelda AS with Professor Dag T. Wisland and Professor Tor Sverre Lande coordinating the research. This project defined a new direction of the research where the goal was to realize miniaturized and low-cost UWB-antennas for high-volume consumer applications. Such antennas possible to manufacture with low-cost materials and capable of mass-production had not been reported and Novelda AS had also tried to source R&D services from leading international R&D institutions and consultants without success. Researchers Kjelgård and

Tømmer were the key researchers from UiO in the project and through a close collaboration with Novelda and large international semiconductor and consumer electronics companies, several novel antenna design concepts and prototypes were developed and tested. A key challenge was to also guarantee regulatory compliance across production variation and across multiple end-product variants. The resulting prototypes demonstrated the feasibility of miniaturized UWB antennas in low-cost materials and were commercialized and deployed in high-volume products as described in the section below. Due to the commercial nature of the project and need for IP protection by the project owner, the results were not published through the project, but scientific publications building upon the project results are expected going forward. In addition, the research has also led to contributions to the upcoming IEEE 802.15.4ab standard currently being developed.

Key researchers:

Research execution: Associate Professor Kristian G. Kjelgård (entire period, PhD→Post.Doc→Researcher→Associate professor), PhD student Mathias Tømmer (2015 to end of project period)

Research coordination and management: Professor Dag T. Wisland (entire period) and Professor Tor Sverre Lande (entire period).

3. References to the research

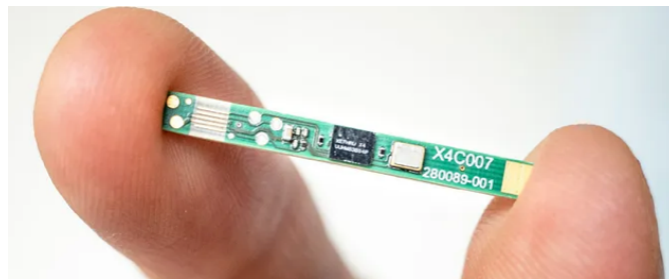
- [1] K. G. Kjelgård, M. Høvin and T. S. Lande, "Body-coupled, wideband antennas," *2015 IEEE Biomedical Circuits and Systems Conference (BioCAS)*, Atlanta, GA, USA, 2015, pp. 1-4, doi: 10.1109/BioCAS.2015.7348386.
- [2] M. Tommer, K. G. Kjelgård and T. S. Lande, "Body coupled wideband monopole antenna," *2016 Loughborough Antennas & Propagation Conference (LAPC)*, Loughborough, UK, 2016, pp. 1-5, doi: 10.1109/LAPC.2016.7807483.
- [3] T. Lauteslager, M. Tommer, K. G. Kjelgård, T. S. Lande and T. G. Constandinou, "Intracranial heart rate detection using UWB radar," *2016 IEEE Biomedical Circuits and Systems Conference (BioCAS)*, Shanghai, China, 2016, pp. 119-122, doi: 10.1109/BioCAS.2016.7833739.
- [4] K. V. Hoel, S. Kristoffersen, J. Moen, K. G. Kjelgård and T. S. Lande, "Broadband antenna design using different 3D printing technologies and metallization processes," *2016 10th European Conference on Antennas and Propagation (EuCAP)*, Davos, Switzerland, 2016, pp. 1-5, doi: 10.1109/EuCAP.2016.7481620.
- [5] V. Midtbøen, K. G. Kjelgård and T. S. Lande, "3D printed horn antenna with PCB microstrip feed for UWB radar applications," *2017 IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications (IMWS-AMP)*, Pavia, Italy, 2017, pp. 1-3, doi: 10.1109/IMWS-AMP.2017.8247374.
- [6] K. G. Kjelgård and T. S. Lande, "Shielding of Tri-Patch Antenna Using 3D Printed Composite Carbon/PLA Absorber for Ultra Wideband Snow Radar Systems," *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*, Brussels, Belgium, 2021, pp. 1039-1042, doi: 10.1109/IGARSS47720.2021.9554338.

4. Details of the impact

As described in section 2 above, a long-term research effort on UWB antenna / module design and characterization resulted in disruptive results in terms of miniaturization and low-cost implementation of UWB antennas. In terms of impact this mainly occurred through the

