Multi-channel Microwave Radiometer for Internal Body Temperature Measurements (MMR-IBTM)	

Ακρωνύμιο: MMR-IBTM
Δράση: ICT-……
Ημ. Έναρξης **GSRT on 13/3/2013**

Ιστοσελίδα:

Διάρκεια:36 months

Προϋπολογισμός **Συνολικός: 441.438,75€**
ΕΜΠ: 91.087,50€
Ρόλος ΕΜΠ:
Επιστημονικός Υπέυθυνος: Χ.Καψάλης
Συντονιστής Έργου/ συμμετέχων Nikolaos-Antonios Livanos / EMTECH

Βαθμολογία πρότασης:

The principal research target of the MMR-IBTM project was to **develop low-cost arrangements with integrated passive microwave radiation monitoring function**, which can be used as early warning and monitoring devices for sub-tissue abnormalities, such as initial stage breast cancer. In addition, a major business target of the MMR-IBTM project was to **harmonically collaborate with a Chinese company** by having complementary research and development competences, as well as by exchanging working methodologies and business mentality, and having as vision a future fruitful continuation of the cooperation, towards industrialization and productization of the project's outcome.
The project **consortium** was composed of partners that provide the relevant and complimentary multi-disciplinary expertise. The main disciplines covered are areas of science and technology, essential for the successful outcome of the overall project objectives. Specifically the project consortium was as follows:

- ***NIKOLAOS & MARINOS LIVANOS OE – EMTECH***; a Greek company involved in embedded systems and software design and development, manufacturing products for the domains of Energy Systems and Automations, Space and Ground Segment Software Applications, and Medical Devices.
- ***Beijing Gk Huayi Technology Co., Ltd.***; a Chinese company that focuses on high technology research, development and marketing of products targeting Medical and Food-Safety application fields.
- *Wireless and Long Distance Communications Laboratory* ***(WLDCL) of the National Technical University of Athens (NTUA)***, with domains of specialty the theoretical and experimental research on telecommunication topics, emphasizing on subjects such as Electromagnetic Compatibility, Antennas, Radiation Effects, Wireless Links and Propagation and Biotechnological issues.
- *Research and Development Electronics and Telecommunications Laboratory (R.D.E.T.L)* ***of the Department of Electronics of the Technological & Educational Institute of Athens (TEI-A)***, having as

principal interests: Simulation and experimental evaluation of RoF components (semiconductor lasers, optical fibres, photodetectors) in analogue/digital modulation techniques (DSB, SSB, M-QAM /OFDM, CDMA) and RoF links based on current and emerging wireless communication standards (WiFi, WiMAX , MB -OFDM)

- ***MEDical Image and Signal Processing laboratory (MEDISP) of the Department of Medical Instruments Technology of the Technological & Educational Institute of Athens (TEI-A)***, involved in research and education of: Medical Signal and Image Processing, Medical Signal and Image Analysis - Pattern Recognition, Medical Informatics & Medical Statistics, Bioinformatics and computational biology.

The MMR-IMTM project can be considered as the research, development and prototyping phase targeting an innovative product, able to non-invasively detect malignant tumors in early development stages. Our intention was, on the one hand, to exhaustively investigate modern radiometer technologies, and on the other hand to proceed to construct prototype arrangements. The innovation of our methodology refers to a multi-channel and multi-frequency approach, enabling the possibility to represent the retrieved information both in 2-D and 3-D visualizations. The block diagram of the application concept, depicted in Figure 1, consists of the following parts:

- Microwave (MW) Antenna: to match human tissue and maximize the MW energy acquisition emitted by thermal body
- RF Front-end: Amplify and filter the acquired signal based on MW radiometer methodologies
- Data Processing Unit (DPU): Digitize signals, control the MW sensor and provide a user's interface
- Imaging algorithms (2-D, 3-D) and human tissue mathematical modelling: to transform signals to valuable medical information.

