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# Reconfigurable antennas and arrays for cognitive radio: polarization and frequency agility and beamforming

**WS4: In Memoriam of Julien Perruisseau-Carrier**

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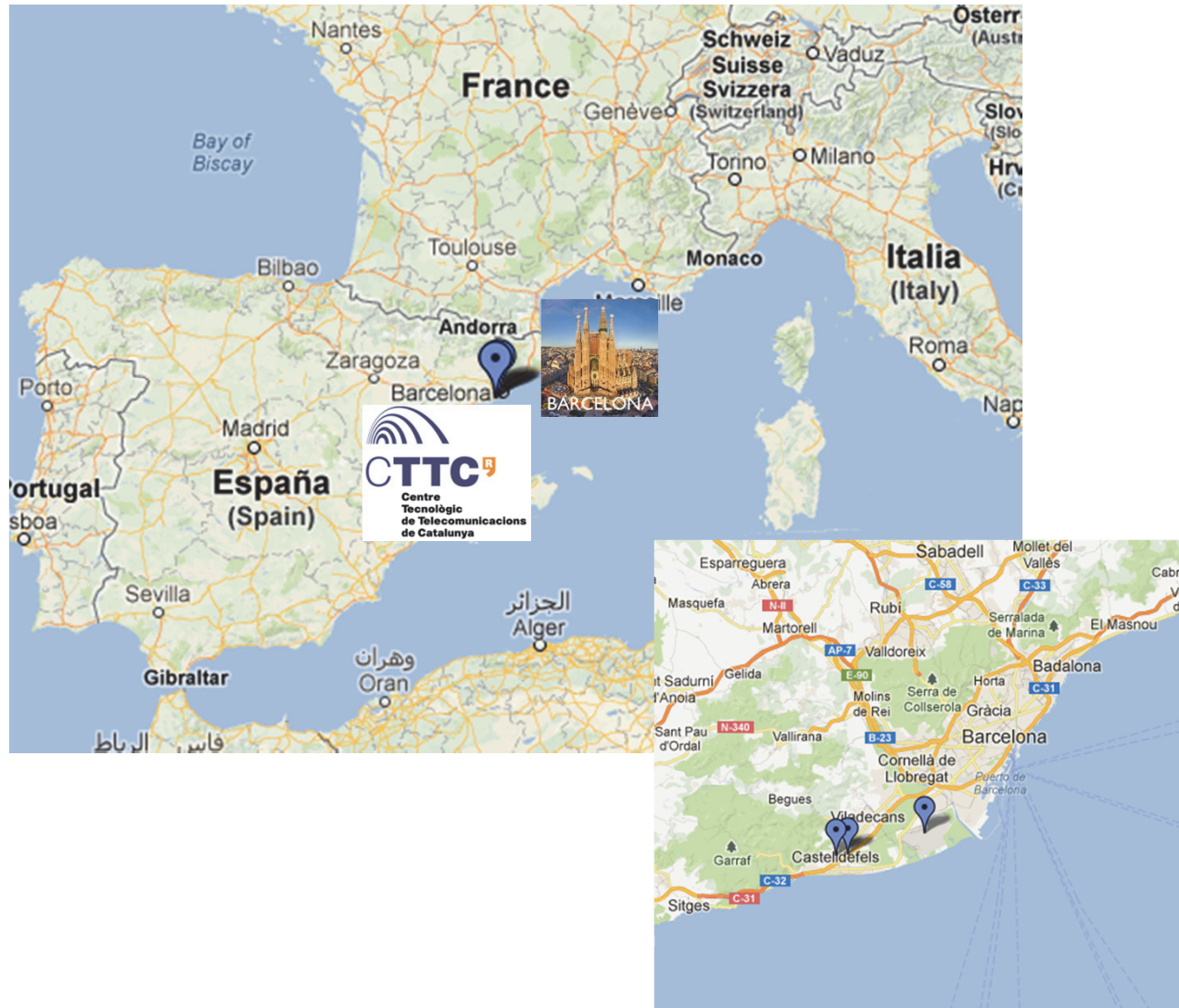
14 Apr. 2015

# Outline

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- Introduction
- Communication Subsystems Area
- Reconfigurable circuits
- Barcelona

