MiBraScan - Microwave Brain Scanner for Cerebrovascular Diseases Monitoring

KO CNR-IREA, 01/02/2017

MiBraScan main expected result

Develop and build the prototype of a microwave imaging (MWI) device able to track the **evolution in time of a stroke, as well as to image the features of the tissues it has affected.**

- non-invasive and safe, thanks to the use of low-power, non ionizing radiations;
- provides real-time images of the stroke evolution, thanks to tailored processing algorithms and their hardware implementation;
- portable at the patient bed, thanks to the use of ad-hoc developed front-end electronics;
- is cost-efficient, thanks to low-cost of the involved technologies.

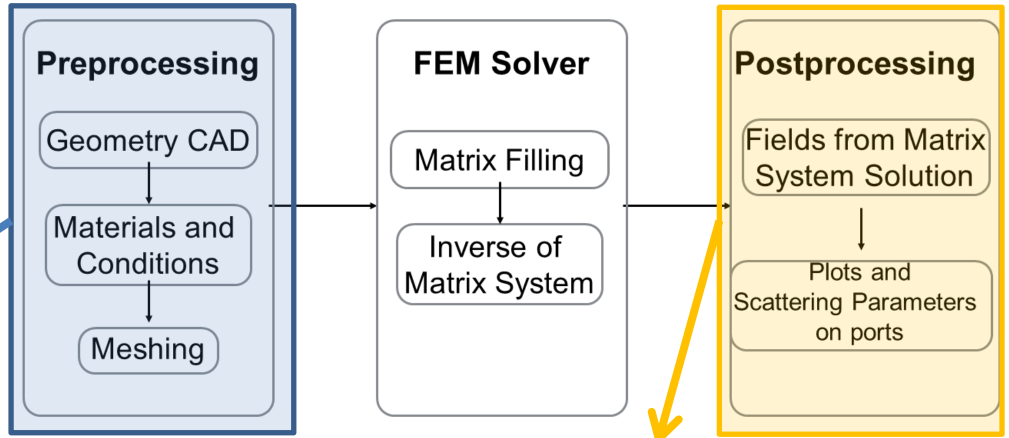
Brief introduction on recent results effort by POLITO (1)

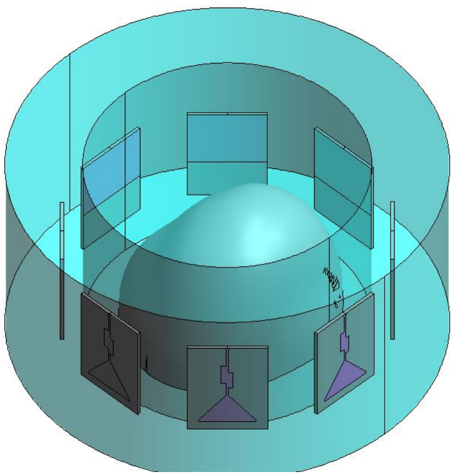
The team:

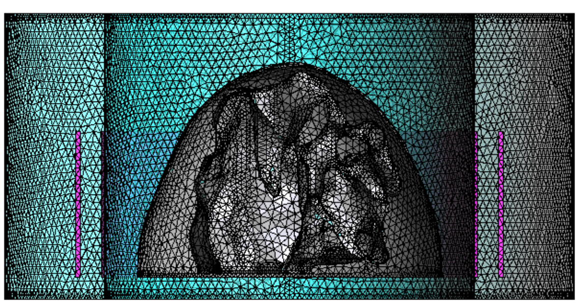
- ✓ **Francesca Vipiana, Jorge Tobon and Gianluca Dassano**, Antenna and EMC Lab (LACE, http://areeweb.polito.it/lace/)
- ✓ **Mario Casu, Giovanna Turvani and Marco Vacca**, VLSI Lab (http://www.det.polito.it/it/the_department/internal_structures/research_labs/vlsi_laboratory)

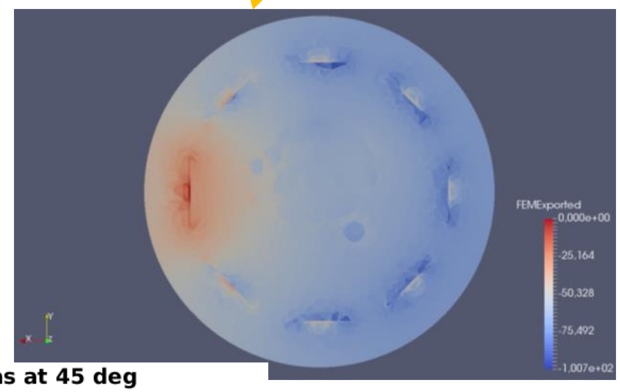
Brief introduction on recent results effort by POLITO (2)

- ✓ **In-house 3-D EM full-wave solver** to model the whole microwave imaging system together with a 3-D anthropomorphic phantom

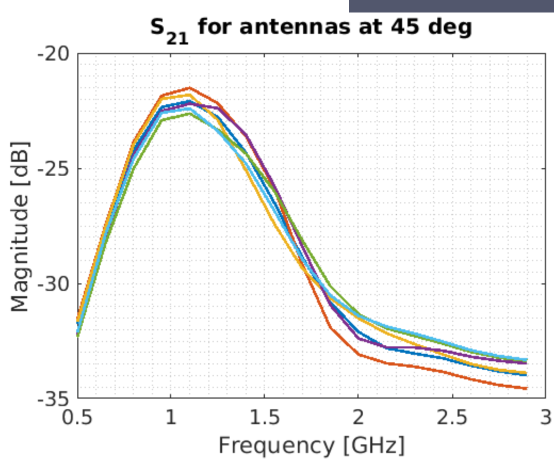








Field map



Brief introduction on recent results effort by POLITO (3)

✓ **Design, prototyping and testing of custom printed antennas**

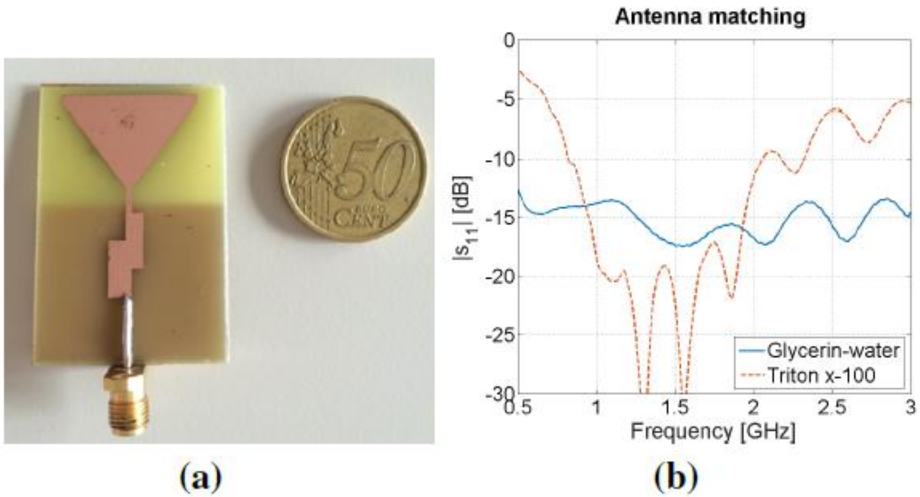


Fig. 3. (a) Antenna and (b) S_{11} measured in 80-20% glycerin-water mixture (solid line) and in Triton x-100 (dashed line).

Brief introduction on recent results effort by POLITO (4)

✓ **Design, prototyping and testing of ad-hoc radiofrequency (RF) front-end systems**

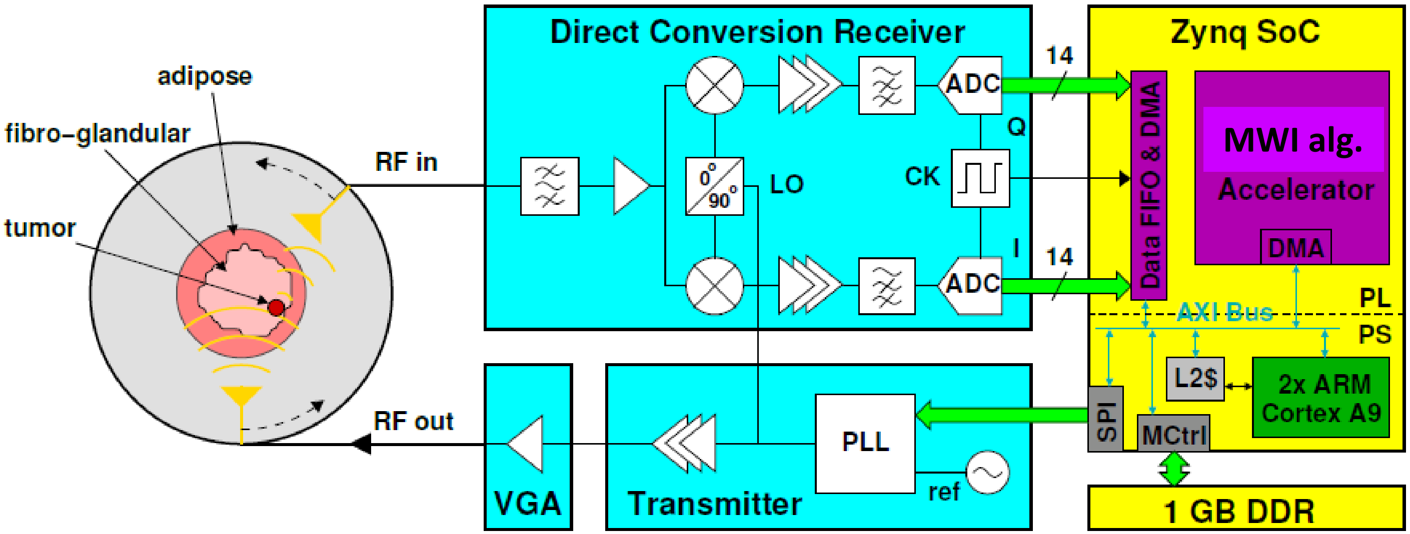


Fig. 1. Architecture of our prototype system for breast-cancer detection using Microwave Imaging.

