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Sensing Local Temperature and Conductivity Changes in a Brain Phantom Using Near-Field Microwave Radiometry

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ABSTRACT

Knowledge of thermal and/or conductivity local changes inside the brain may provide useful information about brain activity. Microwave radiometry may be able to monitor such changes. Based on previous research in brain mapping using microwave radiometry a new prototype near field radiometry system has been used to detect local changes of temperature and conductivity in brain phantom experiments which are herein presented.

KEYWORDS: microwave radiometry; local temperature; conductivity; brain phantom, brain monitoring

BIOGRAPHY

Evangelos Groumpas is a Ph.D. candidate at NTUA, Greece. He received his diploma in Electrical and Computer Engineering in 2013 from NTUA. He is a junior researcher at the Microwaves and Fiber Optics Laboratory, NTUA.

Dr. Maria Koutsoupidou received her diploma (2008) and her Ph.D. degree (2014) in Electrical Engineering and Computer Science from the National Technical University of Athens, Greece. She has been a Research Fellow at the Microwaves and Fiber Optics Laboratory, NTUA, (2009-2016), and she has worked as a Lecturer at the Hellenic Military Academy (2016-2017). Currently, she is a Research Associate at King's College London.

Prof. Irene S. Karanasiou was born in Athens, Greece. She received the Diploma and the Ph.D. degree in Electrical and Computer Engineering from the National Technical University of Athens (NTUA), Athens, in 1999 and 2003, respectively. Since 1999, she has been a Researcher with the Microwave and Fiber Optics Laboratory (MFOL), NTUA and currently is Associate Professor at the Hellenic Military University.

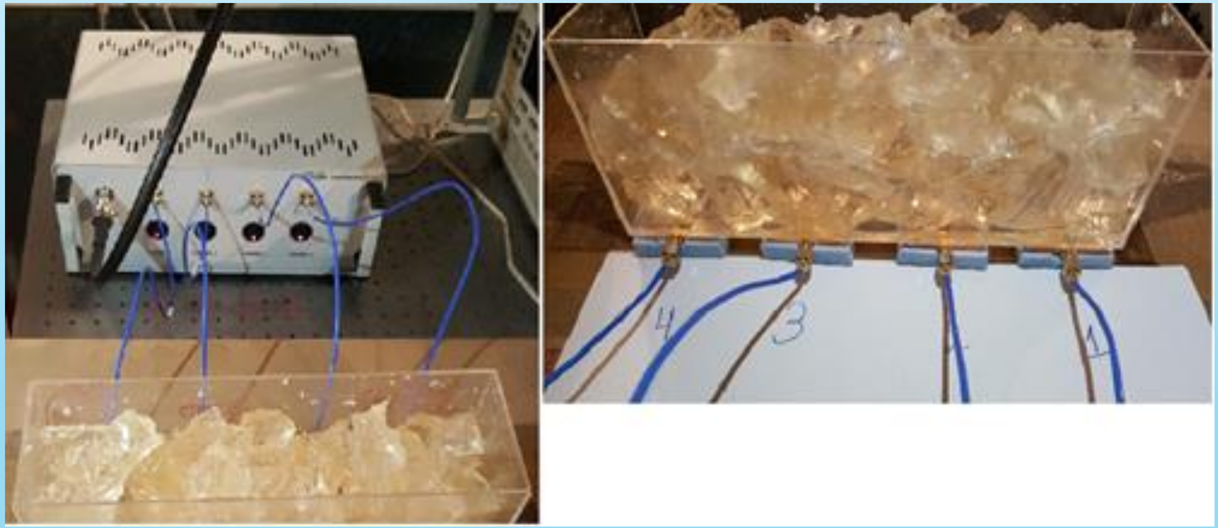
Prof. Nikolaos K. Uzunoglu (M’82–SM’97-FM’06) was born in Constantinople, in 1951. He received the B.Sc. degree in electronics from the Technical University of Istanbul, Turkey, in 1973, the M.Sc. and Ph.D. degrees from the University of Essex, Essex, UK, in 1974 and 1976, respectively, and the D.Sc. Degree from the National Technical University of Athens, Athens, Greece, in 1981.

INTRODUCTION

The past 12 years our group has developed a hybrid biomedical monitoring system for brain diagnostic intracranial applications and hyperthermia treatment based on focused microwave radiometry. The experiments confirmed the theoretical results showing the system's ability to detect real-time temperature and conductivity variations in cylindrical water phantoms, as well as, in human volunteer experiments. Therefore, the radiometric receiver is capable of measuring the temperature distribution of biological tissue, if its conductivity remains unchanged. Additionally, in the case of thermodynamic equilibrium and if there is a tissue macroscopic conductivity variation where the field factor has a significant value, the radiometer will detect this conductivity variation. With the view to develop a low cost, portable, brain monitoring device, a new prototype based on near field radiometry is herein introduced. Similar, temperature and conductivity experiments are presented with the effort to define the new prototype's measurement attributes.