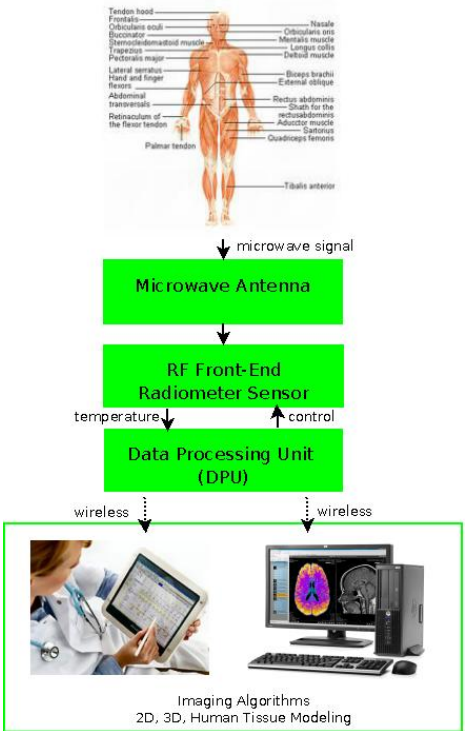

Figure 1: MMR-IBTM Concept of Operation

The project objectives were the following:

- To carry out literature review (journals, patents, market, etc,) in order to establish a comprehensive database related to passive microwave processes for monitoring cancer
- To investigate microwave radiometer technology for medical applications
- To design, develop and prototype, single-channel, multi-frequency, as well as, multi-channel radiometer arrangements for medical applications
- To research microwave imaging algorithms for representing sub-tissue temperature distribution, focused on breast tissues
- To develop mathematical models for human breast tissue temperature distribution
- To research and develop special materials for electromagnetic shielding and antenna-human tissue impedance matching
- To perform experimentation & laboratory measurements using the developed prototype equipment
- To define industrialization requirements regarding the transition form prototype equipment to end user products

Figure 2: Photos taken during the first meeting regarding the visit of HK Huayi company in Athens

proposed work-plan for the MMR-IBTM project had a **duration of thirty-six months (36 months)** and the work-breakdown structure was consisted of **seven (7) major activities** that were sub-divided a total number of **twenty-two (22) work-packages**. The proposed activities plan was the following

Αποτελέσματα του ...MMR-IBTM... για το ΕΜΠ/Σχολή

The WP3.2, namely "Design, Development & Prototyping of Radiometer Antenna", was conducted by the WLDCL-NTUA team, with responsibility and management of professor Christos Capsalis, and lasted nine (9) months (from 1st June 2014 until 28 February 2015). It was WLDCL's target to perform a detailed design for the radiometer antenna based on the Specifications, Logical Design & Requirements defined within WP2.2 for the radiometer antenna front end. Also WLDCL was aiming at providing a prototype antenna by the end of this work package. During the course of this WP two members of the team were replaced by two others. The work continued seamlessly, despite the team composition change. **During the course of the WP3.2, a significant improvement in the design of the selected solution of WP2.2 was achieved concerning the robustness and efficiency of the antenna. WLDCL conducted and delivered a detailed design of the selected improved antenna solution with a study on its operational concepts, as well as the procedure of the development and the implementation of the prototypes**.