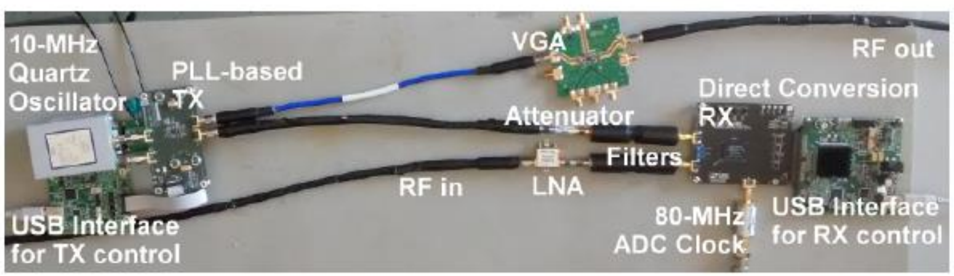


Fig. 7. Low-cost, small-size components off-the-shelf used in our system.

Brief introduction on recent results effort by POLITO (5)

- ✓ **Custom programming of an embedded Field-Programmable Gate Array (FPGA) for accelerating the execution of the imaging algorithm.**

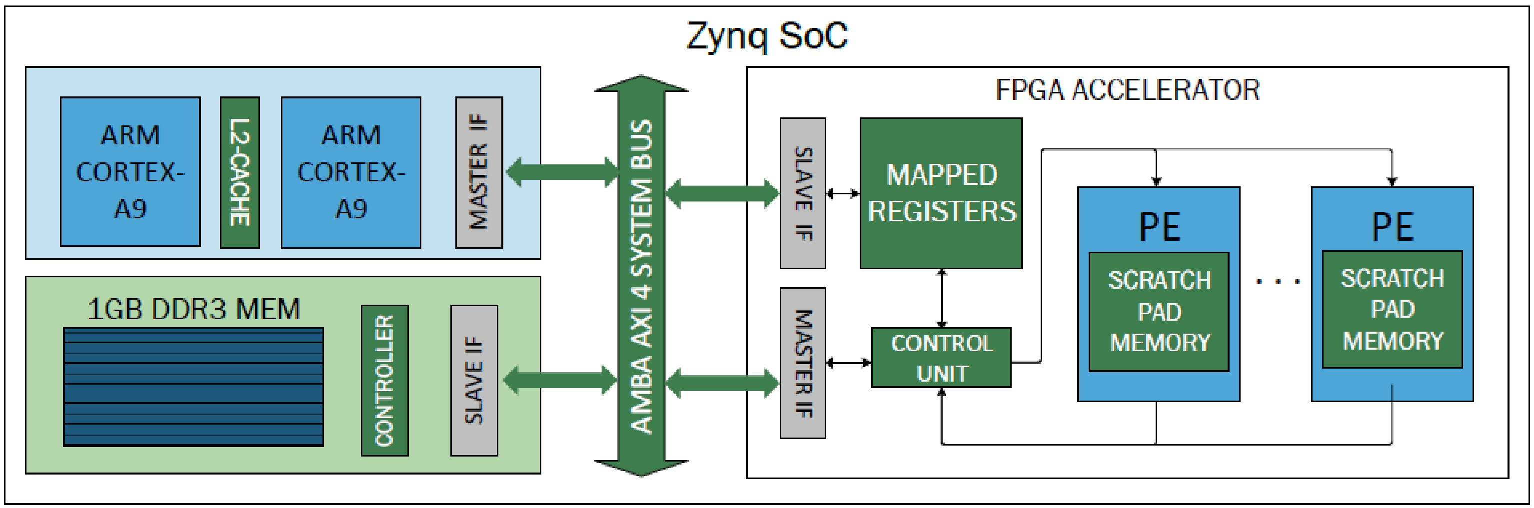


Fig. 8. computing architecture on a Xilinx Zynq SoC.

Overview of recent CNR-IREA results

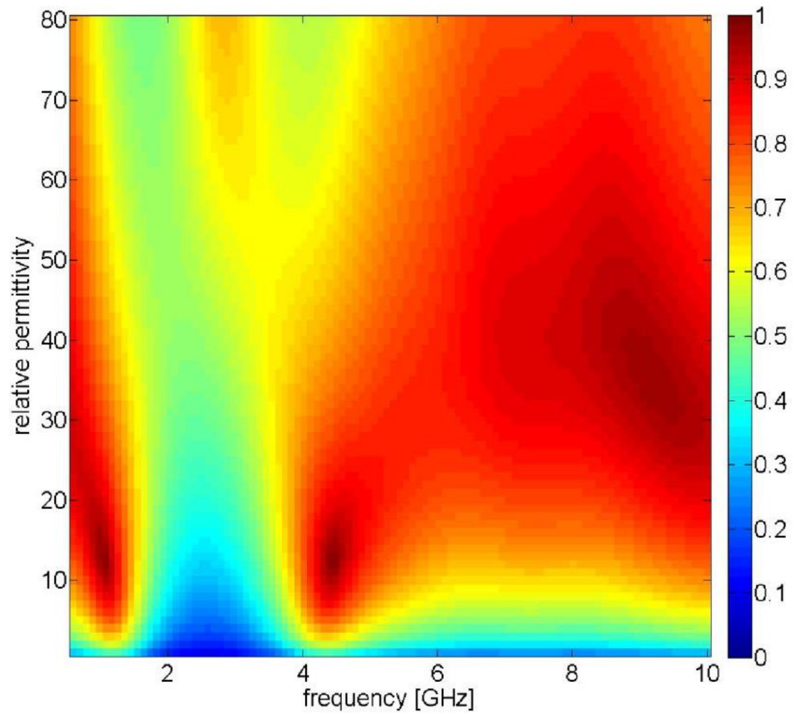
Expertise

- EM modelling in complex environments
- Approaches for imaging problems
- Tools and methodologies to design optimal MWI systems

Overview of recent CNR-IREA results

A simple tool to fix working conditions

Transmission Coefficient

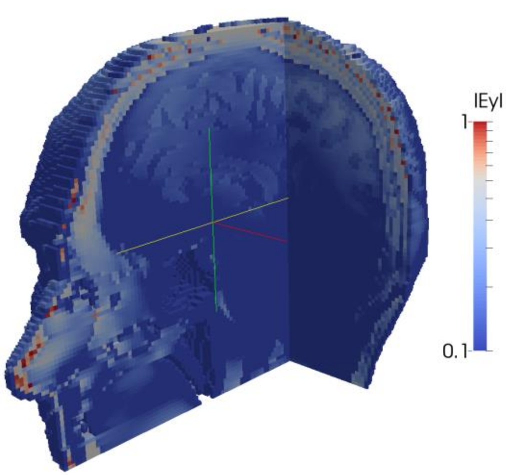


Working frequency <1.5GHz

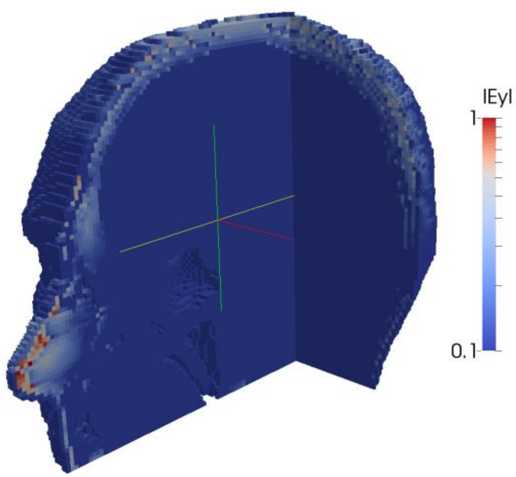
Embedding medium [10-50]

