(1979-2014)

In the memory of Julien Perruisseau-Carrier: *His contributions to reconfigurable reflectarrays and COST Actions on Antennas*

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METU

EuCAP 2015

Outline

- Contributions and impact of Julien on Antenna COST actions
- Collaboration with Julien: Dual Frequency Circularly Polarized Beam Steering Reflectarray
- Fast and efficient analysis method for the design of reflectarrays based on element rotation

Prof. Julien Perruisseau-Carrier

EDUCATION & PROFESSIONAL EMPLOYMENT

- 1999 – 2003: M.Sc in Electrical Engineering, EPFL, Switzerland
- 2003 – 2004: Junior scientist following MSc. thesis, University of Birmingham, UK
- 2004 – 2007: PhD in Electrical Engineering, EPFL, Switzerland
- 2007 – 2011: Research Associate, CTTC, Barcelona, Spain
- 2011 – 2014: Professor (Swiss National Science Foundation), EPFL, Switzerland

RESEARCH AREAS

Interdisciplinary and frontier topics in EM wave theory and applications (microwaves to THz)

- Dynamic reconfiguration and adaptability:

  reconfigurable antennas, reflectarrays

- Micro/Nanotechnology for EM waves

  MEMS, NEMS, Graphene

- Joint antenna-coding techniques

  MIMOs, disruptive techniques for reduced complexity, mobile terminals

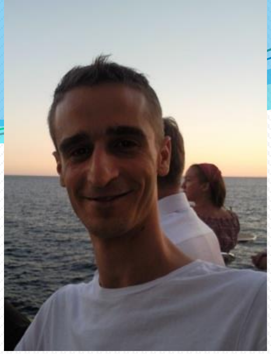
- Electromagnetic metamaterials

  control of phase, amplitude, polarization, and radiation in artificial EM structure

According to Google Scholar

- Citiations: 1555
- h-index: 21
- i10-index: 39

How we met - AMICOM

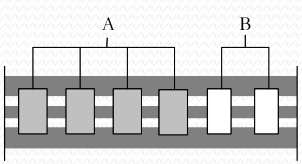


Project: **AMICOM**: European Network of Excellence on RF MEMS and RF Microsystems
Funding: European Union FP6 network of excellence
Role: Various technical collaborations, including the design and realization of MEMS-variable CRLH-TLs and MEMS-reconfigurable reflectarray cells.

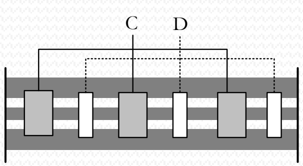
Collaboration with EPFL (Prof. Anja Skrivervik & Julien Perruisseau, PhD canditate):

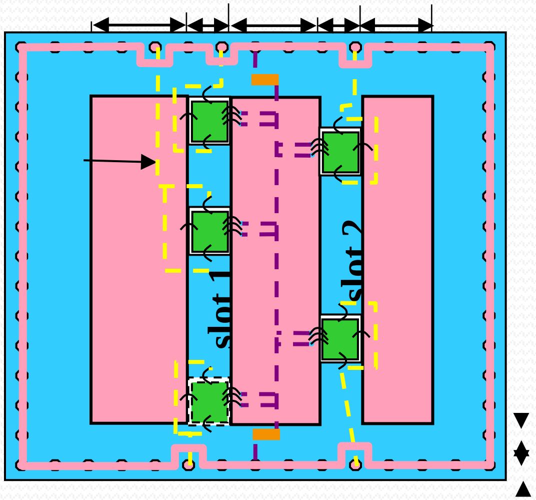
- fabrication of EPFL's devices by METU
- collaboration on EM modelling tools and reflectarrays
- Julien's visit to METU: Oct 18-November 12, 2004

Cascaded DMTLs

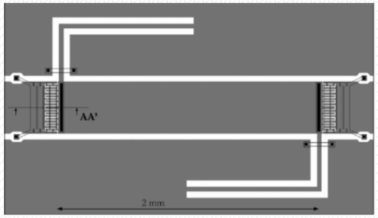


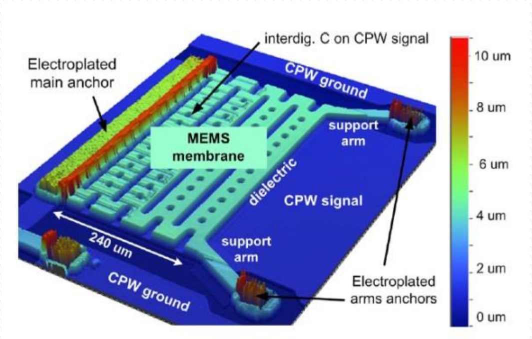
Interlaced Bits





AMICOM MEMSWAVE Workshop, Laussane 2005





J. Perruisseau-Carrier, K. Topalli, and T. Akin, "Low-loss Ku-band Artificial Transmission Line with MEMS Tuning Capability," *IEEE Microwave and Wireless Components Letters*, vol. 19, no. 6, pp. 377-379, June 2009.