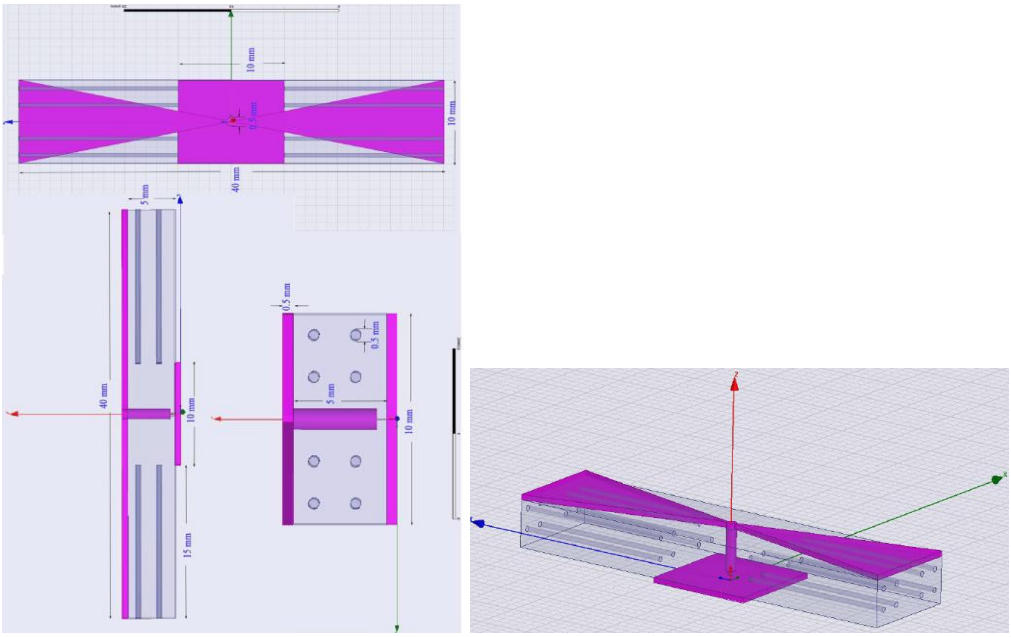

Figure 3: Detailed Design of the Ultra-Wide Band Antenna

In addition a detailed near field study of the proposed antenna was presented, offering radiation characteristics according to the needs of the imaging and modeling process per MEDISP's team request. Extensive laboratory measurements of all realized parts verified and validated functionalities, thus performing preparations for the assembly integration; i.e. integration of all parts in order to evaluate the final radiometer prototype in the following work packages. The outcome of WP3.2 was the Technical Note TN-3.2.1, which present the Detailed Design of the Radiometer Antenna, as well as the final software simulation files (TN-3.2.2) and the implemented hardware prototypes for the single element antenna (TN-3.2.3-2.2.4).

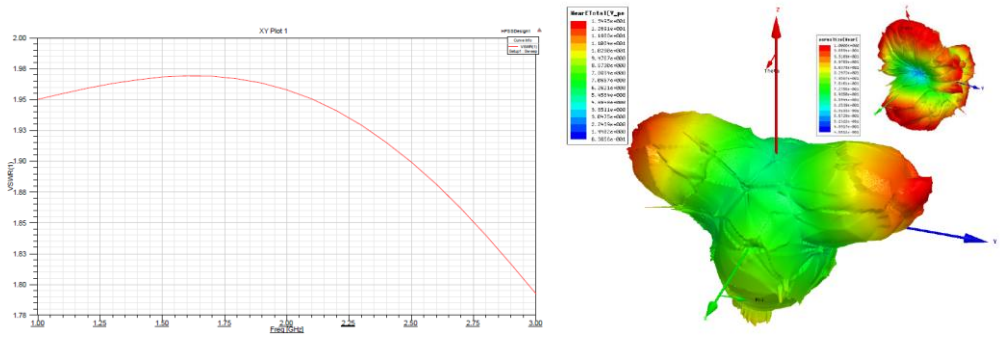

Figure 4: Extensive Simulations of the UWB antenna were performed (VSWR, Near-Field Distribution of the Antenna Pattern for a selected frequency)

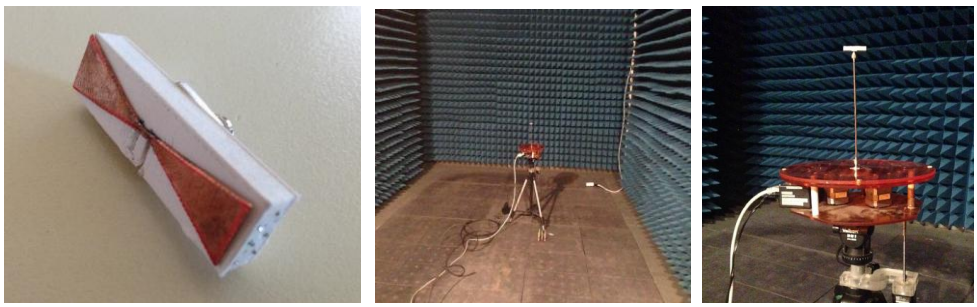

Figure 5: A prototype of the UWB Antenna was constructed and thoroughly examined in the anechoic chamber