# Introduction



# Introduction

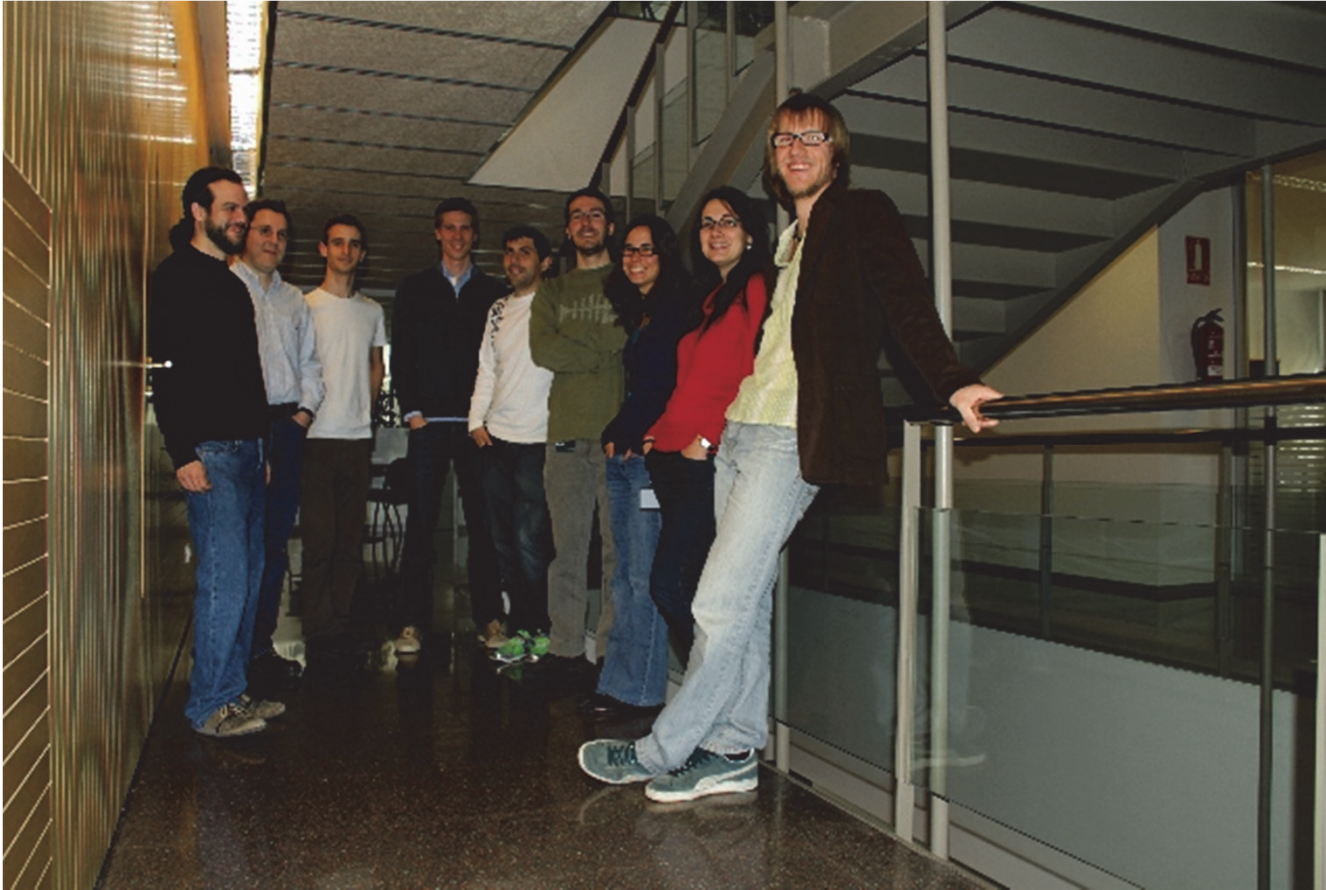
- Centre Tecnologic de Telecomunicacions de Catalunya
  - Founded in 2001
  - Research Staff: 45 Ph.D. and 25 M.Sc.
- NOW (2013 - ) Four Research Divisions
  - Communication Networks, Systems, Technologies & Geomatics
- **THEN (2006 – 2013) Communication Subsystems Area**



# Introduction

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- Communication Subsystems Area





# Introduction

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- Calçotada 2008 !



