Universidade Vigo

Radio Systems
UNIVERSITY OF VIGO

AtlantTIC

DESIGN OF ANTENNAS FOR BREAKTHROUGH RADIO SYSTEMS

by David Álvarez Outerelo , Ana Vázquez Alejos and Fran Díaz Otero

2017 WORKSHOP PhD STUDENT PROGRESS

MOTIVATION OF THE WORK

The continuous demand for better mobile broadband wireless experiences inspires both the research and industry to leverage key system resources in order to meet future extreme capacity and performance requirements.

In other aspects, those emerging large capacity systems demand novels antenna designs that can afford unforeseen features.

In this research work we have focused on three main type of antennas which fall into three different frequency bands and radio systems definition:

- Millimeter wave frequency band antennas (60GHz): 5G wireless systems require of large bitrate and massive density of devices. Miniaturized antennas of large gain jointly to a low side-lobe level (**SLL**) are required to equip devices with MIMO capability.
- THz frequency antennas: THz radio link must be doted of a high gain and minimum SLL to compensate the path losses of the high frequency channel.
- Microwave frequency band: the above experience is aimed to be combined to a quantum transmitter to improve the performance of this emerging radar technology for the 18GHz frequency band.

THESIS OBJECTIVES

In this Thesis we are focusing on the design and implementation of antennas meeting the different frequency bands and radio systems requirements by using novel **design and simulation** techniques and out breaking **materials**, such as superconductors and metamaterials, and setting up the **manufacturing process.**

The improvement of the main characteristics of an antenna involves addressing the study of these aspects:

- The simulation and design technique: use of coplanar microstrip designs introduces coupling issues, being the most important that one due to the included RF connector.
- The material used to manufacture the antenna prototype: most of substrate materials considered are based on Duroid laminates with not fully characterized properties for the frequency bands here considered.
- The inaccuracies and design deviations due to the manufacturing process
- Development of a simulation design that includes inaccuracies and problems arising from both the material and the manufacturing process.

The three main aspects to maximize in an antenna design are the gain, the reduced SLL to achieve MIMO ability and the size miniaturization.

COMPLETED WORK & NEXT YEAR PLANNING

In the present work, the following tasks have been completed:

1. **Analysis and characterization** of the effects due to the material **substrate and manufacturing process** in the coplanar microstrip design of millimeter and THz band antennas.
2. **Simulation of an antenna design** for millimeter band using coupled microstrip line feeding.
3. **Analysis and characterization** of the Graphene for its use in the design of millimeter and THz band antennas.
4. **Simulation of an antenna design** with Graphene for THz band.

The next year planning includes the following tasks to be completed:

1. **Millimeter band antenna prototype** using microstrip technology over metamaterial substrate
2. **THz antenna prototype** will be developed for semiconductor substrate.
3. The study of the quantum transmitter will be initiated and his integration in a silicon wafer.

RESEARCH PLAN

	2017			2018				2019				2020			
	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Literature review															
Millimeter prototype															
THz prototype															
Quantum prototype															
Thesis results															

RESULTS & DISCUSSIONS

Analysis and characterization of the Graphene for its use in the design of millimeter and THz band antennas

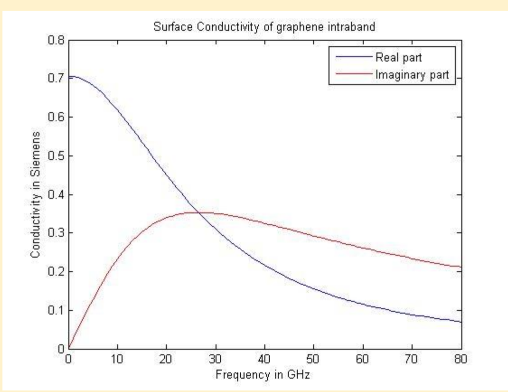
In order to develop a Graphene antenna we need to known the conductivity on the Graphene. For this purpose, Kubo´s formula of the Graphene electric conductivity was studied and simplified using a two-terms Drude model:

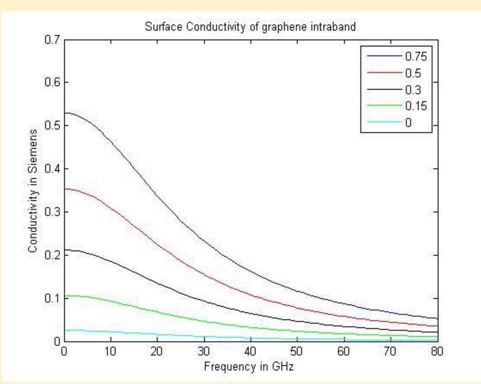
$$\sigma(\omega,\mu_c,\gamma,T) = \sigma_{intra}(\omega,\mu_c,\gamma,T) + \sigma_{inter}(\omega,\mu_c,\gamma)$$

$$\sigma_{intra}(\omega,\mu_c,\gamma,T) = \frac{je_c^2 K_B T}{\pi\hbar^2(\omega - j2\gamma)}\left(\frac{\mu_c}{K_B T} + 2\ln\left(e^{\left(-\frac{\mu_c}{K_B T}\right)} + 1\right)\right)$$