7-15mm spatial resolution

1GHz



2GHz



Overview of recent CNR-IREA results

A methodology for optimal MWI system design

input

- ❖ Mathematical operator of the problem
- ❖ Measurement surface / Imaging domain
- ❖ SNR and Dynamic range of the system

metrics

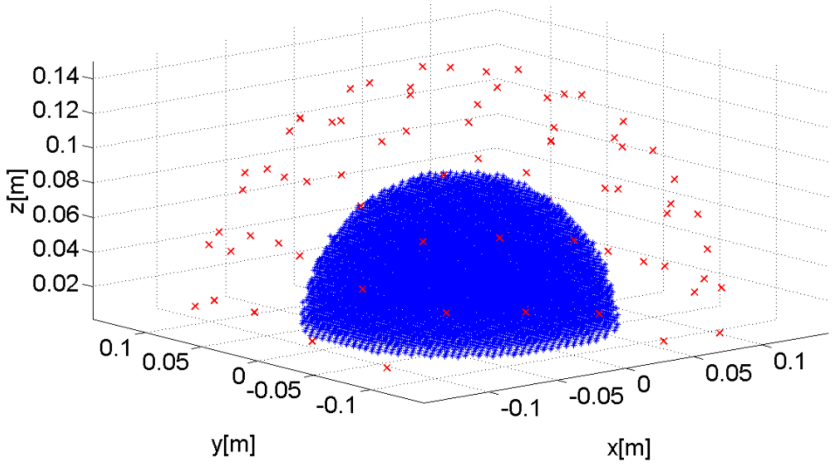
- ✓ Discretization error (on the operator)
- ✓ Condition number

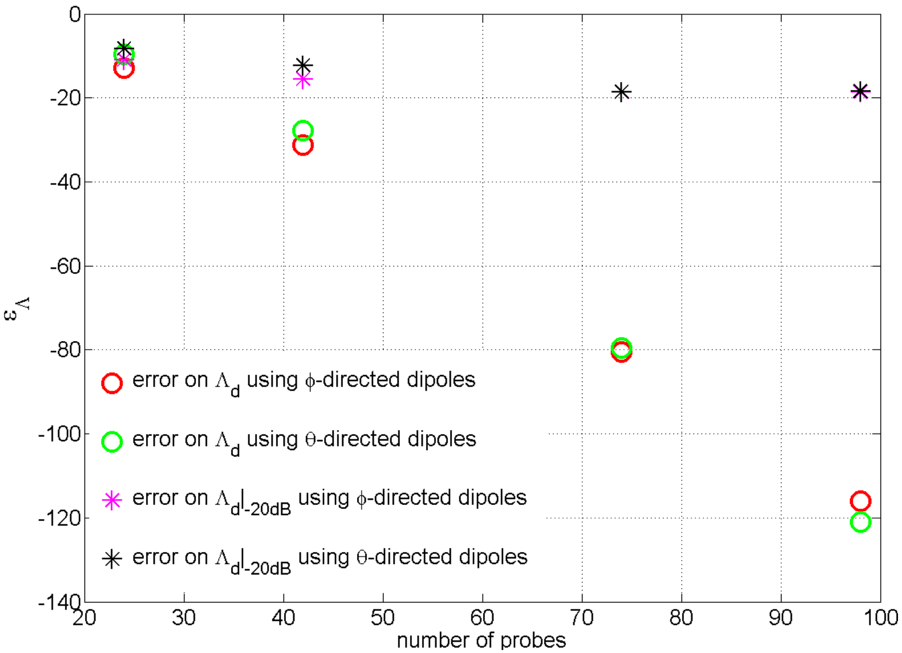
output

- ➢ **Optimal <u>number</u> and <u>positioning</u> of the probes**

Overview of recent CNR-IREA results

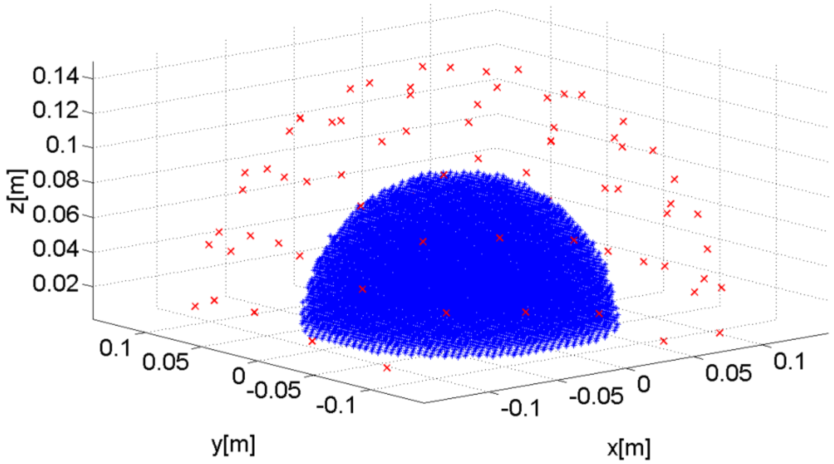
A methodology for optimal MWI system design