# Weekly Seminar 30/01/2008

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# Weekly Seminar 30/01/2008



- Periodic structure modeling
- Distributed MEMS Transmission Lines (DMTL)
- Composite Right/Left Handed Transmission Lines (CRLH-TL)
- Reflectarray cells



# Research

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- **Projects (2008-2011):**
- **NARRA TEC2008-02685. Nuevas Arquitecturas para Reflectarrays Reconfigurables y Antenas phased-array**  
**Also (*Star Wars*)** : Commander Arhul Narra, leader of the Alliance to Restore the Republic's Red Squadron prior to the Battle of Hoth
- **ESA MERCURY (2009) RF MEMS Based Reconfigurable Telecommunication Dual Reflector Antenna**
- **EU COST Antenna Systems & Sensors for Information Society Technologies (ASSIST)**
- **EU COST Action IC0803 RF/Microwave Communication Subsystems for Emerging Wireless Technologies (RFCSET)**

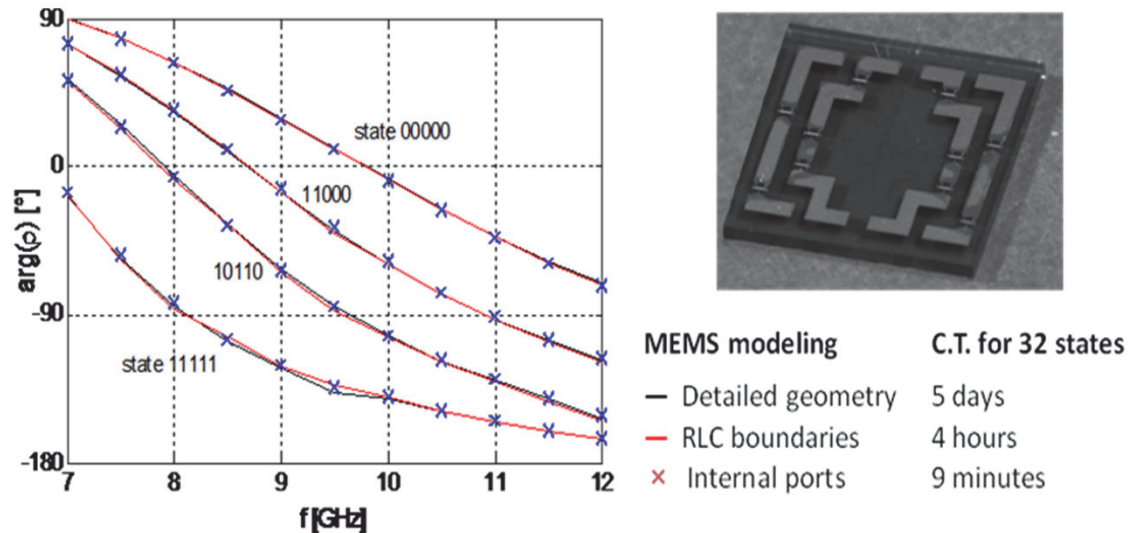
# Research

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- **Publications (2008 - 2012):**
- Publications: 43 (Google scholar)
- 7 Transactions (4 as first author)
- 12 Letters (5 as first author)
  
- **Research Collaborations:**
- EPFL – Switzerland (particle swarm optimizer (PSO))
- METU – Turkey (MEMS technology)
- University of Zagreb – Croatia (co-supervision of PhD thesis)