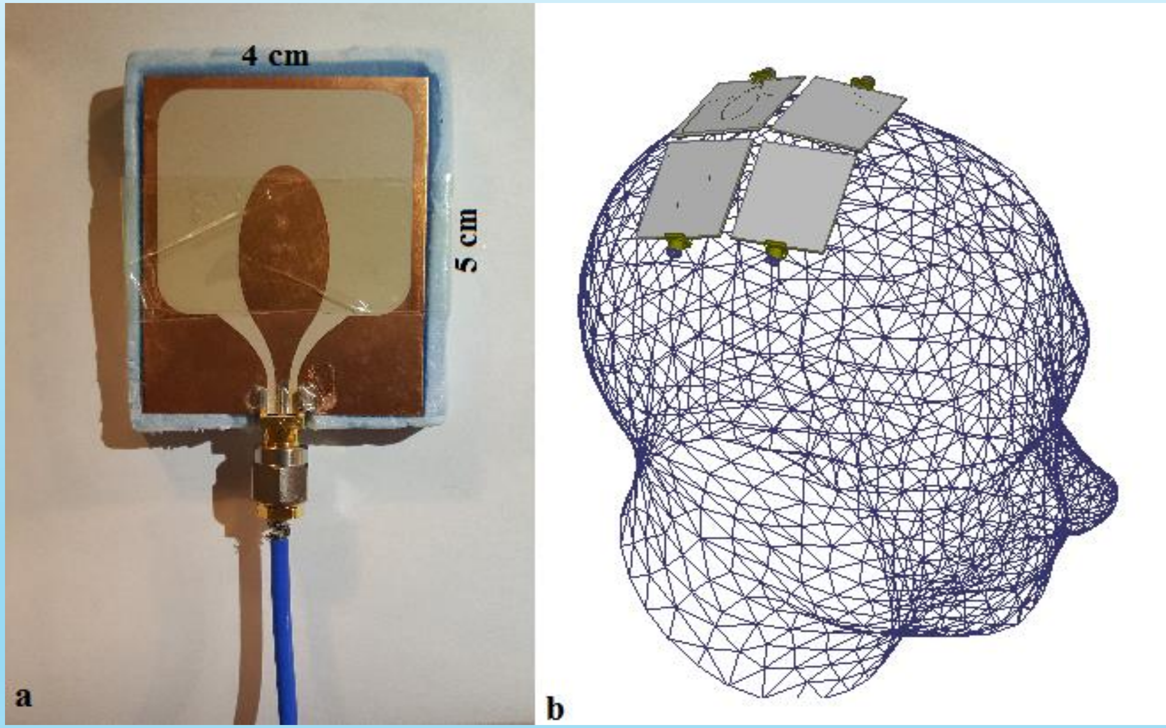
MATERIALS AND METHODS

A. ***Radiometer:*** The developed radiometer is a total power Dicke-switch sensitive receiver operating at (1.5+/-0.05) GHz. The receiver has four inputs one for each antenna used. There are four similar chains comprising amplifiers and filters which are combined through a combiner and the signal after being fed to the detector is driven to a 16 bit analog to digital acquisition card.