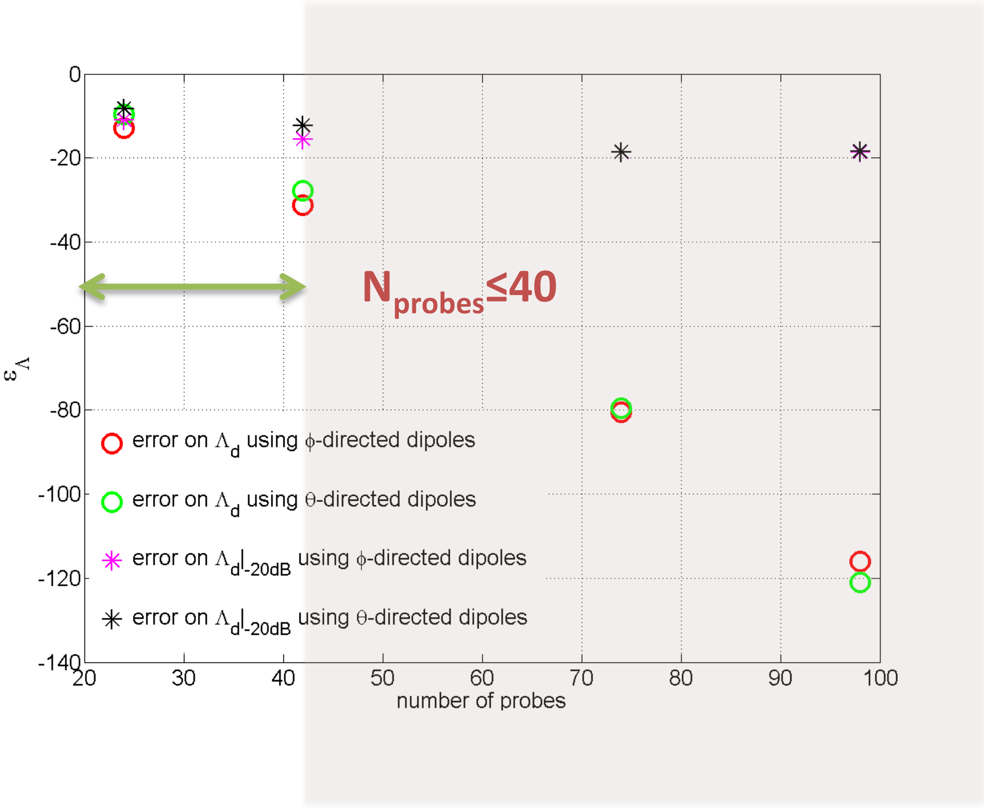




Overview of recent CNR-IREA results

A methodology for optimal MWI system design

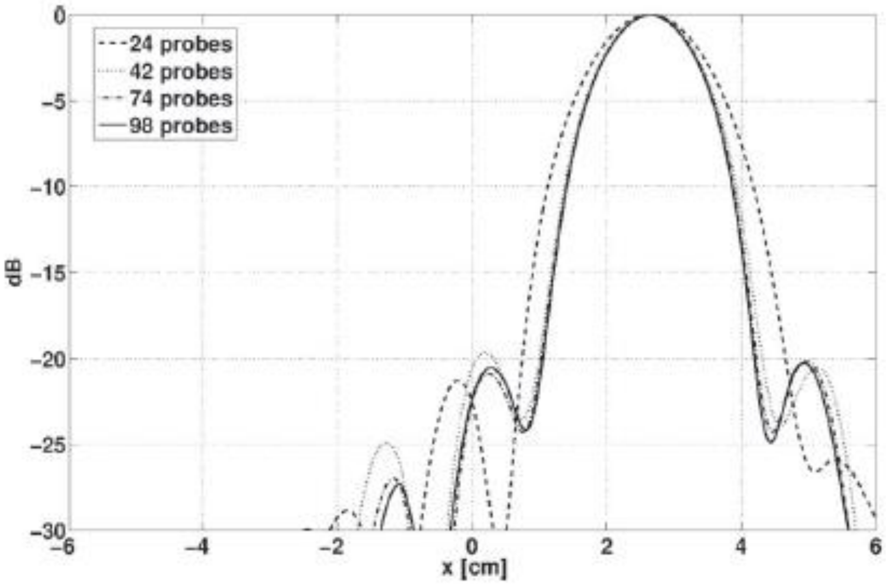




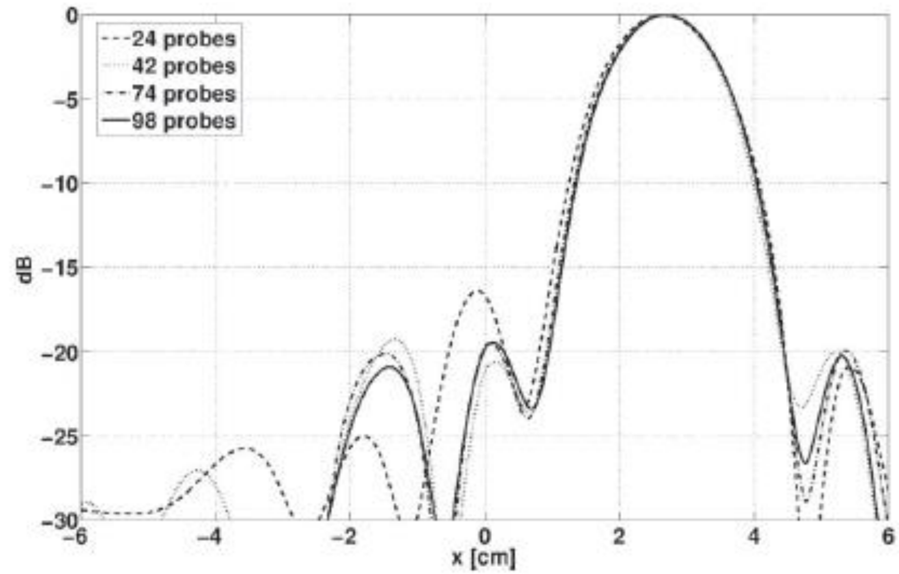
Overview of recent CNR-IREA results

A methodology for optimal MWI system design

Reducing the number of probes (image of a point-like target)



High precision system



Low precision system

Overview of recent CNR-IREA results

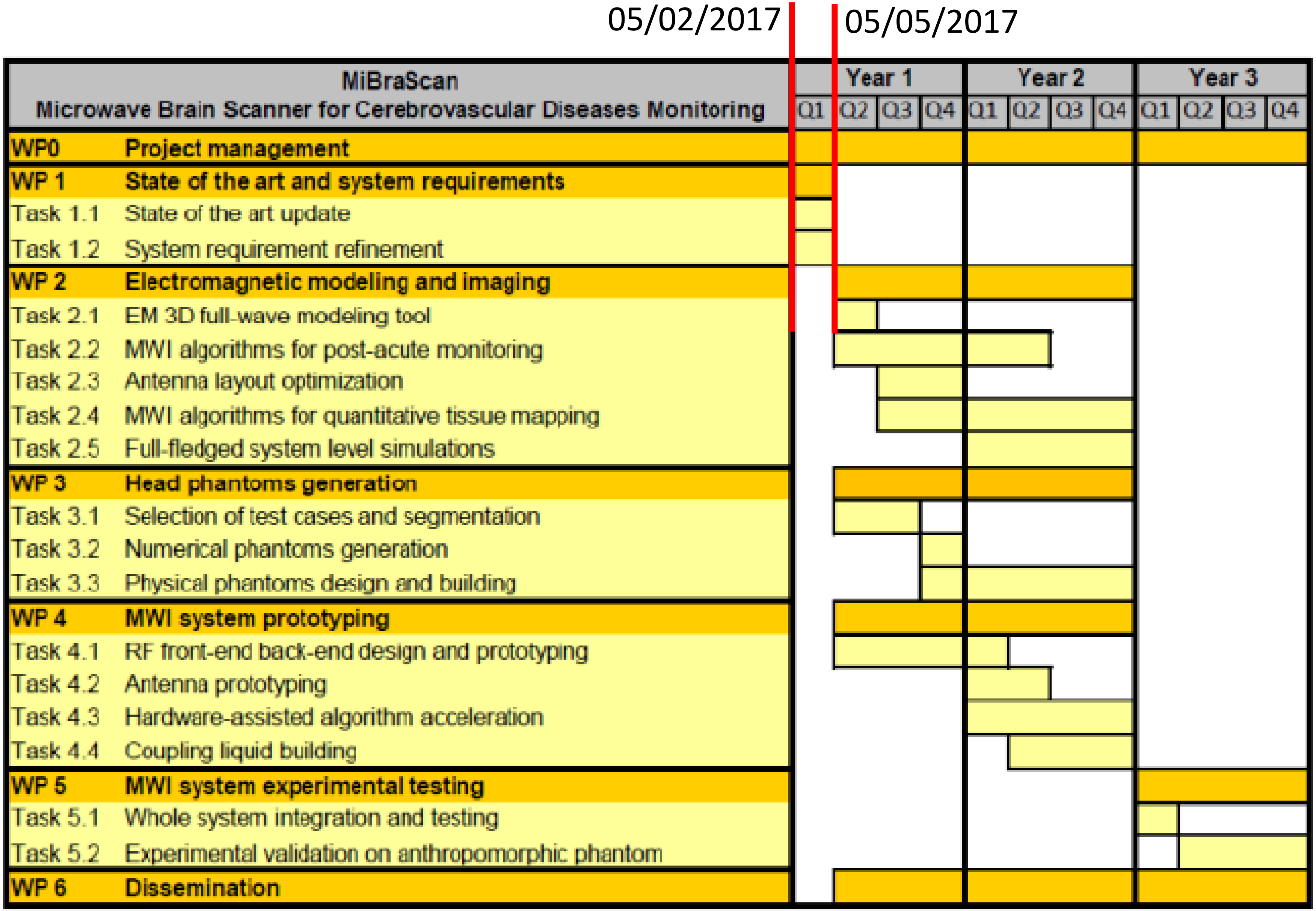
the team

Lorenzo Crocco
Rosa Scapaticci
Gennaro G. Bellizzi

Associated researchers for MIBRASCAN
Enrico Tedeschi
Gennaro Bellizzi

Brief introduction/update on recent results effort by CNRS

Recalling the first steps of the projects (from the gantt chart)



Deliverables

No.	Title	WP/task	Delivery	
D1.1	State of the art report	Task 1.1	Y1-Q1	05/05/2017
D1.2	System requirements report	Task 1.2	Y1-Q1	05/05/2017
D2.1	EM 3D full-wave modeling tool	Task 2.1	Y1-Q2	05/08/2017
D3.1	Segmented head test cases	Task 3.1	Y1-Q3	
D2.3	Report on the designed antenna system	Task 2.3	Y1-Q4	
D3.2	Numerical 3D head phantoms	Task 3.2	Y1-Q4	
D0.1	Annual project management, activity and financial report	WP0	Y1-Q4	
D4.1	RF front-end back-end prototype	Task 4.1	Y2-Q1	
D2.2	MWI code for post-acute monitoring	Task 2.2	Y2-Q2	
D4.2	Antenna system prototype	Task 4.2	Y2-Q2	
D3.3	Physical 3D head phantoms	Task 3.3	Y2-Q4	
D2.4	MWI code for quantitative tissue mapping	Task 2.4	Y2-Q4	
D2.5	Report on the performed system level simulations	Task 2.5	Y2-Q4	
D4.4	Coupling liquid	Task 4.4	Y2-Q4	
D4.3	FPGA code for MWI post-acute monitoring algorithms	Task 4.3	Y2-Q4	
D0.2	Annual project management, activity and financial report	WP0	Y2-Q4	
D5.1	Report on the performed MWI system testing	Task 5.1	Y3-Q1	
D5.2	Report on the performed MWI system validation	Task 5.2	Y3-Q4	
D0.3	Final project management, activity and financial report	WP0	Y3-Q4	

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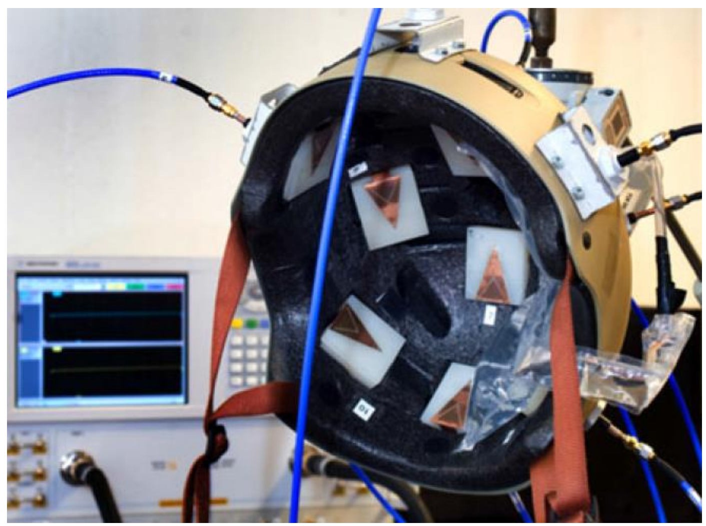
D0.3	Final project management, activity and financial report	WP0	Y3-Q4	

D1.1 State of the art report (POLITO)