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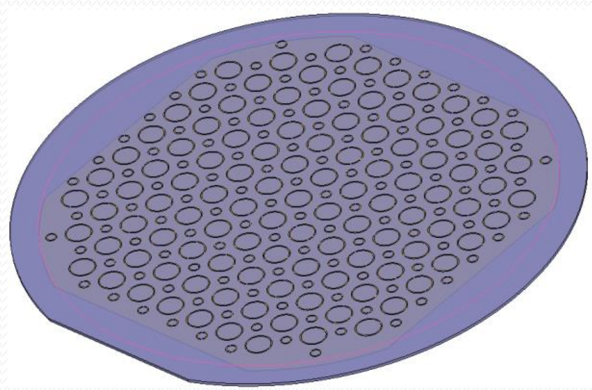
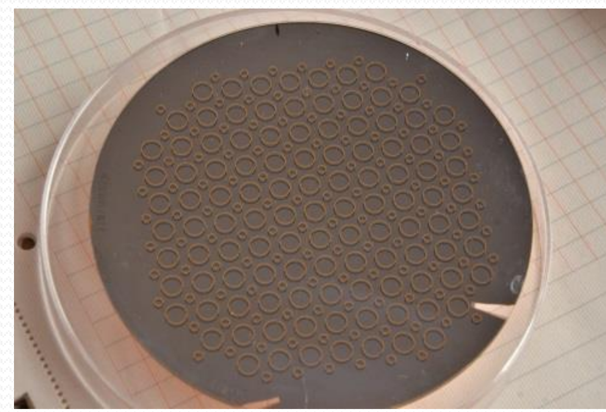
COST ASSIST IC0603

Project: **COST ASSIST** IC0603: Antenna Systems and Sensors for Information Society Technologies.
Funding: European Union, 2007-2011
Role: Leader of the Focus Area 'Reconfigurable & Multibeam Antennas'.

Short Term Scientific Mission: Caner Güçlü from METU visited Julien Perruisseau-Carrier from CTTC
26 October to 7 November 2009





C. Guclu, J. Perruisseau-Carrier, O. Aydın Civi, "Proof of Concept of a Dual-band Circularly-polarized RF MEMS Beam-Switching Reflectarray, IEEE Transactions on Antennas and Propagation, vol.60, no.11, pp. 5451 - 5455, 2012.

8th IC0603 meeting, Les Diablerets, Switzerland, 16-18 March 2011

METU

Contributions to COST VISTA
Versatile, Integrated, and Signal-aware Technologies for Antennas

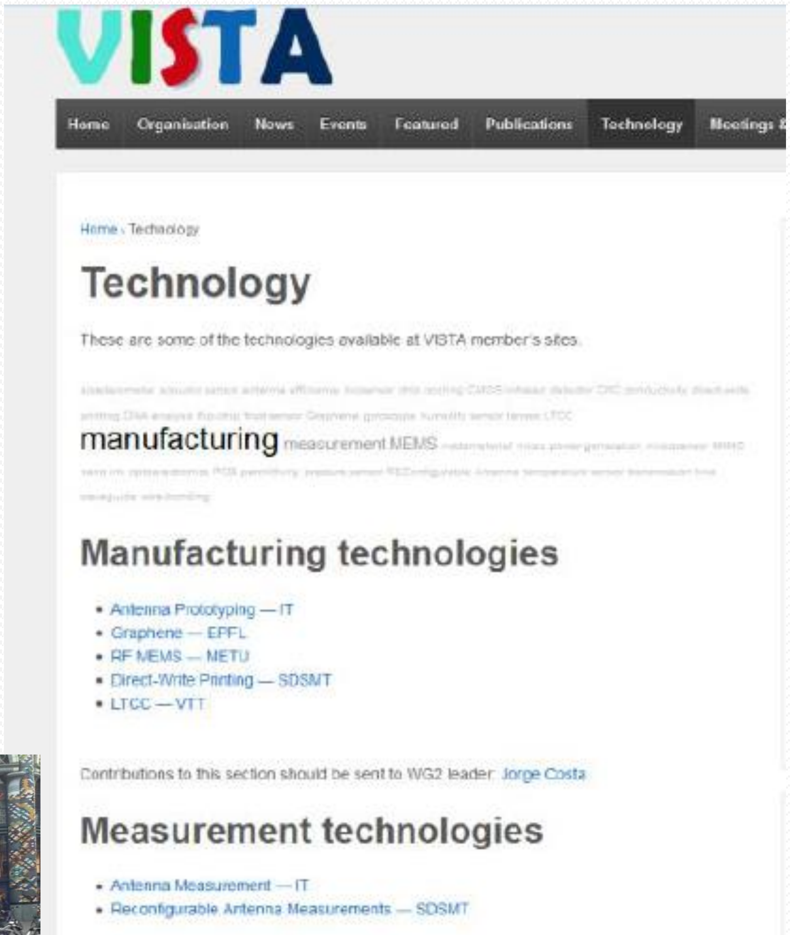
- contributed to the preparation of proposal
- we owe him the "Versatile" "Signal-Aware" part of title

COST VISTA Working Groups

- WG1 – WHY? System applications & requirements
- **WG2 – HOW? Enabling technologies**
- WG3 – WITH WHAT? Supporting technologies: modelling and characterisation
- WG4 – WHO? Support of ESR & societal aspects