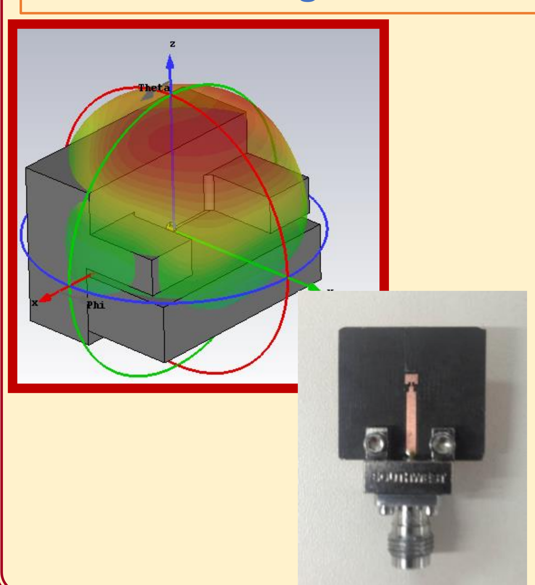
$$\sigma_{inter}(\omega,\mu_c,\gamma) = \frac{-je_c^2}{4\pi\hbar} ln\left(\frac{2|\mu_c| - (\omega - j2\gamma)\hbar}{2|\mu_c| + (\omega - j2\gamma)\hbar}\right)$$

σ_{inter} term can be neglected for the frequency of interest obtaining the surface conductivity and surface impedance.
Chemical potential variation is required for a proper conductivity set up.





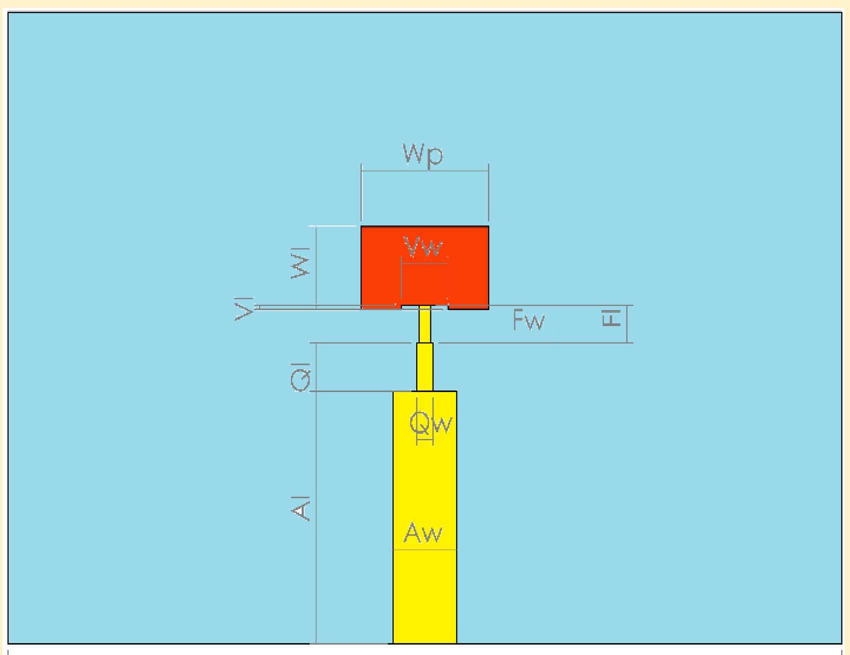
Analysis and characterization of the effects due to the material substrate and manufacturing process in the coplanar microstrip design of millimeter and THz band antennas.