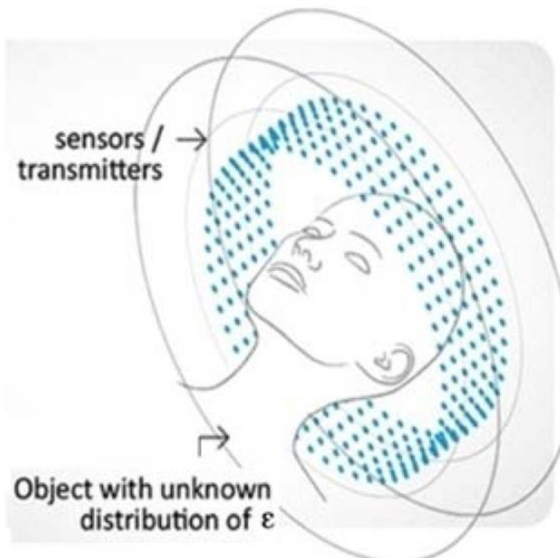
State of the art: experimental devices (1)

Chalmers University, Sweden, “Microwave-Based Stroke Diagnosis Making Global Prehospital Thrombolytic Treatment Possible”, IEEE Trans. Biomedical Eng., 61, 2014: specifically designed for stroke classification, but it cannot provide images of the head



State of the art: experimental devices (2)

S. Semenov (EMTensor, Austria) et al. “Electromagnetic tomography for brain imaging: Initial assessment for stroke detection”, 2015 IEEE Biomedical Circuits and Systems Conference (BioCAS); Semenov, S. Y. Electromagnetic tomography solutions for scanning head. US 20140155740 (2014).
160 antennas; need of improvements of both hardware and imaging algorithms



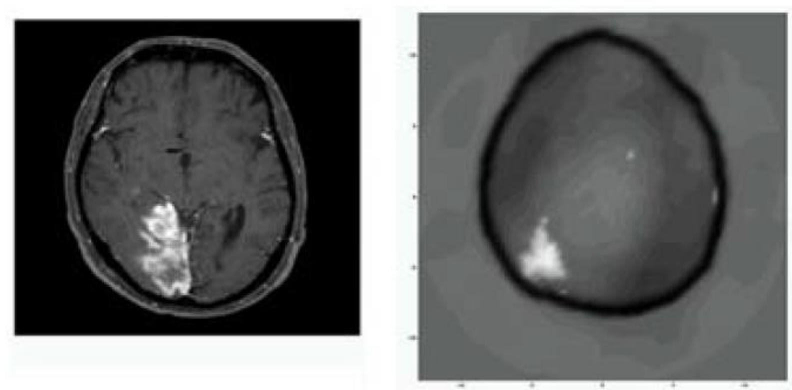
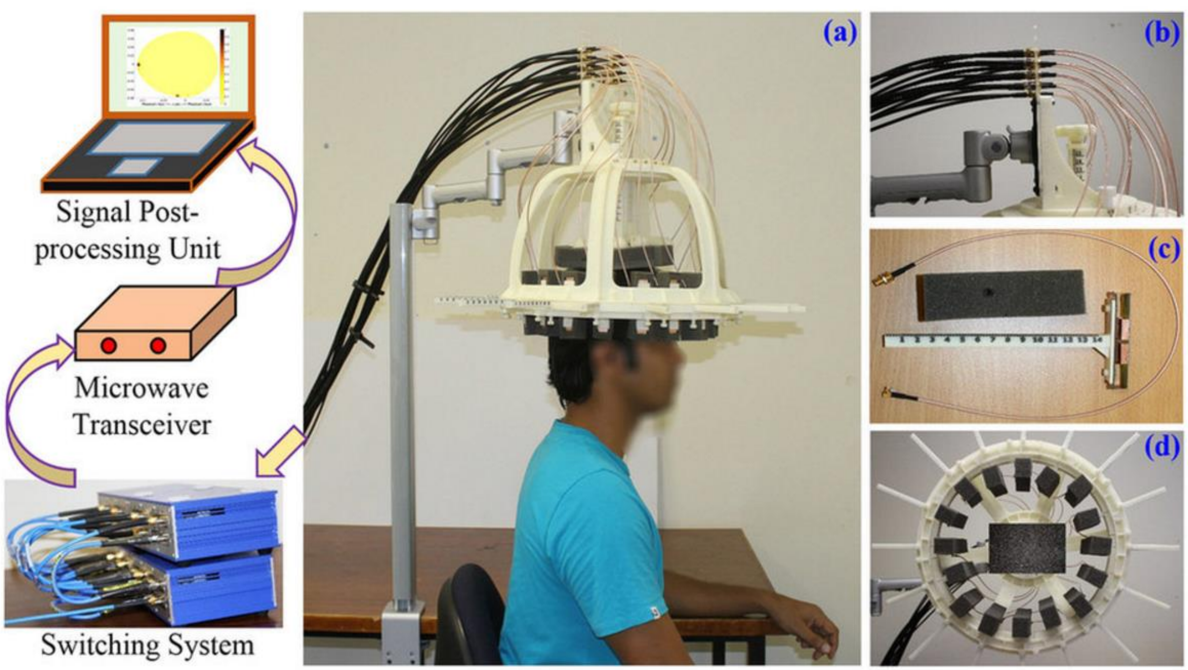


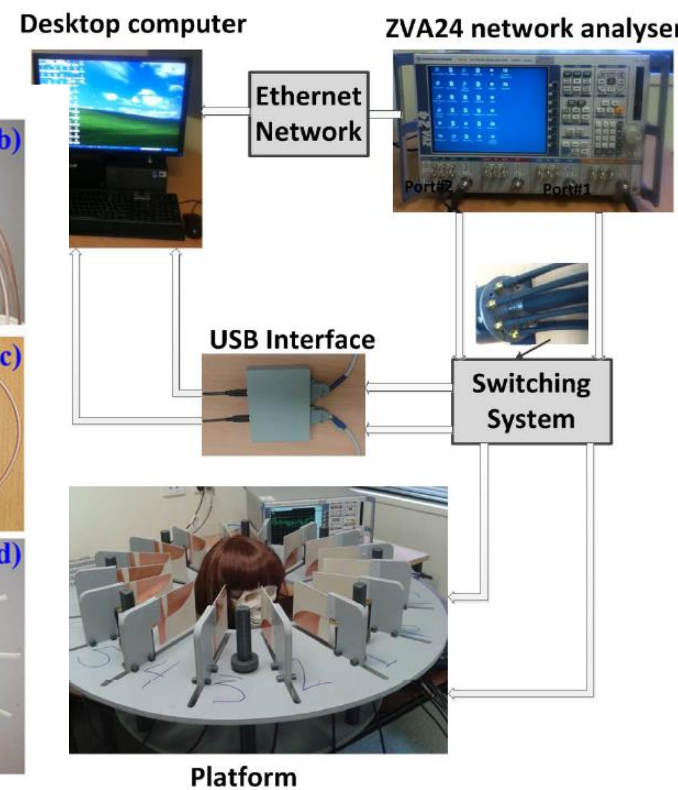
Figure 4. MRI (left) and EMT (right) images of patient stroke. EMT probing frequency was 0.95GHz.

State of the art: experimental devices (3)

A. M. Abbosh et al., IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 63, NO. 1, JANUARY 2014, “Microwave System for Head Imaging”; “On-site Rapid Diagnosis of Intracranial Hematoma using Portable Multi-slice Microwave Imaging System” (2016), http://www.nature.com/articles/srep37620

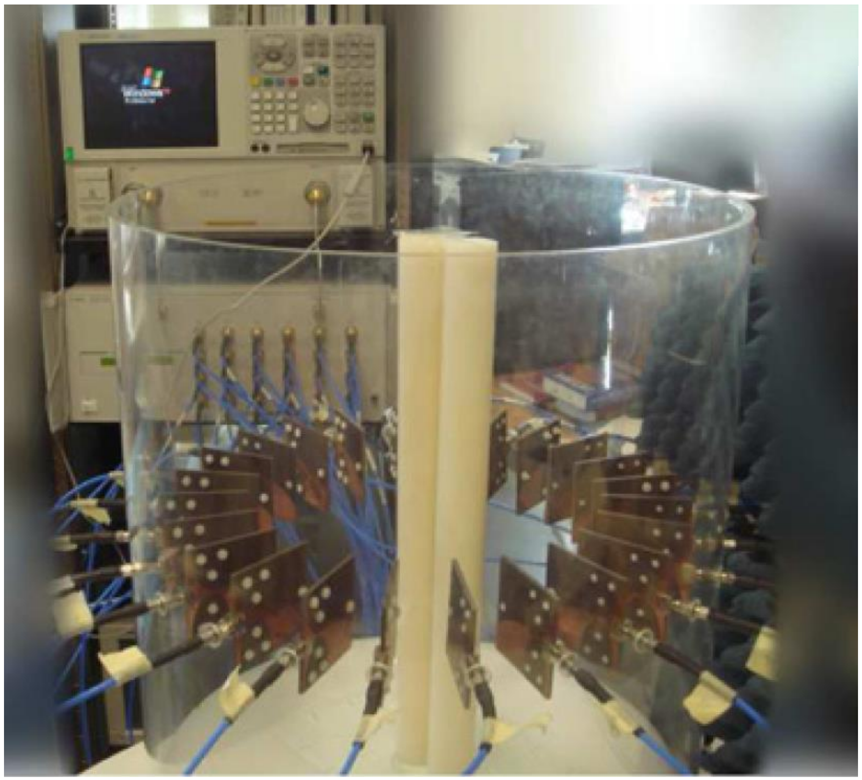
broadband data, which entails significant problems in terms of EM modeling of tissue dispersivity; confocal algorithms that are known to be ineffective in heterogeneous environments