# Research

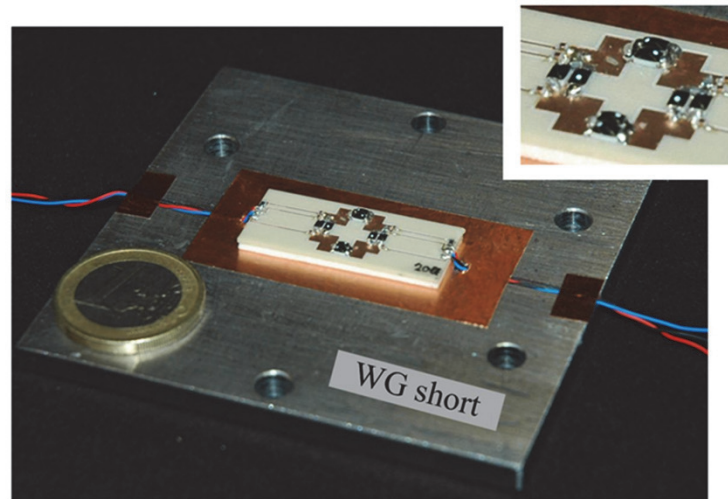
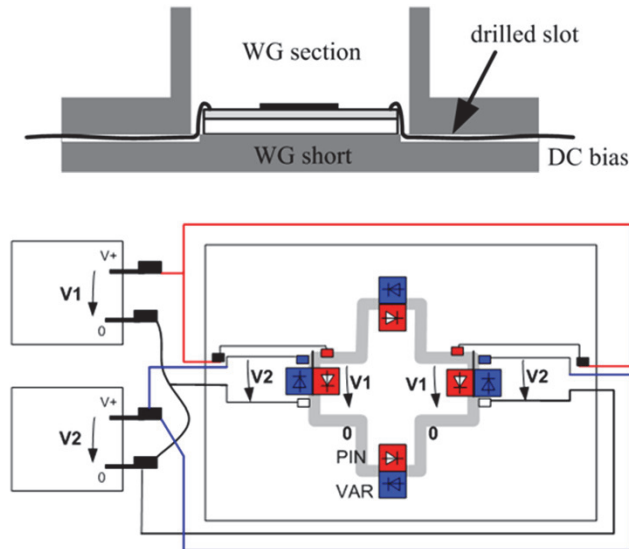
- Reconfigurable reflecting antenna cells



J. Perruisseau-Carrier, F. Bongard, R. Golubovic-Niciforovic, R. Torres-Sánchez, J.R. Mosig, "Contributions to the Modeling and Design of Reconfigurable Reflecting Cells Embedding Discrete Control Elements," *IEEE Transactions on Microwave Theory and Techniques*, vol. 58, no. 6, pp. 1621-1628, June 2010

# Research

A reflecting cell offering dynamic and independent control of the reflection phase of two perpendicular linearly polarized waves.

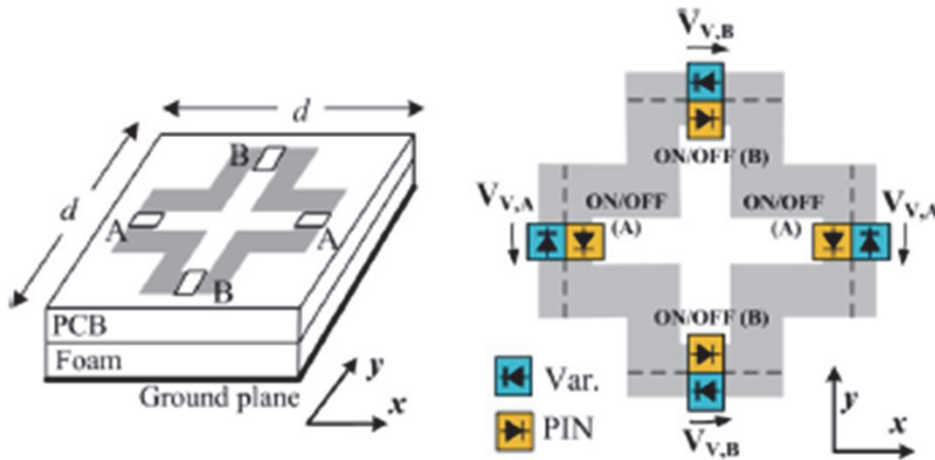


J. Perruisseau-Carrier, "Dual-Polarized and Polarization-Flexible Reflective Cells with Dynamic Phase Control," IEEE Trans. Antennas Propag., vol. 58, no. 5, pp. 1494-1502, May 2010.