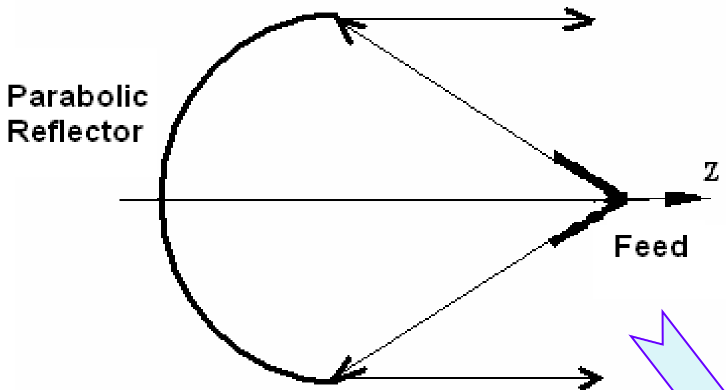
COST VISTA IC1102

- set up the *Technology Platforms* to enhance the exchanges among the participants
- organized several sessions in COST VISTA workshops and EuCAPs

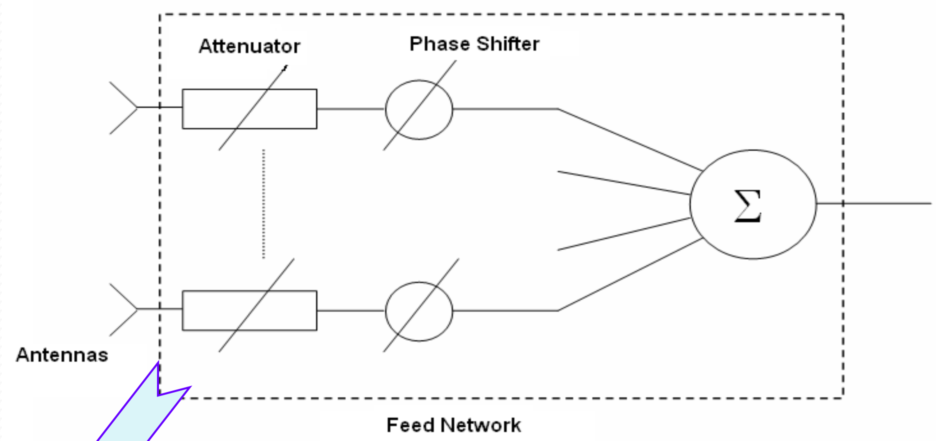


Reflectarrays

METU



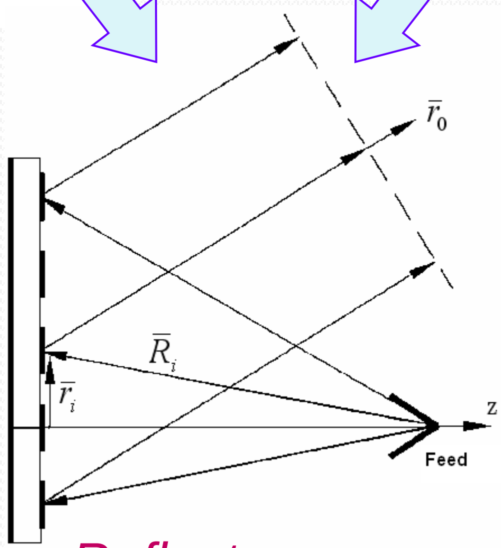
Reflector antenna



Phased array antenna

Some reflectarray elements:

- *patches of varying size*
- *rotated patches*
- *patches with variable length stubs*
- *rotated split rings*



Reflectarray

- *Reflectarrays can be flat or slightly curved printed structures*
- *Reflecting surface consists of many elements with no power division network*
- *By changing phase of each element, beam can be steered*

Reflectarrays – advantages

compared to parabolic reflectors

- Advantages
  - Planar
  - Low mass
  - Low manufacturing cost
  - Easy to fabricate
  - Ease of integration with dynamic components
  - Electronic scanning is possible
- Disadvantages
  - Narrowband

compared to phased arrays

Reflectarrays are space fed arrays

- no need for complex feed network
- eliminates losses and parasitic radiations of the feed network

Dual Frequency Circularly Polarized Beam Steering Reflectarray

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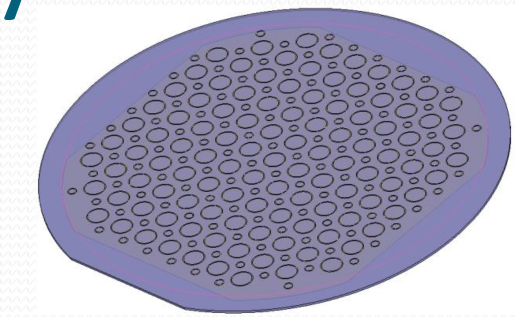
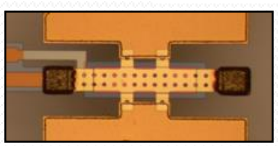
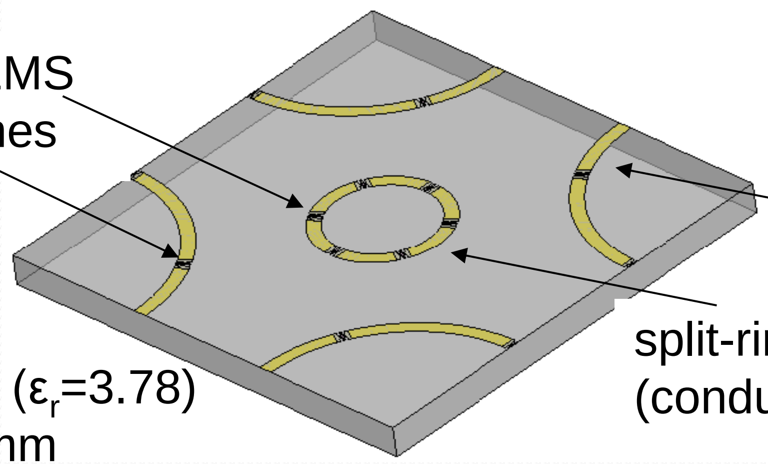
- Prototype on 4” quartz wafer at 24.4 GHz and 35.5 GHz
- Beam steering capability
- Reflectarray element: split ring
- Phase shift is provided by rotation of the ring
- Position of the split is controlled by RF-MEMS swicthes
- Production by micromachining based MEMS process developed in METU
- Monolithic integration of switches with the antenna elements