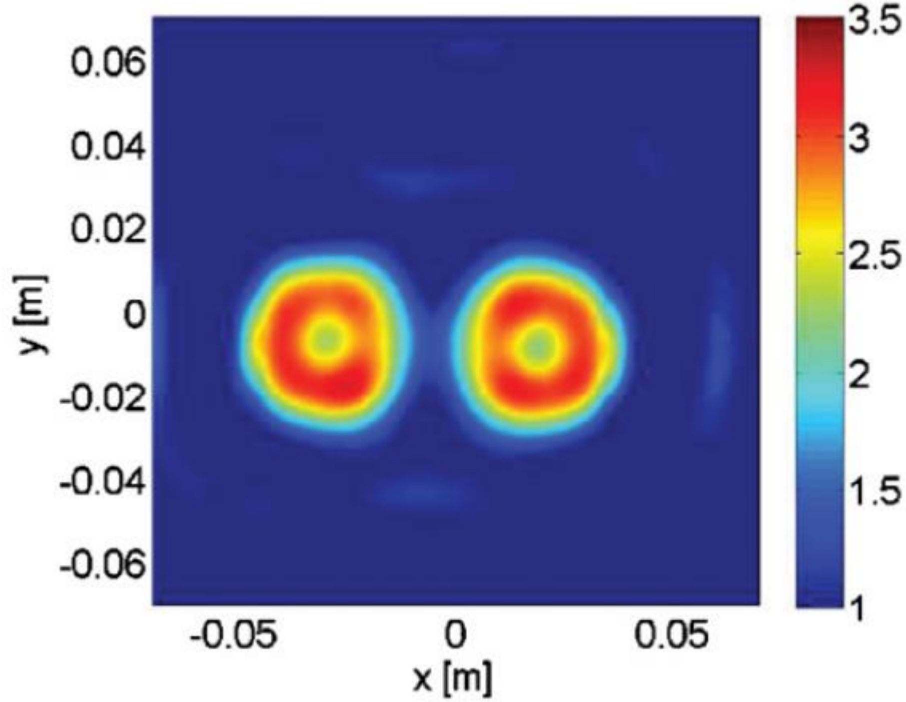




State of the art: experimental devices (4)

Finite-element contrast source inversion method for microwave imaging
Joe LoVetri et al., Inverse Problems 26 (2010) 115010 (21pp)

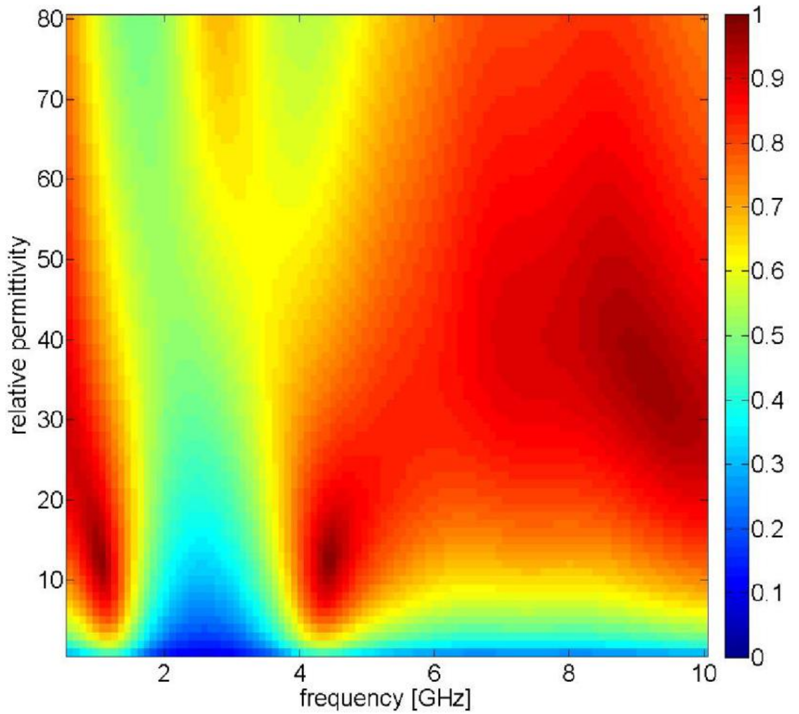




The VNA is connected to the antennas via an Agilent 24-port microwave switch

D1.2 System Requirements (CNR-IREA)

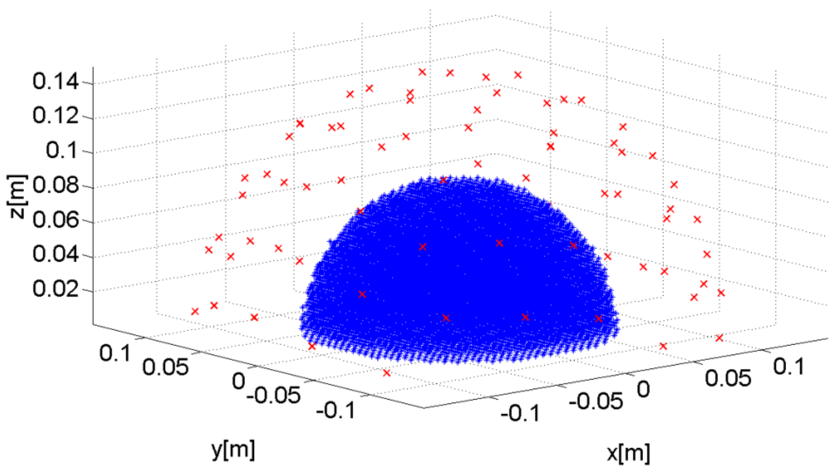
System requirements (1)



Working frequency <1.5GHz

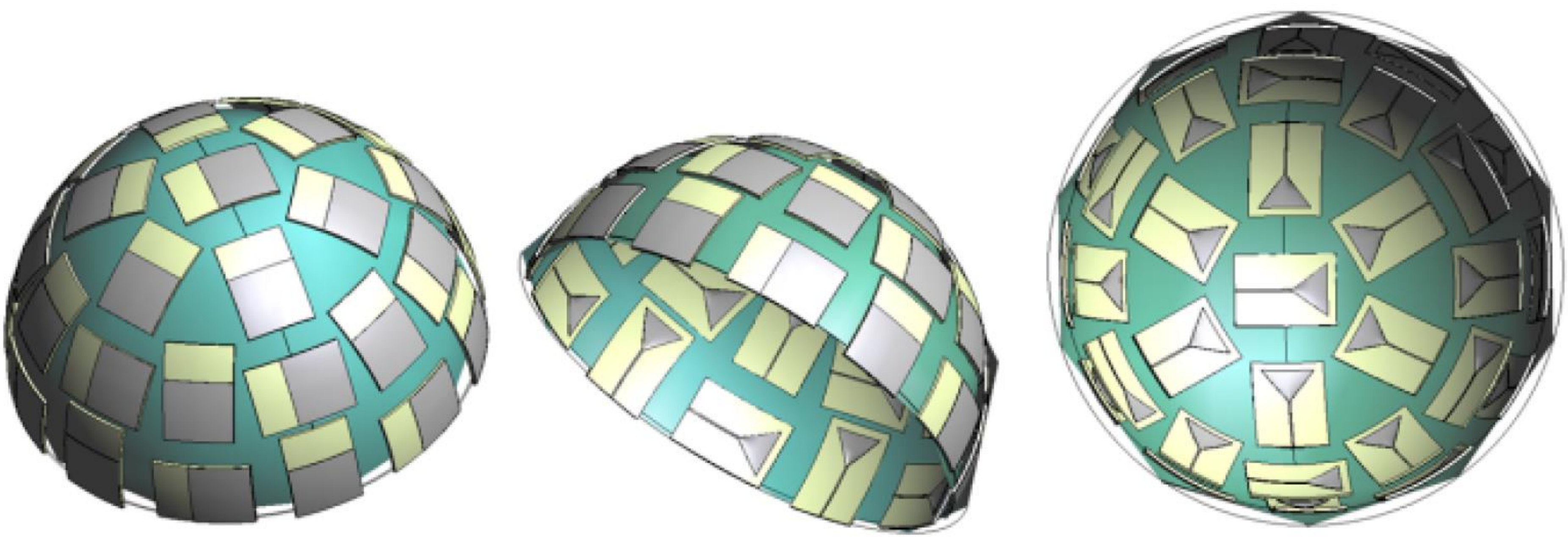
Embedding medium [10-50]