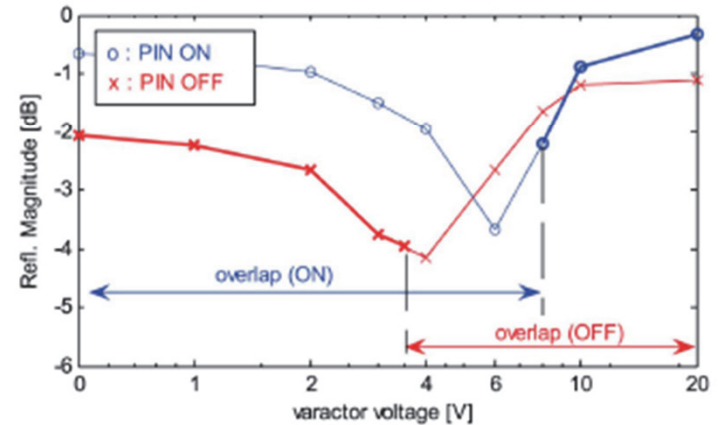
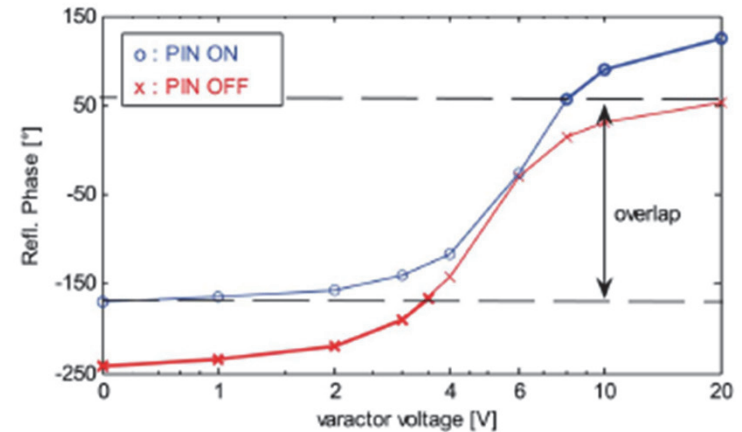
# Research

- Dual polarized and polarization flexible antenna cells



## y-polarized incident wave:

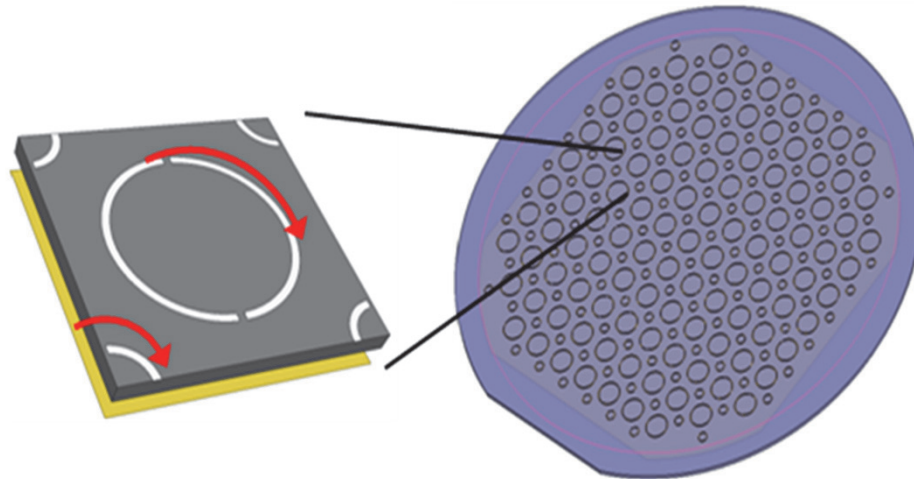
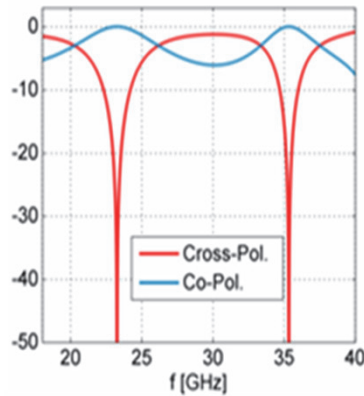
Elements "A" control the reflection phase.  
Elements "B" are placed in zeros of the current distribution.



J. Perruisseau-Carrier, "Dual-Polarized and Polarization-Flexible Reflective Cells with Dynamic Phase Control," IEEE Trans. Antennas Propag., vol. 58, no. 5, pp. 1494-1502, May 2010.