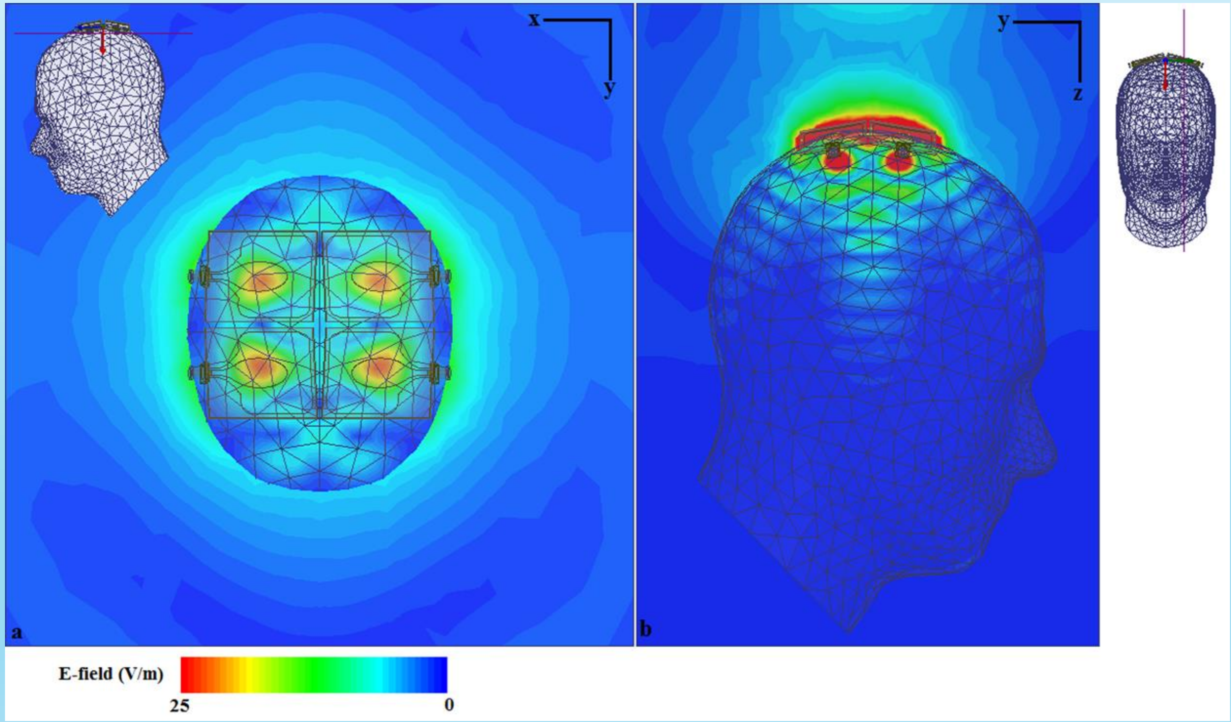
MATERIALS AND METHODS

B. *Antennas:* The near field radiometric system is based upon a 4-element array of uniplanar elliptical antennas. The reflection coefficient of the selected antennas was measured -20 dB in the 1.45-1.55 GHz band when radiating into a biological tissue.



MATERIALS AND METHODS

C. *Numerical Analysis:* The analysis results of E-field magnitude at 1.5 GHz inside the head model reveal that the antennas are capable to effectively sense brain areas 3 cm deep inside the head model (ε_r = 45.5 and conductivity σ = 0.8 S/m).



EXPERIMENTS & RESULTS

A. Local Temperature Changes at 1.5 GHz

Thermal source: a small cylindrical container (5 ml) with deionized water at 38 ◦C.

Experimental procedure:

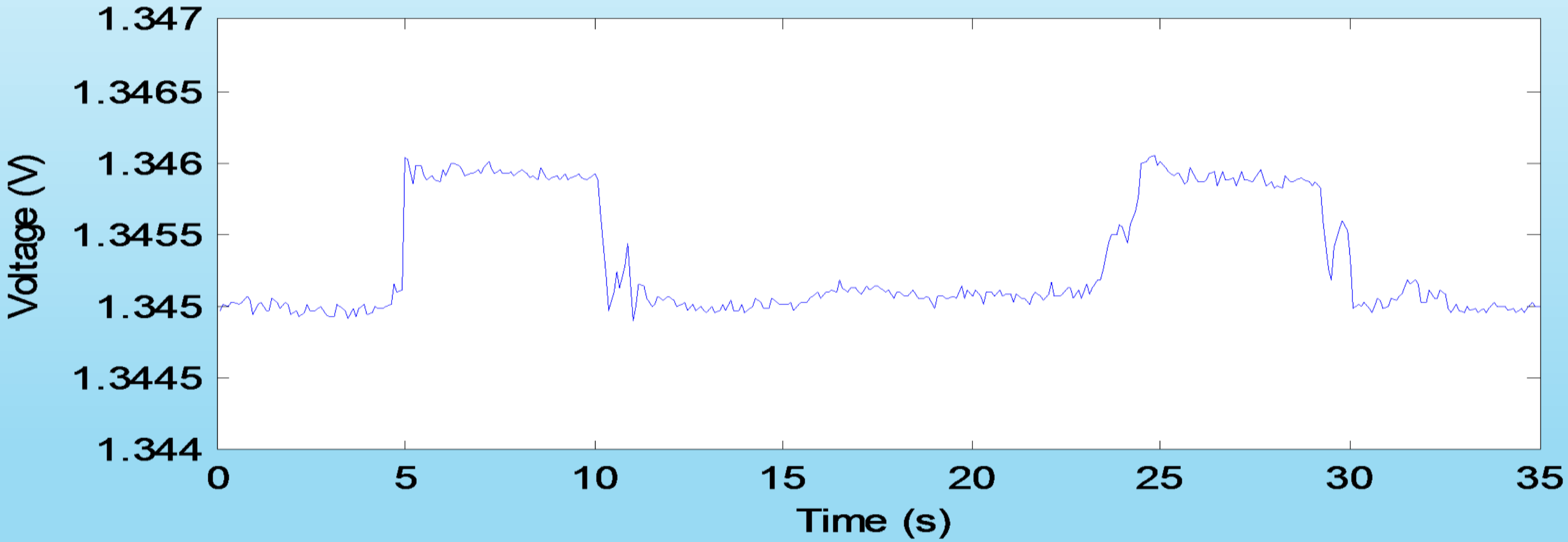
t = 0-5 s → the radiometer measures the background noise.

t = 5-10 s → the container is 1 cm above the first antenna.

t = 10-25 s → the radiometer measures the background noise.

t = 25-30 s → the container is 1 cm above the first antenna.

