Electromagnetic Characterization of Living Microorganims

Alejandra Garrido

Project Proposal and Work Plan

REVISION HISTORY AND APPROVAL RECORD

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1. CONTENTS

2. PROJECT OVERVIEW AND GOALS

The project is carried out at the CommSensLab, at the TSC department.

There is a growing need to interact with the living world and mostly of the time this is performed using some king of physical (i.e electrodes) contacts. This kind of connection while well-known and quite robust, mostly of the time are intrusive and discomforting. In this respect the possibility of having wireless contacts or sensing will certainly easy this kind of interactions.

In this work the general idea is to study the potentiality of a wireless sensing of some functional parameter of a living organism either vegetal or animal. More specifically the idea is to analyze the measurable interaction among the well known radiofrequency and microwave frequencies and some sample of those living organisms.

More specifically the aim of this TFG is the numerical modeling and the experimental validation of a representative sample of basic living microorganisms.

The project main goals are:

1. Numerical modeling of the basic electrical parameters: real and imaginary parts of the complex permittivity.
2. The spectral experimental validation of a representative sample of basic living microorganisms.

3. PROJECT BACKGROUND

The capability to wirelessly interact with the electrical signal system of the living microorganisms may open new possibilities in the field of the biotechnology. Among the different spectral ranges, the low intensity microwave signals are able to propagate into a harmless way through the living beings, and to extract basic physiological functions from the observation of their electrical parameters, meaningful morphological or functional information.

Based on this initial concept the research lab has been studying the physiological and electrical parameters of a vegetal organism (mimosa pudica). From this initial studies it has been found that the electrical changes produces by the physiological functions are very small in both physical sizes and permittivity changes. In order to design a proper experimental setup to measure the electrical changes a numerical study needs to be perform. The numerical results will be contrasted with the analytical model proposed by Bai[1].

Based on the previous results a broad bad coaxial-based experimental setup will be design and build at the research lab. Electromagnetic absolute and differential measurements will be performed for different living microorganisms.

[1] *(Dielectric properties of E. coli cell as simulated by the tree-shell spheroidal model)*.

4. PROJECT REQUIREMENTS AND SPECIFICATIONS

Project requirements:

- For the numerical model the simulator has to be able to obtain basic electrical parameters from realistic models of microorganisms modeled with HFSS and to upload these results into a Matlab code able to post-process these results and to obtain the permittivity vales of the sample and the differential changes as a function of frequency when some functional activity (i.e. action potential) has occurred.
- For the experimental setup it has to be adequate to hold a sample of the biological object and to obtain values of their electrical parameters based on a previous calibration to correct for the measurement errors.

Project specifications:

- To obtain consistent values of the complex (real and imaginary) permittivity of a representative model of the living microorganism between the numerical results and those existing into the literature for frequencies covering from 1 MHz until 10 GHz
- An experimental coaxial setup to measure the S11 and S12 parameters from 1MHz to 10 GHz with S11<-10 dB and S12 < 1 dB
- To obtain experimental results for two samples of living microorganism consistent with the numerically predicted values and representative of the functional activity

5. WORK PLAN

1. *Work Breakdown Structure*

1. Introduction.
2. Electromagnetic properties of microorganism in biological media
    1. Microorganism suspension. A dielectric material
    2. Wave propagation in microorganism suspensions
3. Electromagnetic modeling of microorganism in biological media
    1. Analytical modeling with Matlab
    2. Numerical modeling with HFSS
4. Experimental Characterization of isolated or in-culture microorganism
    1. Design of a Coaxial DC to GHz dielectric probe
    2. Results for different living cells suspensions
5. Conclusions and future work

2. *Work Packages, Tasks and Milestones*

- WP1: **Introductory state of the art study**
- WP2: **Electromagnetic properties of microorganism suspensions**
- WP3: **Project proposal and work plan**
- WP4: **EM properties of microorganism in biological media**
- WP5: **Electromagnetic modeling of microorganism suspensions**
- WP6: **Critical review**
- WP7: **Measurement of living microorganism electrical parameters**
- WP8: **Final report**
- WP9: **Project presentation**

Project: **Introductory state of the art study**	WP ref: **WP1**	
Major constituent: **Documentation**		
Short description:	Planned start date: 01/09/2017 Planned end date: 14/09/2017	
	Start event: T1 End event: T1	
Task 1: Identifying the geometrical model	Deliverables:	Dates:

Project: **EM properties of microorganism in biological media**	WP ref: **WP2**	
Major constituent: **Documentation**		
Short description: Dielectric characterization of the biological media and Wave propagation in biological media	Planned start date: 15/09/2017 Planned end date: 30/09/2017	
	Start event: T1 End event: T2	
Task 1: Main dielectric parameters of the microorganism and biological media Task 2: Main propagation parameters for microorganism: isolated and in suspension	Deliverables:	Dates:

Project: **Electromagnetic properties of microorganism suspensions**	WP ref: **WP3**	
Major constituent: **Simulation**		
Short description:	Planned start date: 01/09/2017 Planned end date: 30/09/2017	
	Start event: T1 End event: T2	
Task 1: HFF numerical simulation of the living microorganism Task 2: Matlab simulation of the microorganism	Deliverables: Results consistent with literature	Dates:

Project: **Project proposal and work plan**	WP ref: **WP4**	
Major constituent: **Documentation**		
Short description: Documentation on project basis, project goals, and project organization (work plan).	Planned start date: 29/09/2017 Planned end date: 06/10/2017	
	Start event: T1 End event: T3	
Task 1: Project description Task 2: Project development plan Task 3: Document review and approval	Deliverables:	Dates:

Project: **Experimental Characterization of microorganism**	WP ref: **WP5**	
Major constituent: **Hardware prototype**		
Short description:	Planned start date:09/10/20 Planned end date: 04/12/2017	
	Start event: T1 End event: T4	
Task 1: Design of the coaxial setup from 1MHz to 10 GHzs Task 2:Measurements of isolated microorganisms Task 3: Measurement of the in-culture microorganisms	Deliverables:	Dates:

Task 4: Differential measurement for functional activities of the microorganisms		

Project: **Critical Review**	WP ref: **WP6**	
Major constituent: **Documentation**		
Short description: Document that discusses the project development until date. It also includes a review of the initial work plan.	Planned start date: 20/11/2017 Planned end date: 01/12/2017	
	Start event: End event:	
Task 1: Writing about progress to date Task 2: Review of the work plan Task 3: Document review and approval	Deliverables:	Dates:

Project: **Conclusive Remarks**	WP ref: **WP7**	
Major constituent: **Documentation**		
Short description:	Planned start date: 04/12/2017 Planned end date: 18/12/2017	
	Start event: T1 End event: T1	
Task 1: Correlation of the electrical permittivity parameters with the functional living actions	Deliverables:	Dates:

Project: **Final Report**	WP ref: **WP8**	
Major constituent: **Documentation**		
Short description: Document that describes the entire project development once it has been finished.	Planned start date: 05/12/2017 Planned end date: 07/01/2018	
	Start event: T1 End event: T2	
Task 1: Writing about the project done and its results Task 2: Document review and approval	Deliverables:	Dates:

Project: **Project presentation**	WP ref: **WP9**	
Major constituent: **Documentation**		
Short description: Oral presentation that overviews the project. It relies on a slide-based presentation document.	Planned start date: 07/01/2018 Planned end date: 30/01/2018	
	Start event: End event:	
Task 1: Slides drafting Task 2: Presentation rehearsal Task 3: Presentation review and approval	Deliverables:	Dates:

Milestones

WP#	Task#	Short title	Milestone / deliverable	Date (week)
1	T1	Bibliographic study	Identifying the geometrical model	Week 2
2	T1	Dielectric characterization of the biological media	Main dielectric parameters of the microorganism and biological media	Week 4
2	T2	Wave propagation in biological media	Main propagation parameters for microorganism: isolated and in suspension	Week 6
3	T1	Matlab simulation of the microorganism	Results consistent with literature	Week 8
3	T2	HFF numerical simulation of the living microorganism	Results consistent with literature	Week 10
4	T1	Project description	Project Proposal and Work plan	Week 12
4	T2	Project development plan		
4	T3	Document review and approval		
5	T1	Design of the coaxial setup from 1MHz to 10 GHz	Calibration and measurement procedure established	Week 14
5	T2	Measurements of isolated microorganisms	Dielectric parameters of the isolated microorganisms	Week 16
5	T3	Measurement of the in-culture microorganisms	Dielectric parameters of the in-culture microorganisms	Week 18
5	T4	Differential measurement for functional activities of the microorganisms	Measurable detection of the functional changes on the microorganisms	Week 20
6	T1	Writing about progress to date	Critical Review	Week 22
6	T2	Review of the work plan		
6	T3	Document review and approval		
7	T1	Correlation of the electrical permittivity parameters with the functional living actions	Positive wireless detection of basic functional actions	Week 24
8	T1	Writing about the project done and its results	Final report	Week 26
8	T2	Document review and approval		
9	T1	Slides drafting	Final presentation	Week 28
9	T2	Presentation rehearsal		
9	T3	Presentation review and approval		

3. *Time Plan (Gantt diagram)*

4. *Meeting and communication plan*

Weekly meetings with the supervisor have already been scheduled at 11:00 on Mondays. Furthermore, occasional meetings will be organized whenever both the supervisor and the project author consider it necessary.

Document Meeting	**Date**
Project Proposal and WorkPlan approval	05/10/2017
Critical Review (midterm)	01/12/2017
Final Review	25/01/2018

Electronic mails will constantly be interchanged with the purpose of organizing future actions and discussing plus solving any problems that may appear throughout the development of the project.

6. GENERIC SKILLS

The following generic skills will be promoted and assessed during the development of the project:

#	Generic Skill	Assessed
1	Innovation and entrepreneurship	X
2	Societal and environmental context	
3	Communication in a foreign language	
4	Oral and written communication	X
5	Teamwork	
6	Survey of information resources	X
7	Autonomous learning	X
8	Ability to identify, formulate and solve engineering problems	X
9	Ability to Conceive, Design, Implement and Operate complex systems in the ICT context	
10	Experimental behaviour and ability to manage instruments	X