Unit Cell

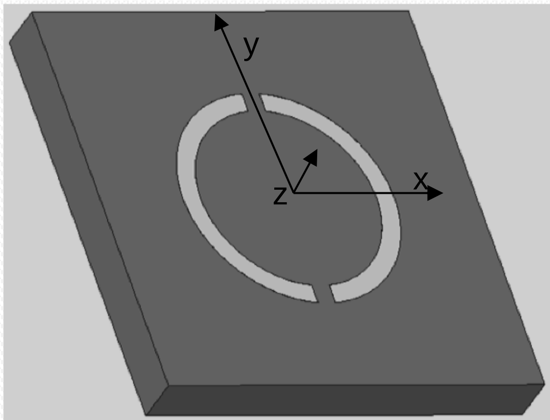


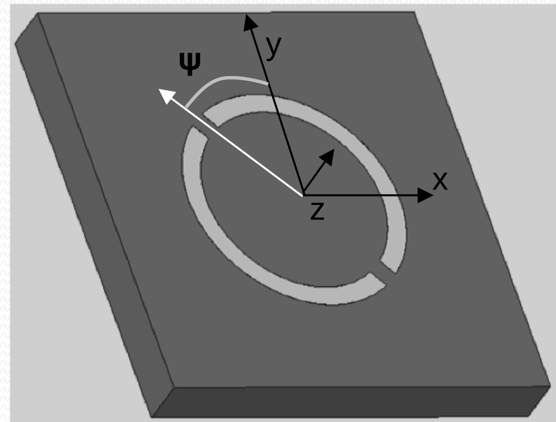


conductor backed quartz (ε_r=3.78)
substrate thickness: 0.5mm

Rotational Phase Shift Principle

METU





CP incident field propagating in the -z direction

$$\overrightarrow{E^i} = (\hat{a}_x + j\,\hat{a}_y)E^i\,e^{jz}$$

Reflected field for the ψ degree-rotated element

$$\overrightarrow{E^r} = 0.5E^i(\Gamma_x - \Gamma_y)(\hat{a}_x - j\,\hat{a}_y)e^{j2\psi}e^{-jz} + 0.5E^i(\Gamma_x + \Gamma_y)(\hat{a}_x + j\,\hat{a}_y)\,e^{-jz}$$

Co-polarized component

Cross-polarized component

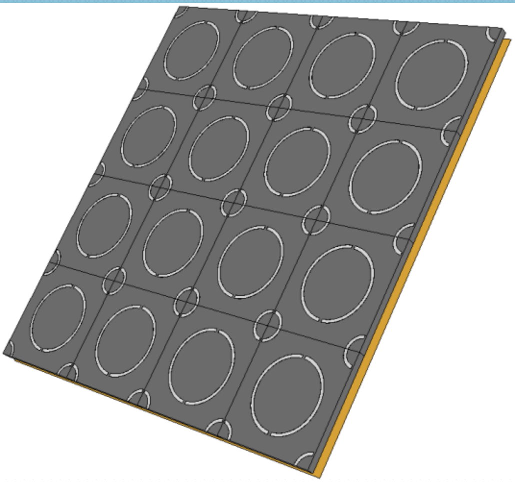
Reflection coefficient of x-pol. component

Reflection coefficient of y-pol. component

Reflection phase of the co-pol. component is linearly proportional to the angle of rotation