The experimental procedure was repeated for all the antennas.



The background noise generated a voltage output of 1.345 V, while the thermal source, water at 38 ◦C, was detected with a clear increase of 1 mV from the baseline. The presence of the thermal source above the antennas #2, #3 and #4 resulted in the same voltage increase.

EXPERIMENTS & RESULTS

B. Local Conductivity changes at 1.5 GHz

Saline solution: 0.5 N concentration of NaCl aqueous solution (5 ml volume).

Experimental procedure:

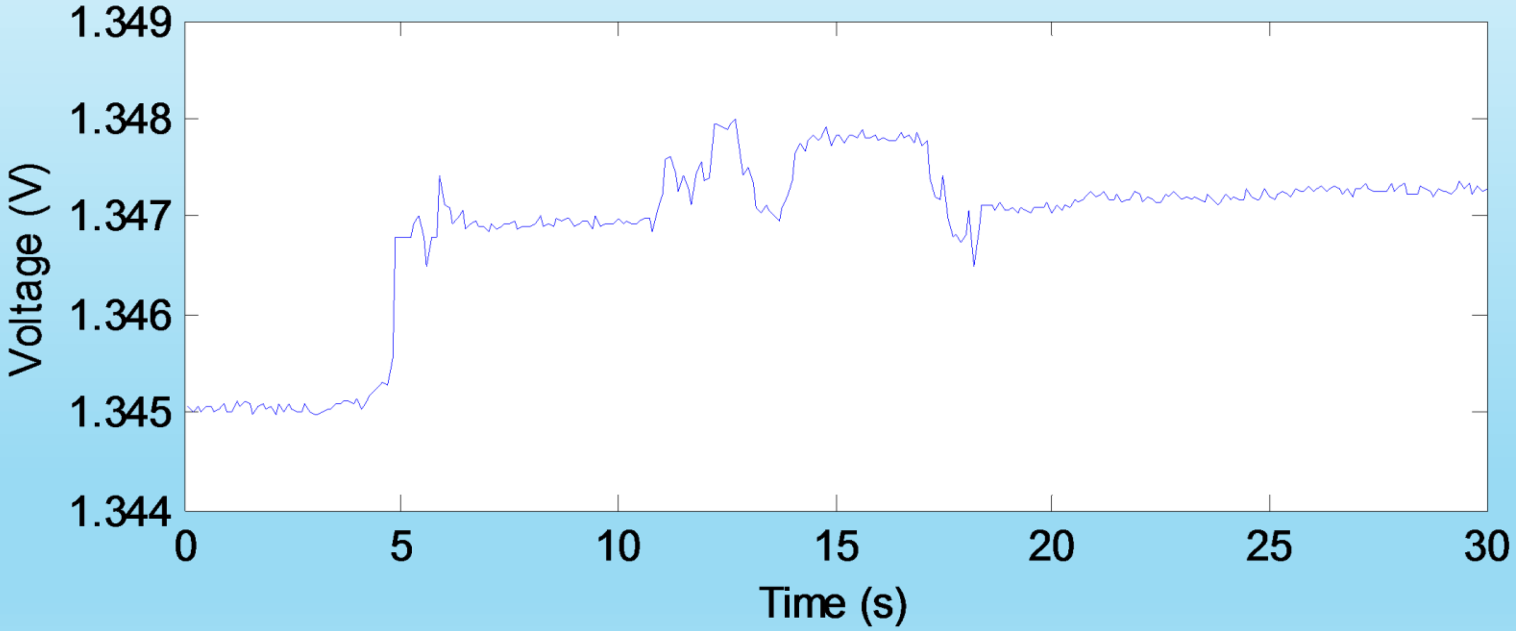
t = 0-5 s → the radiometer measures the background noise.

t = 5 s → the tube is inserted 1 cm above the first antenna.

t = 10-18 s → the saline solution is diffused into the phantom.

t = 18 s → the empty tube is removed.

The experimental procedure was repeated for all the antennas.



The presence of the saline solution inside the tube resulted to a voltage increase of 2 mV. During the injection, a 1 mV increase was observed. After the diffusion, the output voltage returned to the previous state value of 1.347 V.

CONCLUSION

The results presented in the paper are promising regarding the system's ability to detect local changes of temperature and conductivity in brain phantoms. Due to the complexity of brain functional activity research, in order to assess the possible practical value of the system of providing realistic brain activity measurements, further and in-depth investigation with extensive phantom and human measurements is required.

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