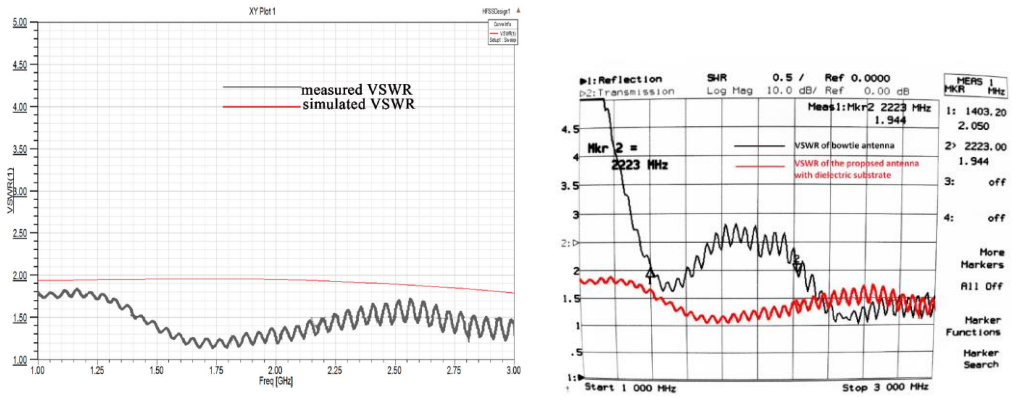

Figure 4.1: The prototype antenna proved to have better performance than the simulated one. The dielectric substrate improved performance.

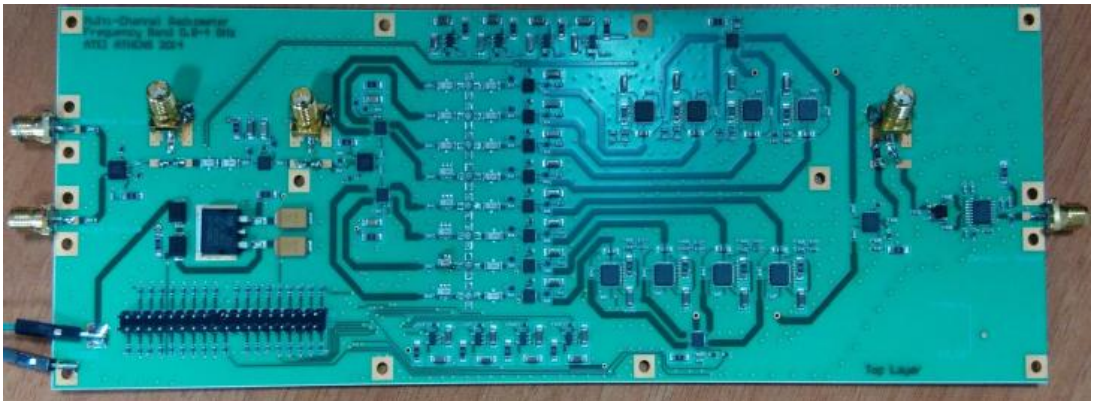

Figure 6: The prototype multi-channel RF front-end

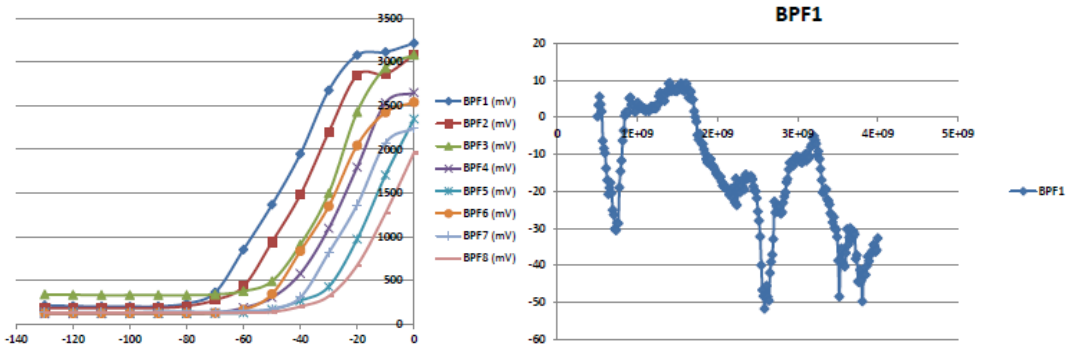

Figure 7: Laboratory Measurements for all channels' sensitivity and response (indicative only BPF1 response is shown at the right figure)