7-15mm spatial resolution

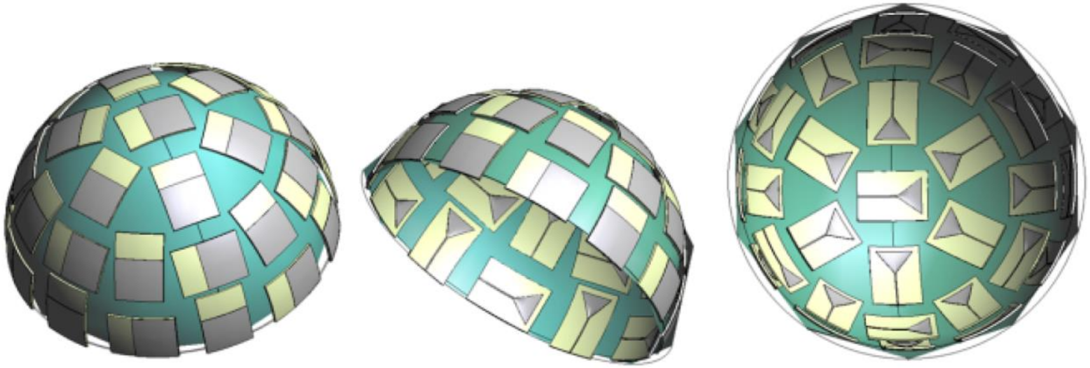


System requirements (2)

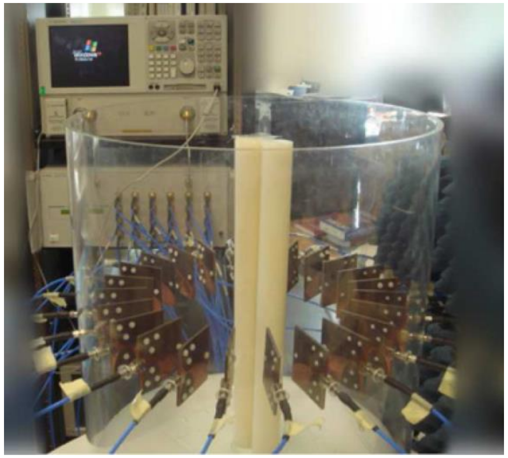
- The system will exploit a narrow working frequency band centered on 1 GHz (e.g. 0.9-1.1 GHz), due to limitations in the wave penetration inside the head
- A coupling liquid with relative permittivity between 30-40 will be selected to improve both matching and achievable spatial resolution
- The system will use around 25 antennas, assuming that the hemi-spherical surface has a radius of 12cm. This number is determined, with respect to the adopted frequency and coupling medium.
- a system dynamic range of at least 90 dB.



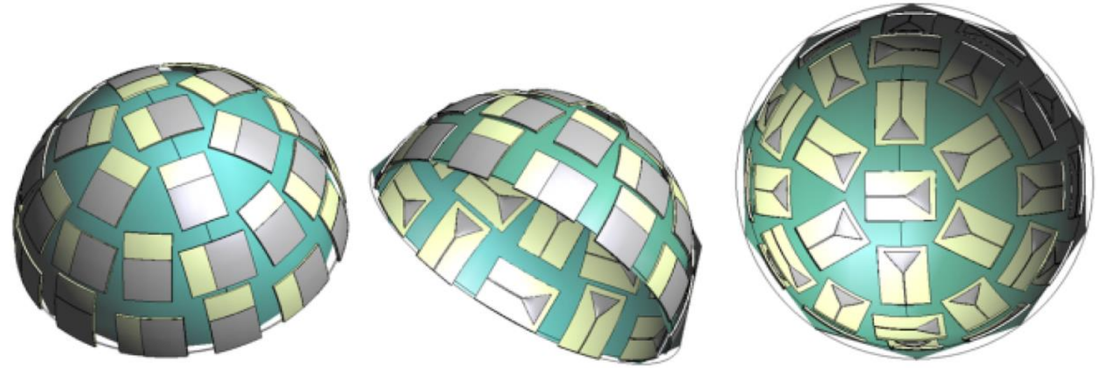
System requirements (3)

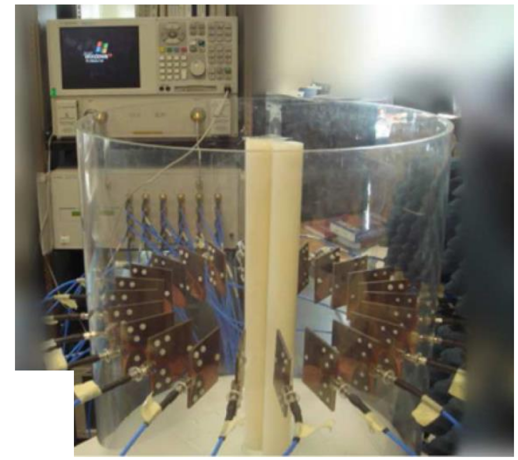


- Realize as first a **2-D scanner** to experimentally test the 2-D imaging algorithms ? How many antennas ?



System requirements (3)





- Realize as first a **2-D scanner** to experimentally test the 2-D imaging algorithms ? How many antennas ?
- Realize the coupling «liquid» in the 3-D scanner using a mixture of **silicone rubber and carbon powder** ? It can be realized easily a soft headset; it is not a liquid (it does not require a «plastic bag» to keep it on the head…)

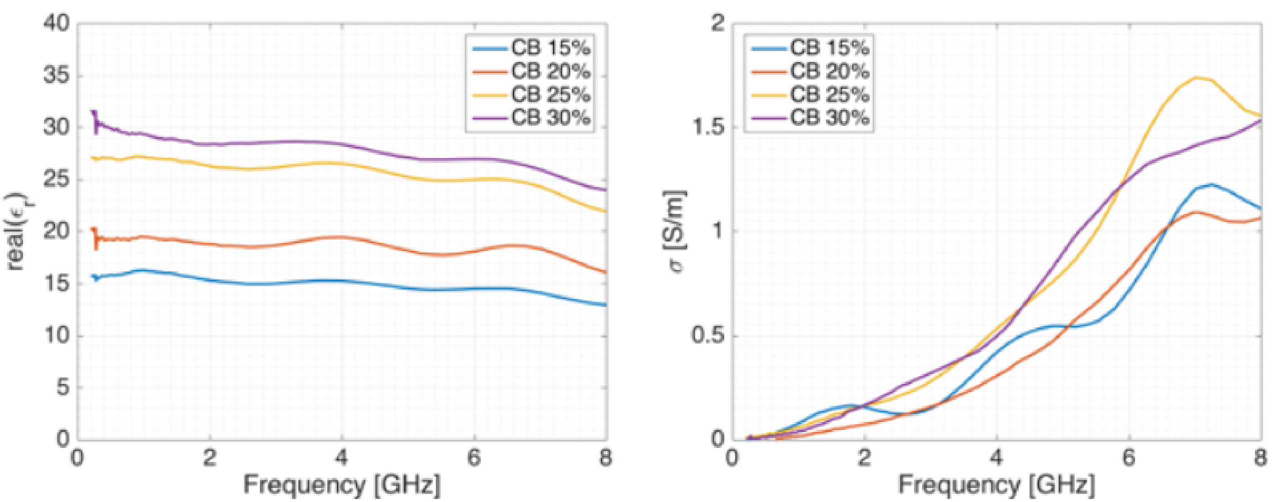


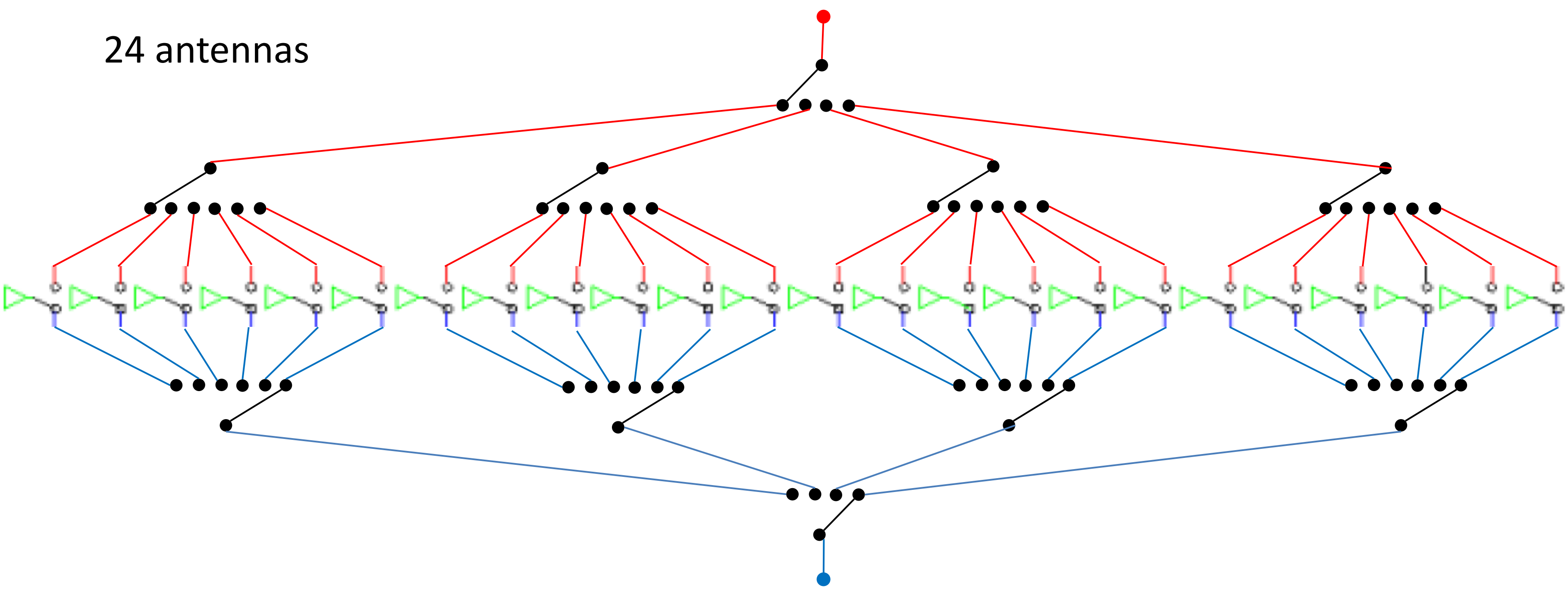
Figure 4. *Dielectric properties for different concentrations of Carbon Powder in*