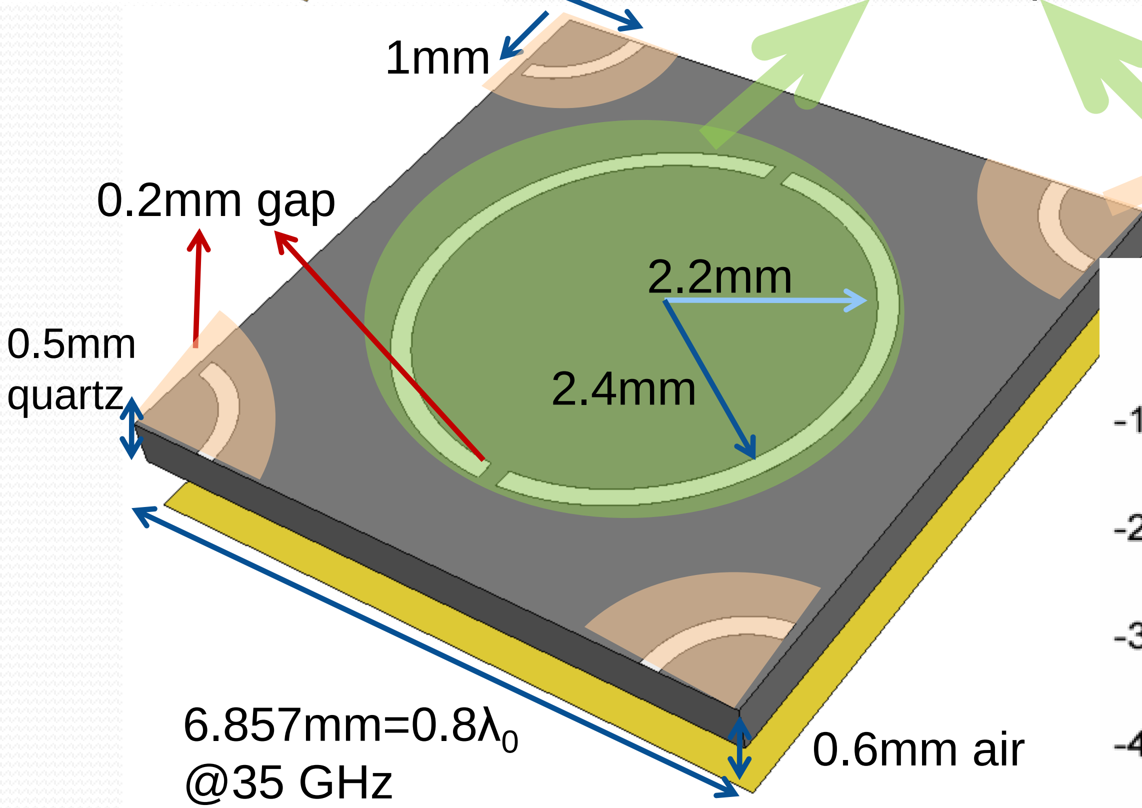
Huang, J.; Pogorzelski, R.J., "A Ka-band microstrip reflectarray with elements having variable rotation angles," *Antennas and Propagation, IEEE Transactions on* , vol.46, no.5, pp.650-656, May 1998