# Research

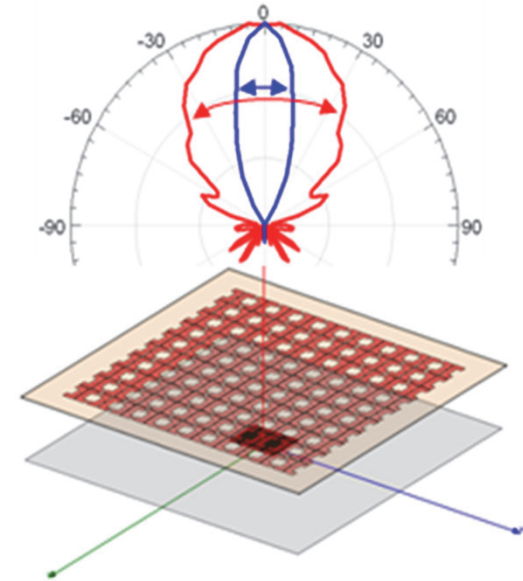
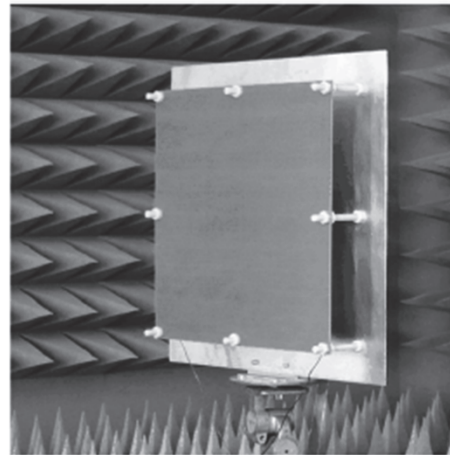
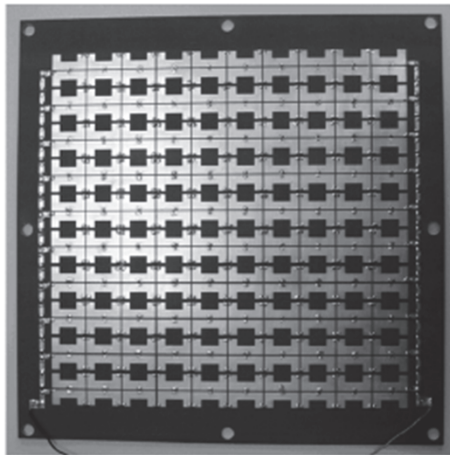
- **Dual-frequency MEMS-based circular polarized reflectarray**



C. Guclu, J. Perruisseau-Carrier, and O. A. Civi, "Dual Frequency Reflectarray Cell Using Split-ring Elements with RF MEMS Switches" in IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting, Toronto, Canada, 2010.

# Research

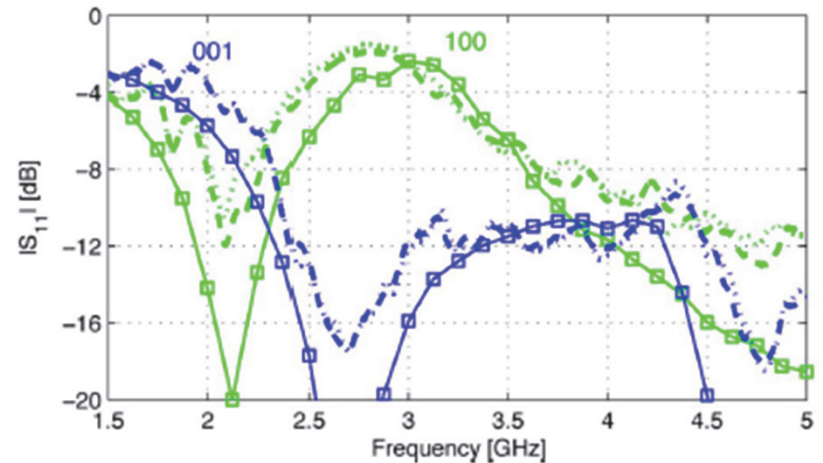
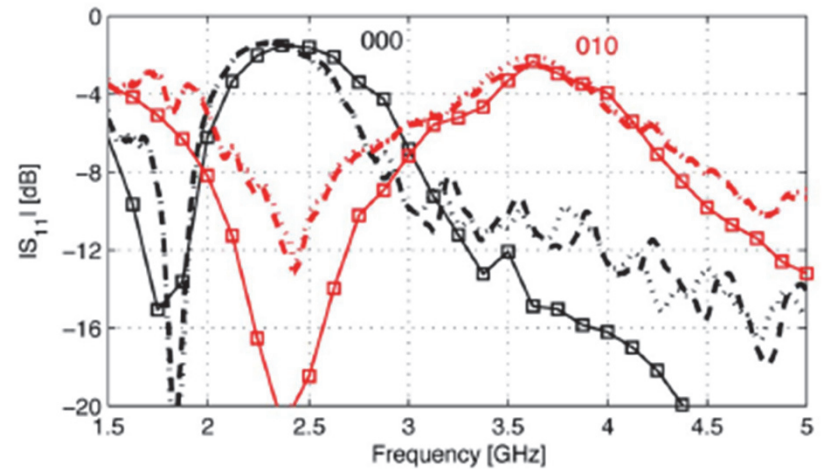
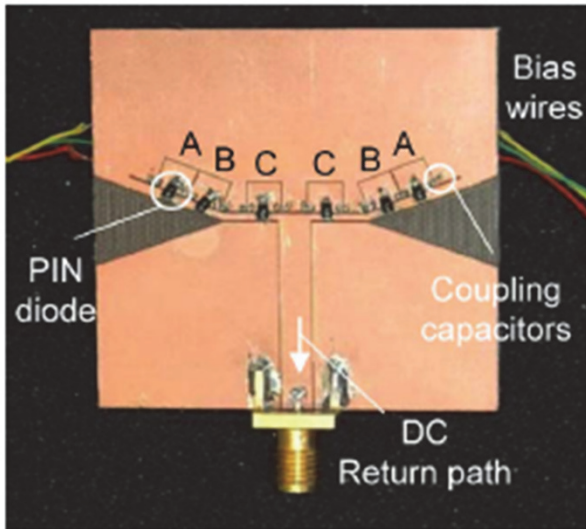
- **Partially-reflective uniform reflector for beamwidth-control**