The WP3.4, namely "Design, Development & Prototyping for Radiometer DPU", was conducted by EMTECH team, with responsibility and management of Nikolaos-Antonios Livanos, and lasted nine (9) months (from 1st June 2014 until 28 February 2015). **A prototype single channel DPU was designed and implemented**. The firmware for the device was developed and experimentation with an available microwave radiometer sensor was carried-out. A redesign of the prototype targeting a light DPU including all major systems to interface the

RF-Front end was implemented. The available firmware was modified according to the needs of the redesigned hardware. **Furthermore, a complete DPU for single-channel, stand-alone operation was designed and implemented.** Finally, a motherboard card (back-plane), able to hold several single channel radiometers was designed and the team is currently expecting Printed Circuit Boards (PCB). In order to provide a means of management of the devices a GUI software was implemented. The outcome of this WP were the Technical Note TN-3.4.1, as well as the firmware files (TN-3.4.2), the implemented hardware DPU proof-of-concepts (TN-3.4.3), and the software application (TN-3.4.4).

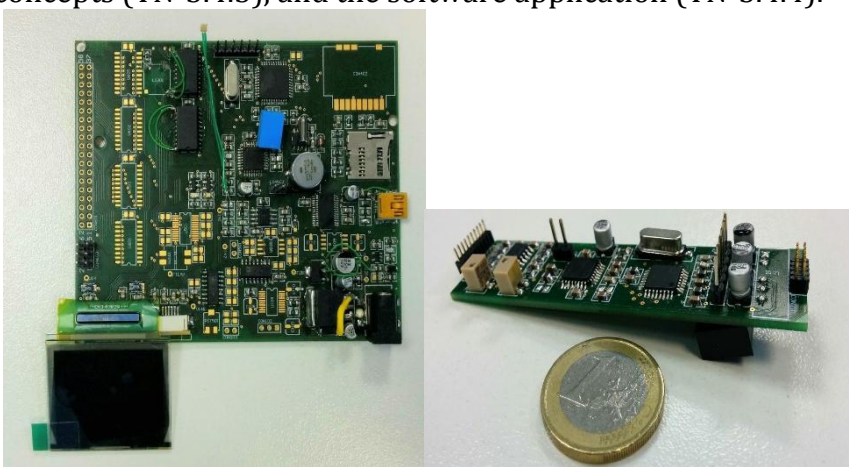

Figure 8: 2 DPU realizations were implemented: stand-alone and single channel

A Graphical User Interface (GUI) for Radiometer Imaging and Modeling Algorithms was also delivered. The GUI was developed, in addition to Technical Annex prerequisites, so as all the algorithms concerning the imaging and modeling to be collected and easily accessed, as a pilot for integration with the other members of the project. The GUI was developed in MATLAB programming environment and is presented and sufficiently explained in the form of functions. The outcome of this WP was the Technical Note TN-3.5.1 providing the detailed design and the simulations outcome, as well as the final imaging (TN-3.5.2) and modelling simulation software (TN-3.5.3).