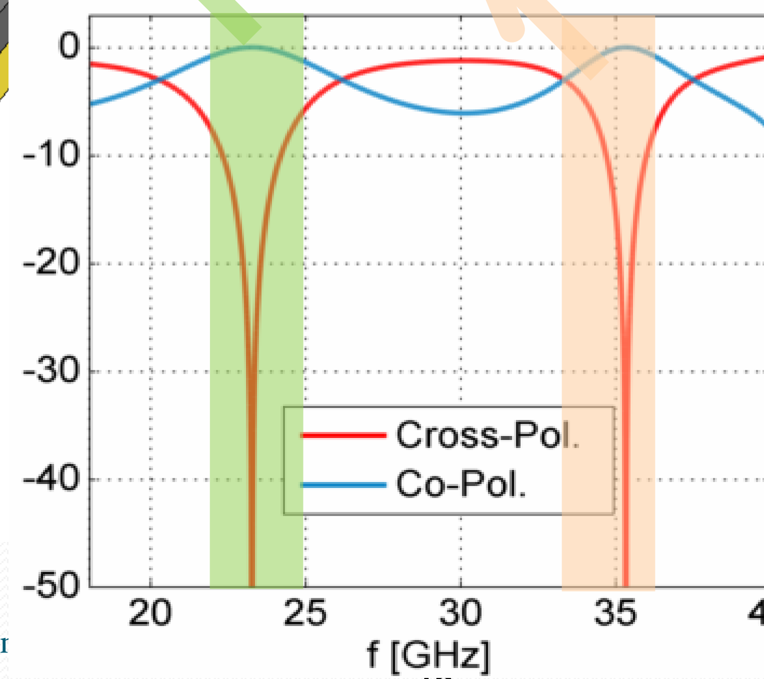
Dual Frequency Operation



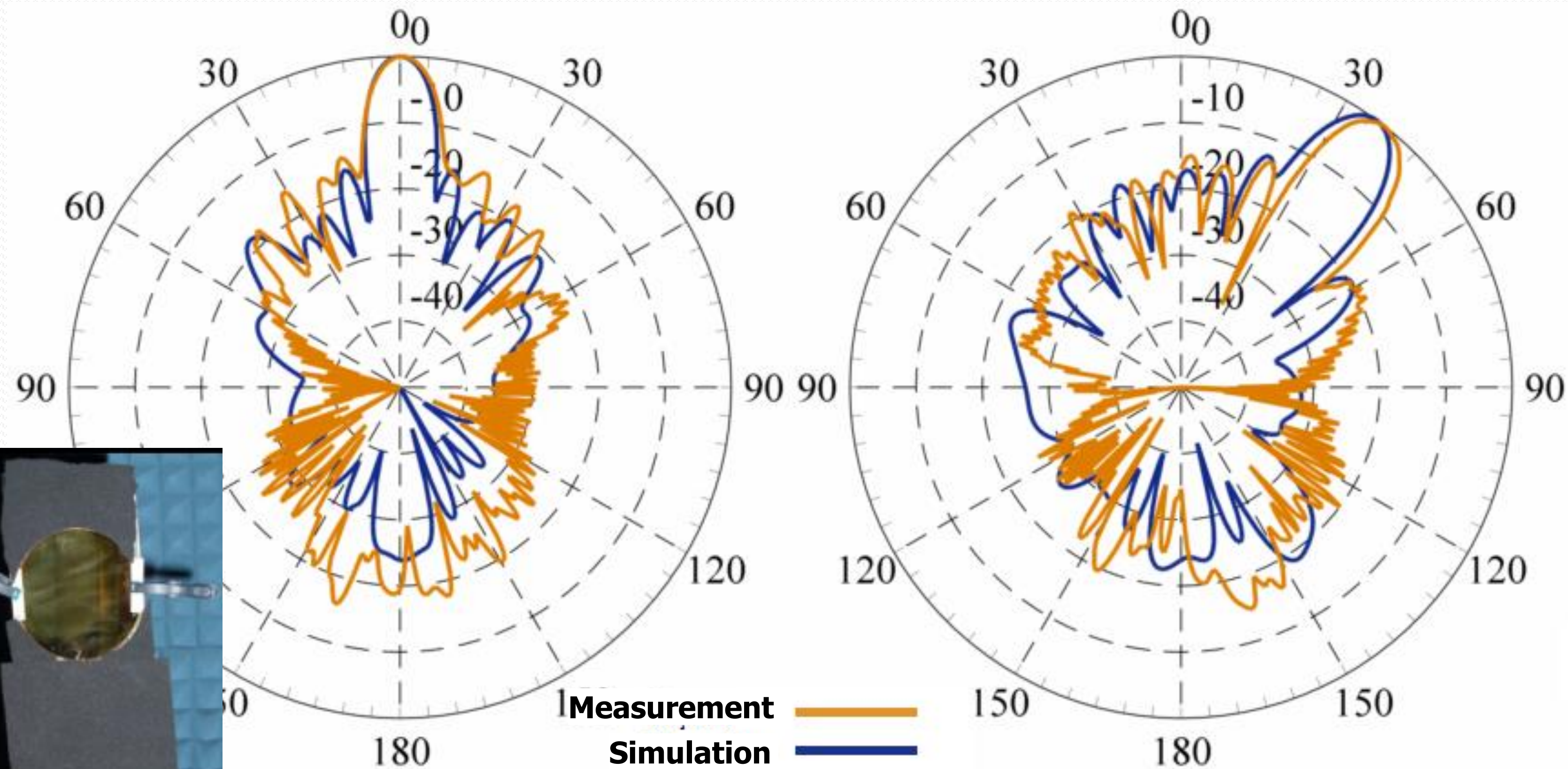
Larger ring, controlling phase at the lower operating frequency.

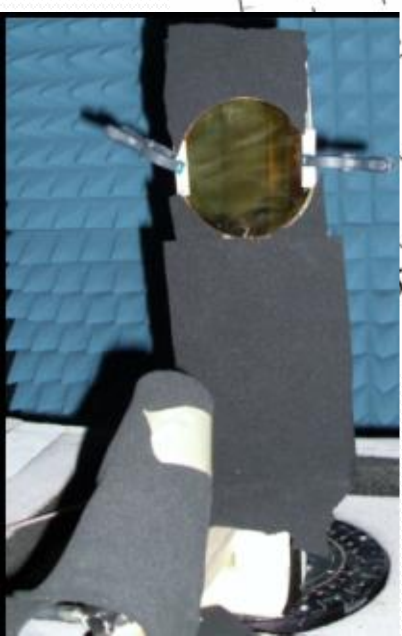
Smaller ring, controlling phase at the higher operating frequency.



