An Innovative Framework for Advancing Microwave Medical Imaging: The EMERALD European Network

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Lorenzo Crocco[1] and Francesca Vipiana[2]

[1] Institute for Electromagnetic Sensing of the Environment, National Research Council of Italy, IREA-CNR, Napoli, Italy, crocco.l@irea.cnr.it

[2] Dept. Electronics and Telecommunications, Politecnico di Torino, DET-POLITO, Torino, Italy, francesca.vipiana@polito.it

***Abstract*— Nowadays, medical imaging technologies play a key role to face the ever-growing number of challenges due to aging populations, as they are the essential clinical tool to deliver accurate initial diagnosis and monitor the evolution of disease over time. For this reason, a whole range of new imaging modalities is currently being developed to supplement and support current modalities. This communication introduces the recently started "EMERALD - ElectroMagnetic imaging for a novel genERation of medicAL Devices" project, which is a European network of nested doctoral projects pursuing the development innovative medical imaging devices based on electromagnetic technology. The original implementation of the network structure and the highly focused nature of each project is such that the global resultant of this European research effort may provide a systemic answer to some emerging clinical needs.**

***Index Terms*—microwave imaging, medical technologies.**

I. Introduction

The use of microwave imaging (MWI) for medical applications is nowadays an established field, as testified by the number of dedicated sessions in conferences as well as special issues and sections in topical journals [1][2][3]. The interest is of course motivated by the unique features offered by MWI, such as its low-cost, portability, non-ionizing nature and even the perspective theragnostic potential, derived from the dual capability of microwaves of sensing and healing (via thermally induced effects).

However, despite the large efforts done so far by scholars, researchers and practitioners, an actual breakthrough of these technologies in the clinical practice has not been yet achieved.

One of the possible reasons of such a state of thing can be found in the lack of critical mass. As a matter of fact, most if not all of the efforts and activities have been pursued by single research groups. Hence, while some of these achievements are certainly notable and brought to significant scientific advancements (see e.g. [4][5][6][7]), no example is available of a broad synergic research effort aimed at facing the main challenges that have still to be overcome to make MWI progress "from research bench to patient bedside".

These challenges include:

- the definition of standardized methods to measure the electromagnetic properties of human tissues;
- the creation of accessible databases;
- the development of standardized phantoms for laboratory assessment;
- the design and realization of new, dedicated components and core elements for MWI systems;
- the development and implementation of tailored modelling and image formation tools.

The need of a broad cooperative effort to address these challenges was somehow recognized by the researchers working on medical MWI when peers from more than 20 European countries joined together in "MiMed – Accelerating the Technological, Clinical, and Commercialization Progress in the Area of Medical Microwave Imaging" COST network [8]. This network, operating from 2013 to 2017, fostered the cooperation between many research groups and gave a significant push to the creation of recognizable community of scholars working on medical MWI.

The MiMed legacy has provided a solid basis for future developments, one of the most important is the EMERALD network, which is described in this invited contribution.

II. The EMERALD Network and its Innovative Aspects

The "EMERALD - ElectroMagnetic imaging for a novel genERation of medicAL Devices" action is a recently started Marie Slodowskwa-Curie Innovative Training Network (ITN), constituted by 13 Ph.D. projects pursuing the overall aim of accelerate translation of research in electromagnetic (EM) medical imaging into preclinical prototypes [9]. This network represents the first European synergic effort aimed at systematically face the still open challenges mentioned above.

According to the proposers, ITNs represent the right instrument to achieve the goal. As a matter of fact, the peculiar, interdisciplinary and intersectoral nature of the research activities that have to be carried out to develop successful medical MWI devices calls for a specialized training. Hence, the ultimate goal of EMERALD is to establish a unique scientific and training programme, which takes advantage of the individual contribution of all the involved institutions as well as of established connection with clinicians and stakeholders (hospitals and university medical centers) involved in EMERALD network as partners, in a continuous feedback loop between technology, clinical needs and user awareness.

This concept has been implemented into the structure depicted in Fig. 1.

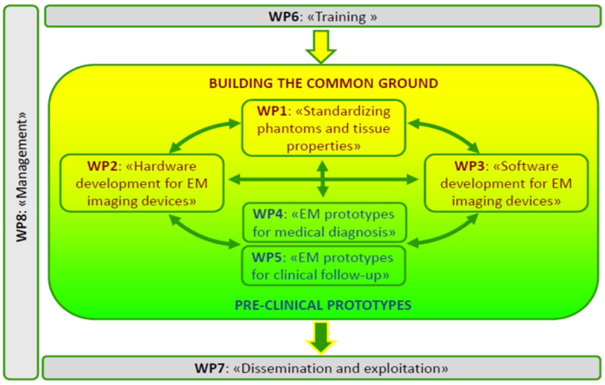

Fig. 1. EMERALD WP structure.

The EMERALD project is organized in five scientific WPs together with one WP dedicated to training, another to dissemination, exploitation and outreach activities, and the last one for the management. The main objectives of the scientific WPs are briefly summarized in the following.

WP1 deals with the design and realization of standardized phantoms for EM device testing, which is essential to assess devices under repeatable conditions, as well as updating and completing the information on the dielectric properties of human tissue, which are the basis of EM imaging and are essential to set models and design systems.

WP2 addresses a number of hardware developments essential to deliver enhanced performance EM medical devices, including the hardware acceleration of imaging algorithms, the development of customized radiofrequency front-end systems, as well as the exploitation of metamaterial technology for antennas and matching layers.

WP3 deals with the software developments needed by the new generation of EM medical devices, which includes appropriate port-to-port modelling of the whole device and its component, as well as the development of ad-hoc image formation strategies and algorithms purposely designed and implemented for specific clinical tasks such as diagnosis, clinical follow-up and image-guided treatment, respectively.

WP4 is dedicated to the design, preclinical prototypization and controlled testing of two EM imaging diagnostic devices. The first is devoted to the diagnostic imaging of cerebrovascular diseases (stroke, haemorrhage, and hematoma), and the second device is meant for the diagnosis of axillary lymph nodes.

Finally, WP5 is dedicated to the design, preclinical prototypization and controlled testing of three EM imaging devices for clinical follow-up and image-guided treatment. The first device is devoted to the clinical follow-up of breast cancer chemotherapy/radiotherapy to monitor the regression of the tumor. The second device will be designed for imaging temperature monitoring during non-invasive hyperthermia treatments. The third device will pursue the monitoring of an invasive tumor ablation process, to both control temperature and monitor the extent of the ablated zone.

WP1-3 objectives aim as building the common ground upon which the next generation of EM medical imaging devices will stand on, by addressing technological aspects that are common to the development of any EM medical imaging device. Instead WP4-5 pursue the development of preclinical prototypal devices that target some new applications of EM imaging, with the explicit aim of accelerating the progress towards clinical translation.

The training (WP6) is focused on 13 coordinated Ph.D. research projects and it includes three Summer Schools, three General Workshops, and one Final Conference that will be the project's backbone to support the fellows' network wide training. Moreover, all the Ph.D. student will carry secondments at participating organizations, and in particular at clinical and industrial partners.

Finally, the EMERALD network will take care of disseminating its results in the European society: proper dissemination channels will be exploited to reach all target groups interested in EMERALD, such as scientific communities, industrial and market stakeholders, policy makers, medical associations and the general public.

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