Experimental results realized by Jorge Tobon in his STSM at Technische Universität Ilmenau, Ilmenau (DE).

System requirements (4)

- The antenna array will be connected to a switching matrix in order to drive each antenna in the receiving or transmitting mode.
- The switching matrix is constituted by 8 7-ports switches, 2 5-ports switches and 24 3-ports switches. The expected isolation, needed to minimize the crosstalk, is **+110dB.**

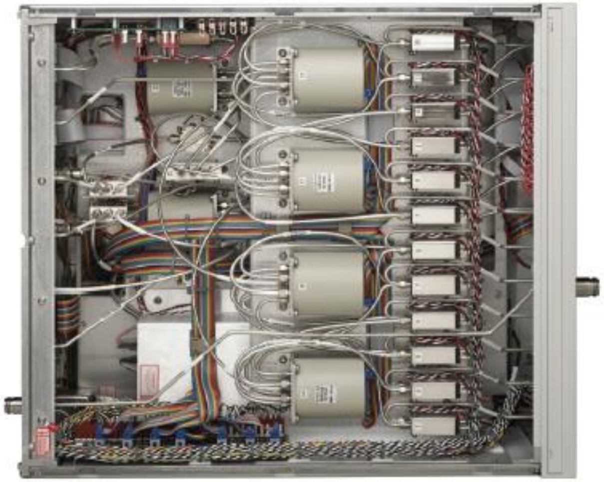
24 antennas



System requirements (5)

- Keysight Technologies N1810TL, L7104A, and L7106A coaxial switches (isolation >110dB at 1 GHz)

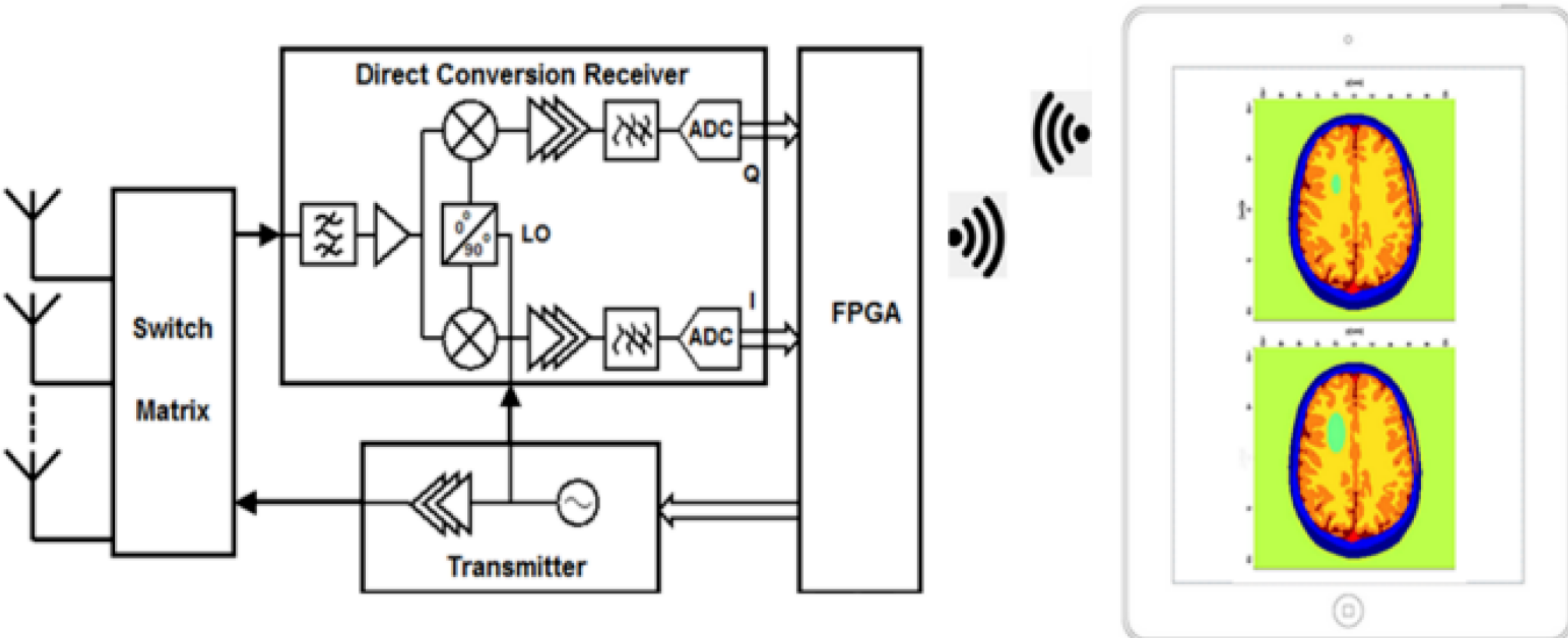
- custom designed switch driver: Keysight L4490A/91A RF Switch Platform



Possible final custom switch matrix

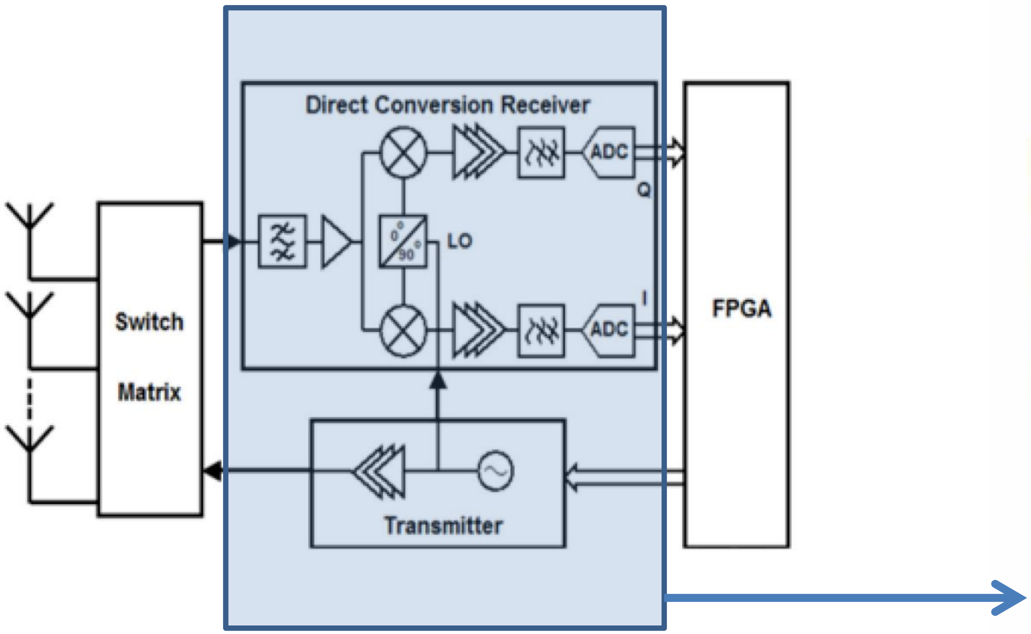
System requirements (6)

- an ad-hoc radiofrequency (RF) front-end system, which consists of a transmitter (TX), a receiver (RX), and the above mentioned switch matrix to connect TX and RX to the antennas.



System requirements (7)

- M9370A PXIe Vector Network Analyzer, 300 kHz to 4 GHz



Final issues

- Mibrascan Logo contest – bring your proposal! (as ppt)
- MiBraScan web site: https://wordpress.org/themes/

Mibrascan Logo contest

MiBraScan
Microwave Brain Scanner

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Microwave Brain Scanner for Cerebrovascular Diseases Monitoring

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