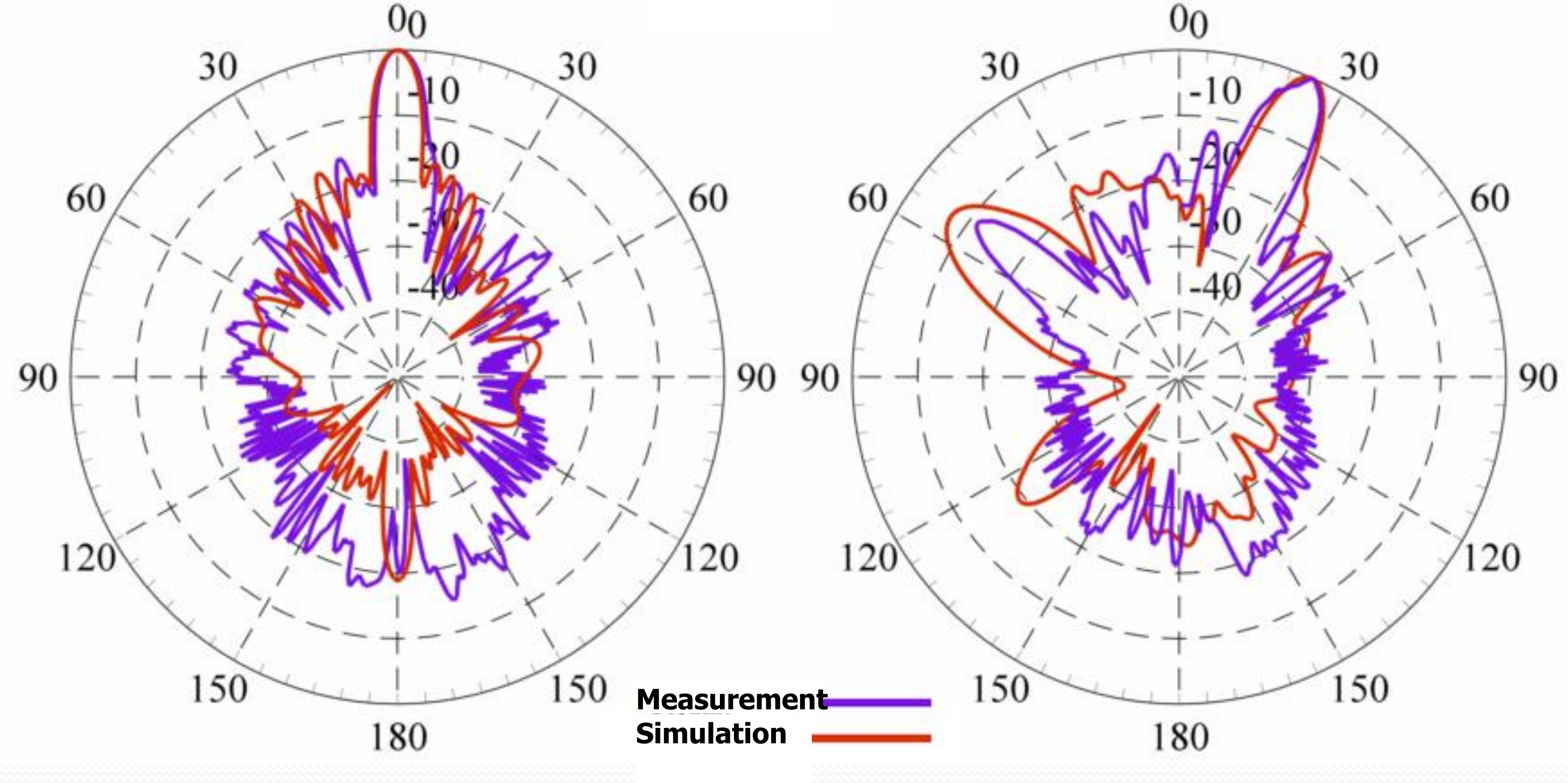


Comparison of Simulations and Measurements at 24.4 GHz



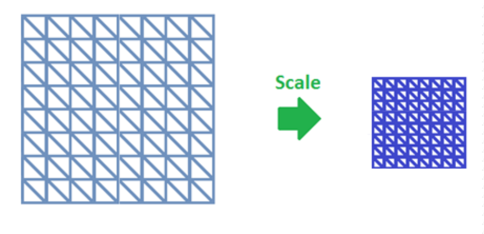


Comparison of Simulations and Measurements at 35.5 GHz



Fast and efficient analysis method

- Reduction of the MoM matrix equation size significantly using characteristic modes as macro basis functions
- Reusability of characteristic modes



  - dominant characteristic mode of the resonant patch can be used for all differently sized patches on the array
- Construction of reduced impedance matrix in a very efficient way

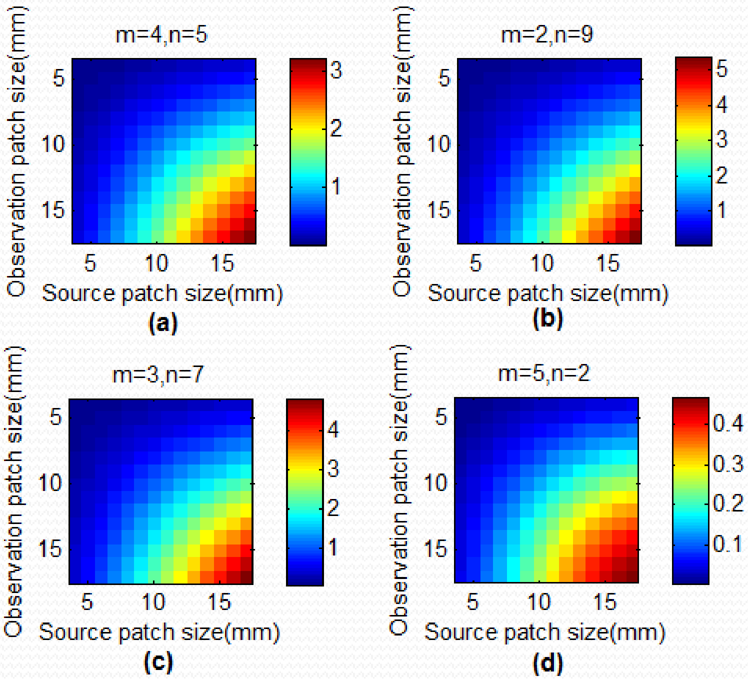
For details: Wednesday **C26 INTELLECT Session:** Diogo Cão (Aud 8)
17.10: Efficient Analysis of Reflectarrays Through the Use of Characteristic Modes, E. Erçil, L. Alatan, Ö. Aydin Civi