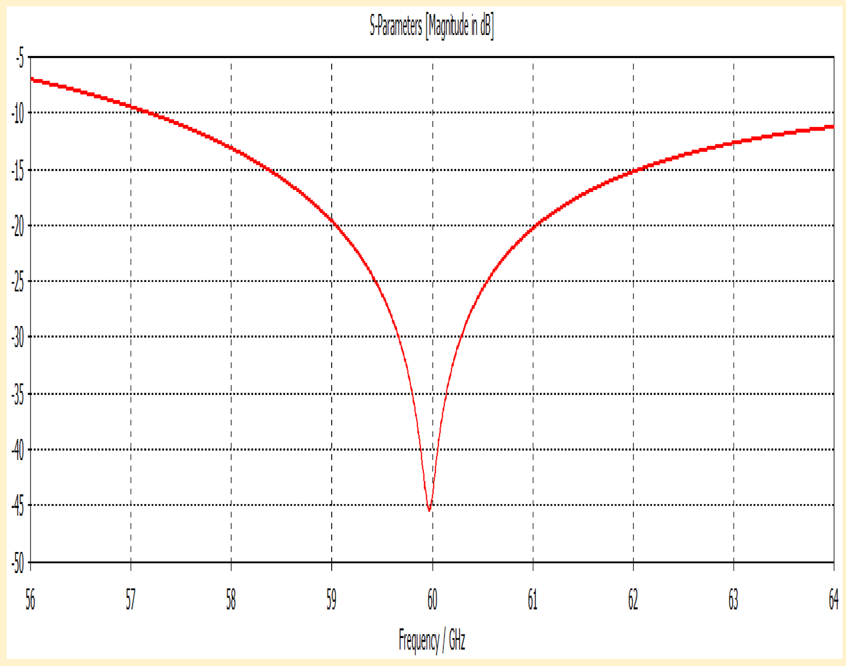


1. Inaccurate value of relative dielectric permittivity ε_r:
2. Connector - feed line soldering:
3. Fabrication mechanical inaccuracies and errors.

Simulation of an antenna design with Graphene for 5G band

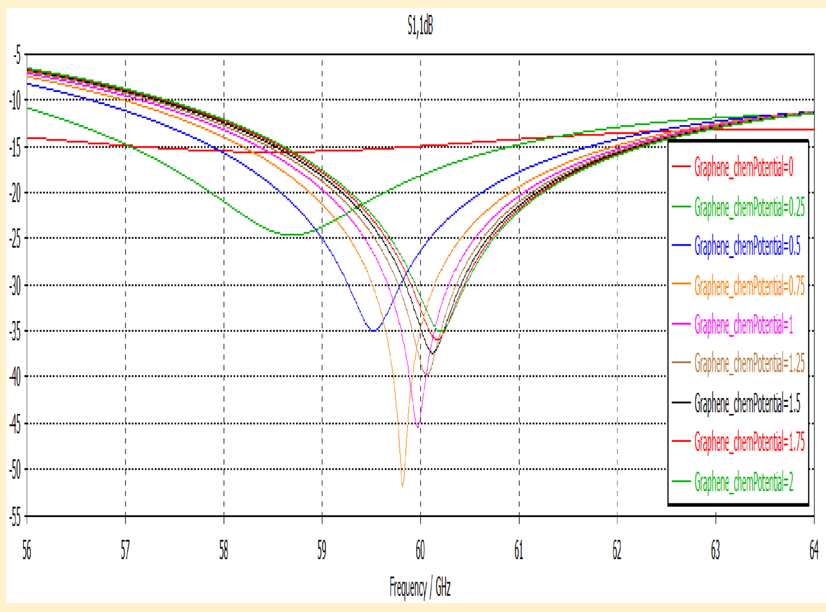
Theoretical design and simulation of a Single graphene patch prototype on *different substrates.*





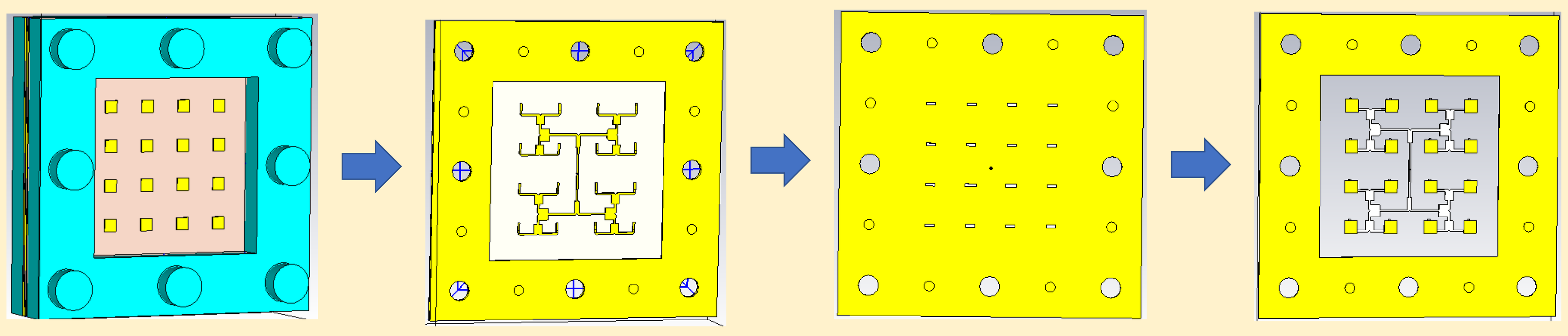
S_l	S_w	S_h	W_l	W_p	V_w	V_l
10	15	0.381	1.26	2.3	0.93	0.05
F_l	F_w	Q_l	Q_w	A_l	A_w	
0.6	0.2	0.79	0.23	4	1.15	