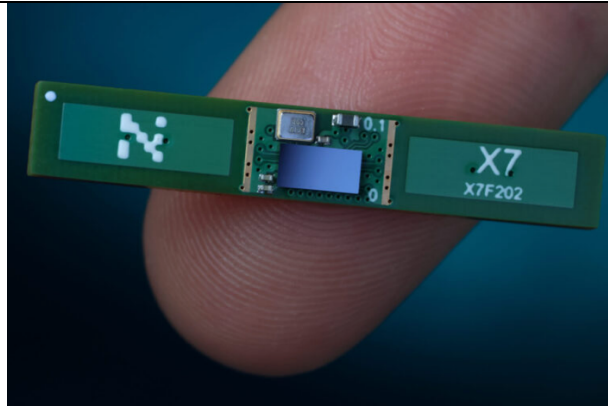
collaboration in the RCN WellSafe project which led to tangible results currently deployed in high-volume consumer products, but also transfer of competence from university research to the industry. In the final stage of the WellSafe project PhD student Mathias Tømmer moved to Novelda AS as a lead antenna designer enabling scaling the specific project results into multiple product families, leading to a strong competitive advantage towards international competitors enabled by scientific research. Associate professor Kristian G. Kjølgaard is still with the NANO group at UiO and is securing continuation of the scientific research within the field at UiO.

The most tangible and visual result of the impact is the Novelda X4C007 module deployed in several different Lenovo laptop models [7]. The size of this module is 3x30mm and at that time the smallest self-contained UWB sensor module in the world. The purpose of this sensor was to enable fast and no-touch user log-in and immediate lock-on-leave to improve user experience, security and save energy. Estimated energy-savings were around 20%. Researchers mentioned above were directly involved in the design- and prototype phases including Lenovo and their ecosystem partners (names not disclosed due to NDA). The X4C007 product including the embedded UWB antennas is illustrated below:

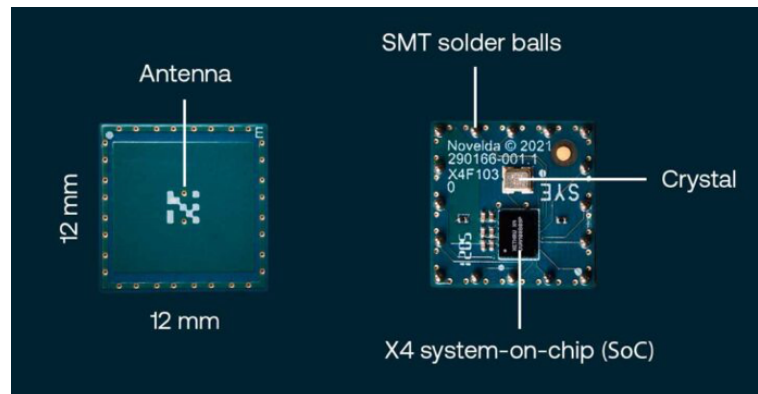


Following Apple releasing UWB for ranging purposes in their iPhones, the deployment of UWB sensor technology from Novelda AS was the first high-volume UWB sensor in consumer products which made a strong impact internationally and also contributed to large international companies like NXP, Qorvo, Qualcomm, Samsung, Huawei initiating development of UWB sensing products. This also led to a revision of the existing UWB communication standard IEEE 802.15.4z, where sensing has been included and will be released as the new IEEE 802.15.4ab standard [8]. Researchers from UiO together with Novelda have been heavily involved in standard development together with the global UWB ecosystem players.

Recently, UWB sensor product development has also reached the automotive industry due to its competitive advantage over 60 GHz radar technology when it comes to energy efficiency, cost, and robustness. The key application is Child Presence Detection (CPD) in cars driven by the very sad fact that several children die every year due to heatstroke because they are left behind in overheated cars. As a result, NCAP has made mandatory to have systems that detect children in the car and set an alarm if the driver leaves and lock the door with the child left in the car. Like competitors, Novelda just announced a CPD product where the antenna / module design originates from results brought forward in the mentioned research project [9]. The most recent UWB sensor module is illustrated below.



Different from the X4C007 module, the X7F202 module has two transmitter and two receiver channels to support beamforming making the design slightly larger. This research results from designing this chip / module has also been accepted for publication at the prestigious IEEE International Solid-State Circuit Conference (ISSCC-24) in February 2024 [10]. Another tangible documentation of the impact is the X4F103 [11] module targeting general-purpose products within building automation, appliances etc as illustrated below.



5. Sources to corroborate the impact

- [7] <https://medium.com/novelda-news/two-new-lenovo-laptops-with-the-novelda-hpd-sensor-launched-at-ces-2021-c82fc67f3ee7>
- [8] <https://www.ieee802.org/15/pub/TG4ab.html>
- [9] <https://novelda.com/news/novelda-announces-new-ultra-wideband-child-presence-detection-cpd-sensor-2>
- [10] <http://submissions.mirasmart.com/ISSCC2024/PDF/ISSCC2024AdvanceProgram.pdf> (page 17).
- [11] <https://www.hackster.io/news/novelda-s-tiny-uwband-x4f103-uses-impulse-radar-to-monitor-movement-right-down-to-individual-breaths-3614aa2b03d0>