Efficient Calculation of Mutual Couplings

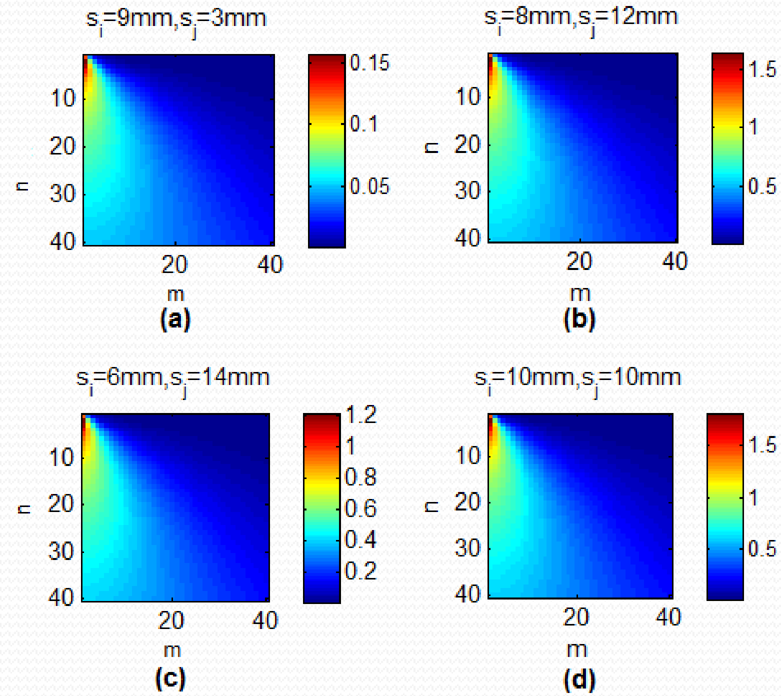
METU

$$\tilde{Z}_{ij} = \overline{J}_1^T \overline{\overline{Z}}^{ij} \overline{J}_1 = f\left(d_x, d_y, s_i, s_j\right) \approx g(d_x, d_y) h(s_i, s_j)$$

1) Observe $\tilde{Z}_{ij}$ for fixed values of s_i, s_j



2) Observe $\tilde{Z}_{ij}$ for fixed values of d_x, d_y



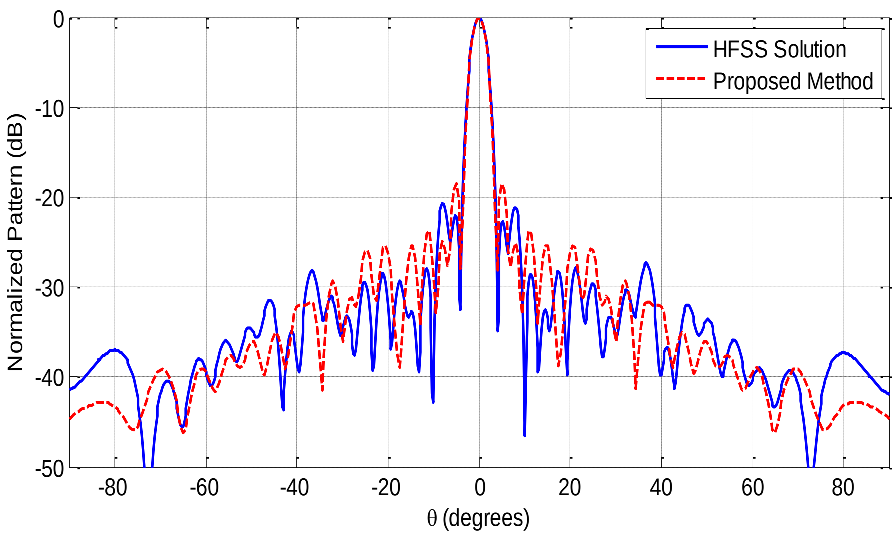
1) **f 's at different (d_x,d_y) are almost same within a scaling constant**

2) **f's at different (s_i,s_j) are almost same within a scaling constant**

→ f is almost separable

Analysis Example

- cosecant square fan beam pattern
- Frequency: 10 GHz.
- Reflectarray size: 30 × 30 elements.
- Spacing between elements: 0.6λ in both dimensions
- Substrate: thickness=1.588 mm, ε_r=4.2.
- Distance of feed antenna: 12 λ_0.
- Feed antenna: Horn : $1.3\lambda_o \times 0.58\lambda_o$.

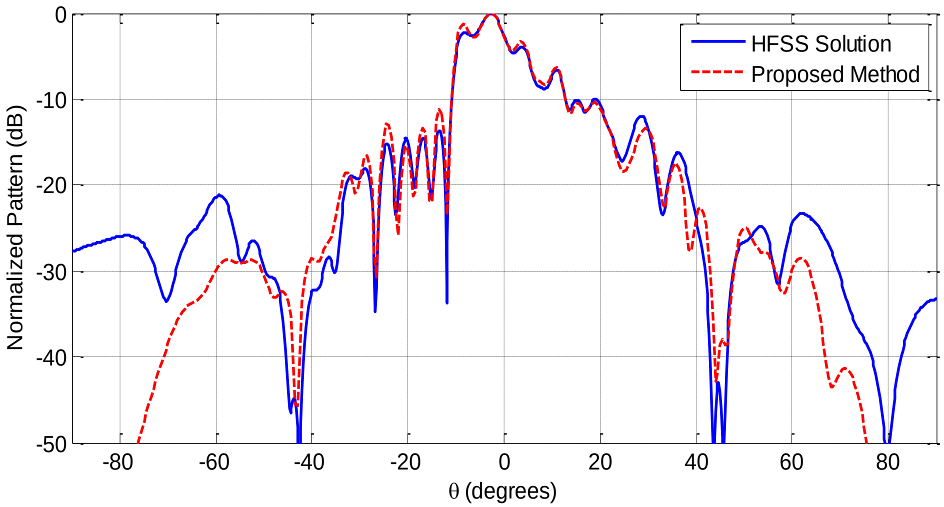


HFSS:

run on super computer with 512 CPUs

Solution time: 9 hours

Memory : 179 GB



Proposed Method:

Run on Intel Core i5 2500, 3.3 GHz Clock Speed, 64 Bit OS.

Solution time < 0.33 sec

Contributors

- Julien Perruisseau-Carrier
- Lale Alatan
- Erdinc Ercil
- Caner Güçlü
- Ömer Bayraktar

We miss Julien!