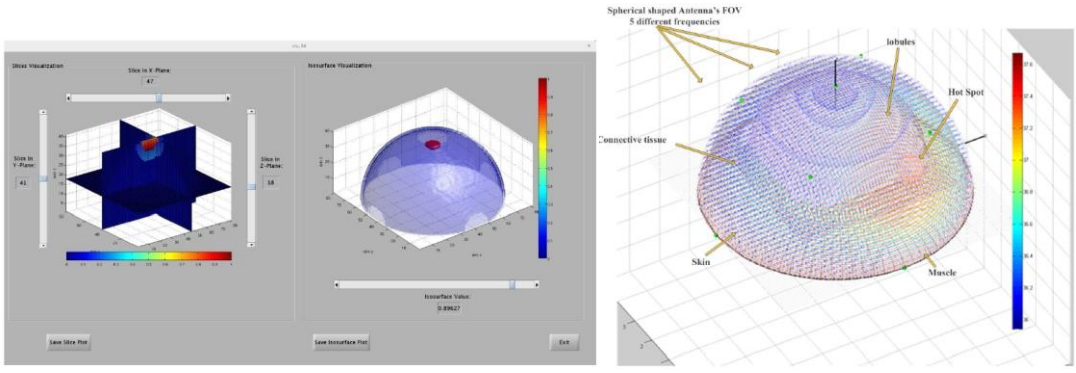

Figure 9: Human Tissue Modeling Software

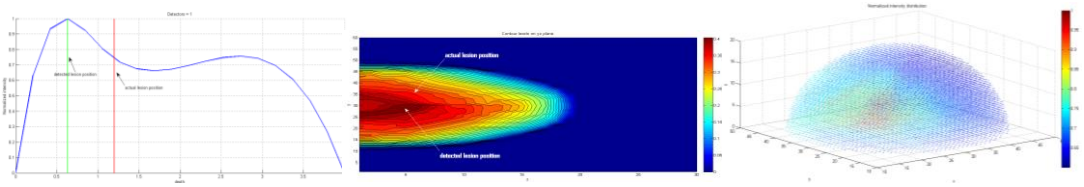

Figure10: 1D, 2D & 3D Imaging Perspectives of the developed software

In parallel to the integration activity, EMTECH initiated the activity related to the Definition of the Industrialization Requirements (WP5). Informally, the task had already produced certain industrial design concepts and according to our plan these should be extensively discussed with the Chinese partner. Although, the concepts involved both the single and the multi-channel approaches, the former was extensively elaborated, as this would be the cornerstone to build the multi-channel arrangement.

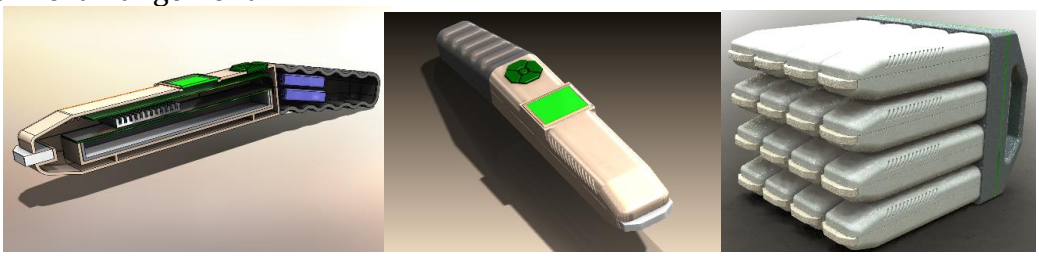

Figure 11: Concept of 1st Industrialization step towards both single-channel and multi-channel arrangements

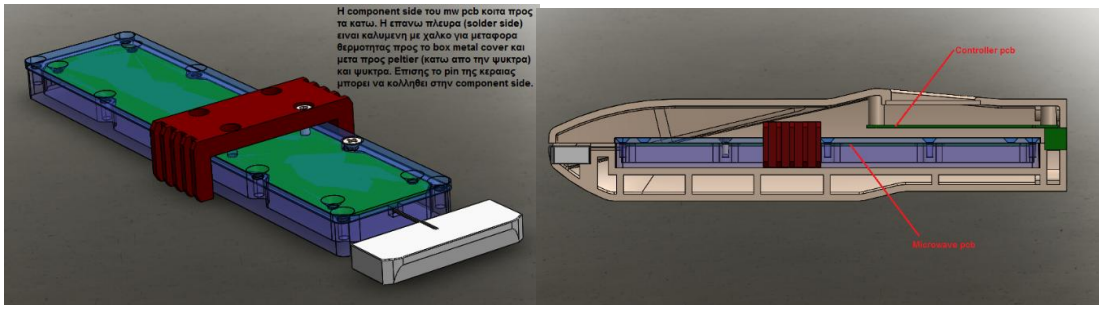

Figure 12: Concepts of operation where elaborated and designed to support 1st Industrialization step towards the single-channel, multi-band approach

Moreover, a detailed approach regarding world-wide patents, was also carried-out. Based on our findings, we consider possible a patent application, namely “3D visualization of human body temperature based on MW radiometry arrangements”. Within the industrialization activity, we performed initial discussions with a patent attorney/consultant, and we have already prepared drafts of the descriptions