T. Debogovic, J. Perruisseau-Carrier, and J. Bartolic, Partially Reflective Surface Antenna with Dynamic Beamwidth Control, IEEE Antennas Wireless Propagation Letters, Jan. 2011.

# Research

- **Wideband slot antenna with reconfigurable band rejection**

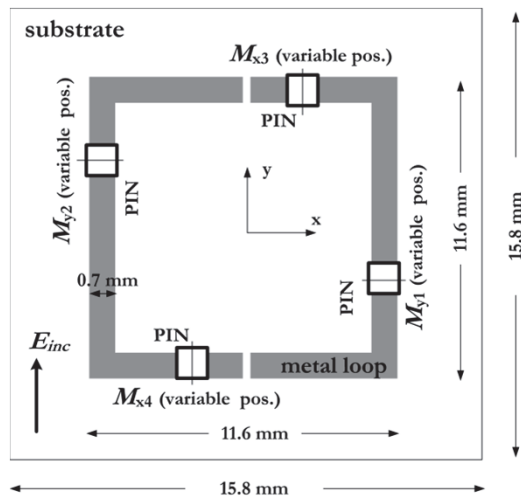


J. Perruisseau-Carrier, P. Pardo-Carrera, P. Miskovsky, "Modeling, Design and Characterization of a Very Wideband Slot Antenna With Reconfigurable Band Rejection," IEEE Transactions on Antennas and Propagation, vol.58, no.7, pp.2218-2226, July 2010.



# Research

- Efficient Optimization of the Phase Diagram in Digitally-Controlled Reflective Cells
- Two – tier algorithm
- Least-squares optimization and genetic optimization



**Efficient Optimization of the Phase Diagram in Digitally-Controlled Reflective Cells**  
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 Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Barcelona, Spain  
 julien.perruisseau@cttc.es

**I Abstract**

- An efficient hybrid method to optimize the phase status distribution (phase diagram) of a digitally-reconfigurable reflective cell is presented. It allows minimizing phase quantization errors in applications such as reflectarrays.
- Digital control of the reflected wave phase is achieved by placing a given number of control elements within the reflecting cell (e.g. PIN diodes or MEMS).
- The method is based on a perturbation of the control elements positions and combines a genetic algorithm and a least squares optimization. It only requires running a very small number of full-wave simulations prior to the optimization process.
- The method is illustrated by the optimization of a reflective cell based on PIN diodes technology, but could equally be applied to a MEMS-based digital implementation.

**II Description and cell modeling**

- The study is based on the linearly-polarized reflective cell of Fig. 1. It is a square ring loaded by  $N$  digital control elements (PIN or MEMS) and exhibits  $2^N$  phase states, which can be placed as a function of the different states as shown in the phase diagram of Fig. 3.
- Determining the locations of the control elements to obtain a good phase repartition is a complex issue in the cell design and should thus be achieved by a dedicated optimization technique.
- We use an hybrid simulated/measured model of the cell. The cell is first full-wave simulated in a periodic environment using Ansoft HFSS. The final reflection phase is then obtained by post-processing the simulation results using the measured impedance of the PIN loading elements (Fig. 2).