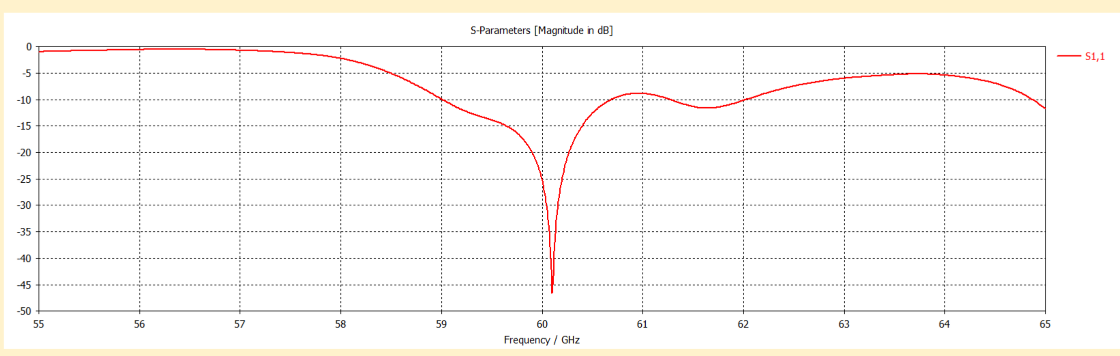
Design and simulation of reconfiguration of the patch resonant frequency using a bias potential →

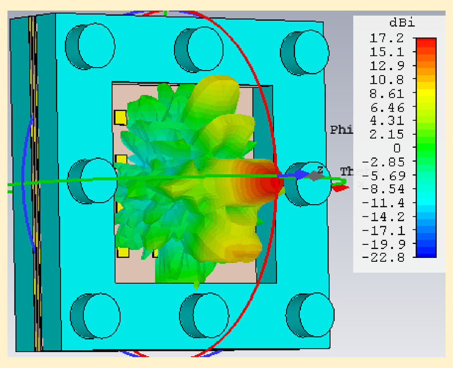


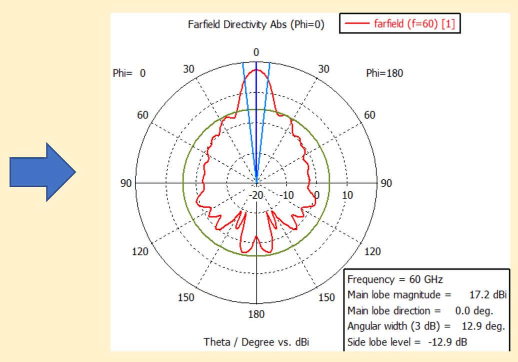
Simulation of an antenna design for millimeter band using coupled microstrip line feeding

Theoretical design and simulation of 16 elements Array excited by coupling and built in 3 layers









REFERENCES

1. Xue Yu *et al.*, "FDTD Modeling of Graphene-Based RF Devices: Fundamental Aspects and Applications", Master thesis, University of Toronto, 2013.
2. J. Perruisseau-Carrier et al., "Graphene Antennas: Can Integration and Reconfigurability Compensate for the Loss?", *IEEE* 43rd European Microwave Conference., 10 Oct 2013, Nuremberg, Germany.
3. **David Alvarez Outerelo**, Ana Vazquez Alejos, Manuel Garcia Sanchez, "Microstrip Antenna for 5G Broadband Communications: Overview of Design Issues", *IEEE APS-URSI*, Vancouver (Canada), July 2015.
4. W. Roh et al., "Millimeter-Wave Beamforming as an enabling technology for 5G cellular communications: theoretical feasibility and prototype results", IEEE Comm. Magazine, pp. 106-113, Feb. 2014
5. X.-P. Chen, K. Wu, L. Han, F. He, "Low-cost high gain planar antenna array for 60-GHz band applications", IEEE Trans. Antennas Propag., vol. 58, no. 6, pp. 2126–2129, June 2010.
6. B. Biglarbegian, M. Fakharzadeh, D. Busuioc, M.-R. N. -Ahmadi, S. S. - Naeini, "Optimized microstrip antenna arrays for emerging millimeterwave wireless applications", IEEE Trans. Antennas Propag., vol. 59, no. 5, pp.