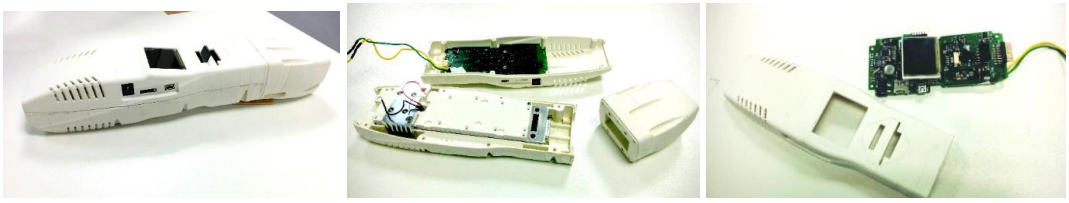

Figure 13: 3-D Printed Enclosure and Redesigned DPU for the Single-Channel Multi-Band Medical Radiometer 1st Industrialized Prototype

Δημοσιεύσεις (ενδεικτικά)

- Nikolopoulos, C. D., Baklezos, A. T., & Capsalis, C. N. (2014). Auto Reconfigurable Patch Antenna for Biomedical Single Channel Multi-Frequency Microwave Radiometry Applications. Progress In Electromagnetics Research C, 49, 19-29.
- A.D. Savva, S.A. Kostopoulos, P.A. Asvestas, C.D. Nikolopoulos, C.N. Capsalis, and D.A. Cavouras, Breast Tumor Presence And Site Detection Employing Passive Microwave Radiometry Imaging, 6th Panhellenic Conference of Biomedical Engineering, Athens, 6-8 May, 2015.
- S. A. Kostopoulos, A. D. Savva, P. A. Asvestas, C. D. Nikolopoulos, C. N. Capsalis, and D. A. Cavouras, Early breast cancer detection method based on a simulation study of single-channel passive microwave radiometry imaging, International Conference on Mathematical Modeling in Physical Sciences, Mykonos, Greece, 5-8 June, 2015.
- Baklezos, A. T., Nikolopoulos, C. D., Katsouris, A. G., & Capsalis, C. N. (2015). Analysis of Ultra-Wideband Elliptical Monopole with Modified Ground for Applications in Radiometric Measurements. International Journal on Communications Antenna and Propagation (IRECAP), 5(1), 46-53.
- A. T. Baklezos, C. D. Nikolopoulos, C. N. Capsalis, "A Planar On-Body Antenna System for Cancerous Tumor Detection through Microwave Transmission Sensing," Journal of Engineering, 2016 (Accepted)

Για παράδειγμα:

i. δημιουργία/ανάπτυξη καινούριας ερευνητικής περιοχής
Πρώιμη Ανίχνευση Καρκινικών όγκων με χρήση παθητικής ραδιομετρίας
ii. ονόματα έμπειρων/μεταδιδακτορικών ερευνητών που συνεισέφεραν/ υποστηρίχθηκαν
Δρ. Χρήστος Δ. Νικολόπουλος
iii. υποψήφιοι διδάκτορες που υποστηρίχθηκαν: τίτλοι διατριβών
Ανάργυρος Θ. Μπακλέζος
iv. αριθμός άρθρων σε περιοδικά και συνέδρια: 5
v. διπλώματα ευρεσιτεχνίας : 1 (σε εξέλιξη)
vi. βραβεία: **Θωμαϊδειο Βραβείο για τα έτη 2013 για 1 δημοσιεύσεις σε επιστημονικά περιοδικά που περιλαμβάνονται σε έγκριτες βάσεις δεδομένων (π.χ. Scopus, Science Citation Index Expanded).**
vii. αξιόλογος νέος εξοπλισμός

viii. νέες συνεργασίες με ερευνητικούς φορείς και βιομηχανία
1. Συνεργασία με την EMTech, μέλος του Space Cluster της Ελλάδας.
2. Συνεργασία με την BEIJING GK HUAYI Technology Co. Ltd

ix. περιθώρια για καινοτομία ως αποτέλεσμα έργου

x. κάτι ιδιαίτερο που πρόσφερε, π.χ. Πειράματα ερευνητών της Σχολής στο εξωτερικό, φιλοξενία και πειράματα απο ξένους ερευνητές στη Σχολή