**III Optimization and results**

**Optimization**

- A hybrid algorithm is used, that employs a genetic algorithm to find the optimum ordering of the reflection phase states, while for a given ordering the element locations are determined by a least squares method.
- The genetic algorithm uses  $Q$  chromosomes of dimension  $M$  equal to the number of states. Each state is allowed to take a discrete value in a  $M$ -ary (0 to  $2^N$ ) alphabet. A number  $Q = 4$  of chromosomes were used in the simulations and a mutation probability of 0.1%.
- For a given ordering of the  $M$  phase states and location vector  $x$  of the  $N$  control elements,  $RF(x)$  is a vector containing the  $M$  possible reflection phase states (Fig. 3). The least squares formulation assumes that small perturbations  $\Delta x$  in the control element initial location  $x_0$  result in a linear perturbation of the reflection phase:
 
$$\Delta \theta(x) = \Delta x(x) + \Delta R(x) \Delta x$$
- The optimization process only requires  $N + 1$  full-wave simulations: one reference simulation to evaluate  $f(x_0)$ , and  $N$  simulations with a small displacement of each of the  $N$  control elements to evaluate  $\Delta R(x)$ .

**Discussion**

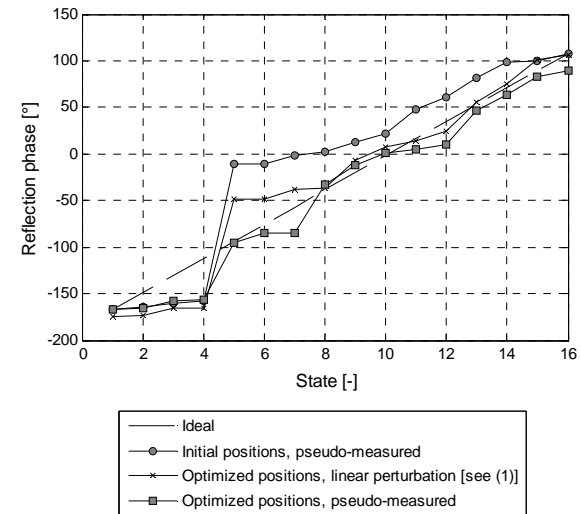
- The linear assumption relies on moderate displacements of the PIN elements; however, the large displacement obtained at the output of the algorithm shows that the optimum solution requires relatively large position variations.
- In the example presented here, it is observed that although the linear assumption results in some non-negligible approximation, a significant improvement in the phase distribution is achieved with a very fast optimization method.
- The validity of the assumption strongly depends on the reflective element to be optimized. In the case where the non-linearity of the phase to the element displacement is too large for the presented method, a global optimization technique would be needed, but is much more computationally intensive since requiring a large number of full-wave simulations.
- Even in such case, the faster method presented here can be used to identify the control element locations allowing larger reflection phase sensitivity, providing relevant information for a potential global optimization.

**Fig. 1.** Schematic of the reflective cell. **Fig. 2.** Photograph of the PIN diodes and measured phase responses and comparison with the results obtained by the hybrid simulation/measured modeling method. **Fig. 3.** Phase diagram (phase as a function of the PIN diodes status) obtained with the hybrid method.

J. Perruisseau-Carrier, A. Georgiadis, "Efficient optimization of the phase diagram in digitally-controlled reflective cells," *Antennas and Propagation, 2009. EuCAP 2009. 3rd European Conference on*, vol., no., pp.1230,1233, 23-27 March 2009

# Research

- **Two – tier algorithm**
- **Genetic algorithm:** ordering of the reflection phase states
- **Least squares:** element locations, assuming linear perturbation
- **N + 1 full-wave simulations:** 1 simulation to evaluate reference reflection phase  $J_0(x_0)$ , and N simulations with a small displacement of each of the N control elements to evaluate  $dJ(x_0)$ .



J. Perruisseau-Carrier, A. Georgiadis, "Efficient optimization of the phase diagram in digitally-controlled reflective cells," *Antennas and Propagation, 2009. EuCAP 2009. 3rd European Conference on*, vol., no., pp.1230,1233, 23-27 March 2009

# CTTC

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- Office mates, Paolo Dini !



# Julien and Friends

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- Julien and friends, courtesy of Marco Miozzo

