INSTITUT D'ÉLECTRONIQUE ET DE TÉLÉCOMMUNICATIONS DE RENNES

New Results from the SoftLAB Benchmark of Antenna Software

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UMR
6164

- SoftLAB Presentation
- Test-case #1 : reflectarray
- Test-case #2 : small folded GSM antenna
- Conclusion

❑ What is SoftLAB?

- SOFTware on Line Antenna Benchmark
- Started in 2004 within the Antenna Center of Excellence, ACE (FP6 NoE)
- Continued within the EurAAP association since 2009
- Goal : Assess antenna software tools (both commercial and in-house) using a set of agreed test-cases.
- Main results :
  - 4 completed benchmark runs gathering 21 antenna test-cases
  - More than 100 achieved simulations from about 25 contributors
  - More than 20 tested software packages (including commercial tools such as HFSS, FEKO, CST MWS, IE3D, Empire, Microstripes, …)

❑ How does it work?

- On line process

  All benchmarking steps achievable online (propose your challenging antenna test-cases, get information about a selected test-case, upload your simulation results, get simulation results from someone else, …)

- Open process

  Full access to all test-cases and all results for EurAPP members (after completion of benchmark run)

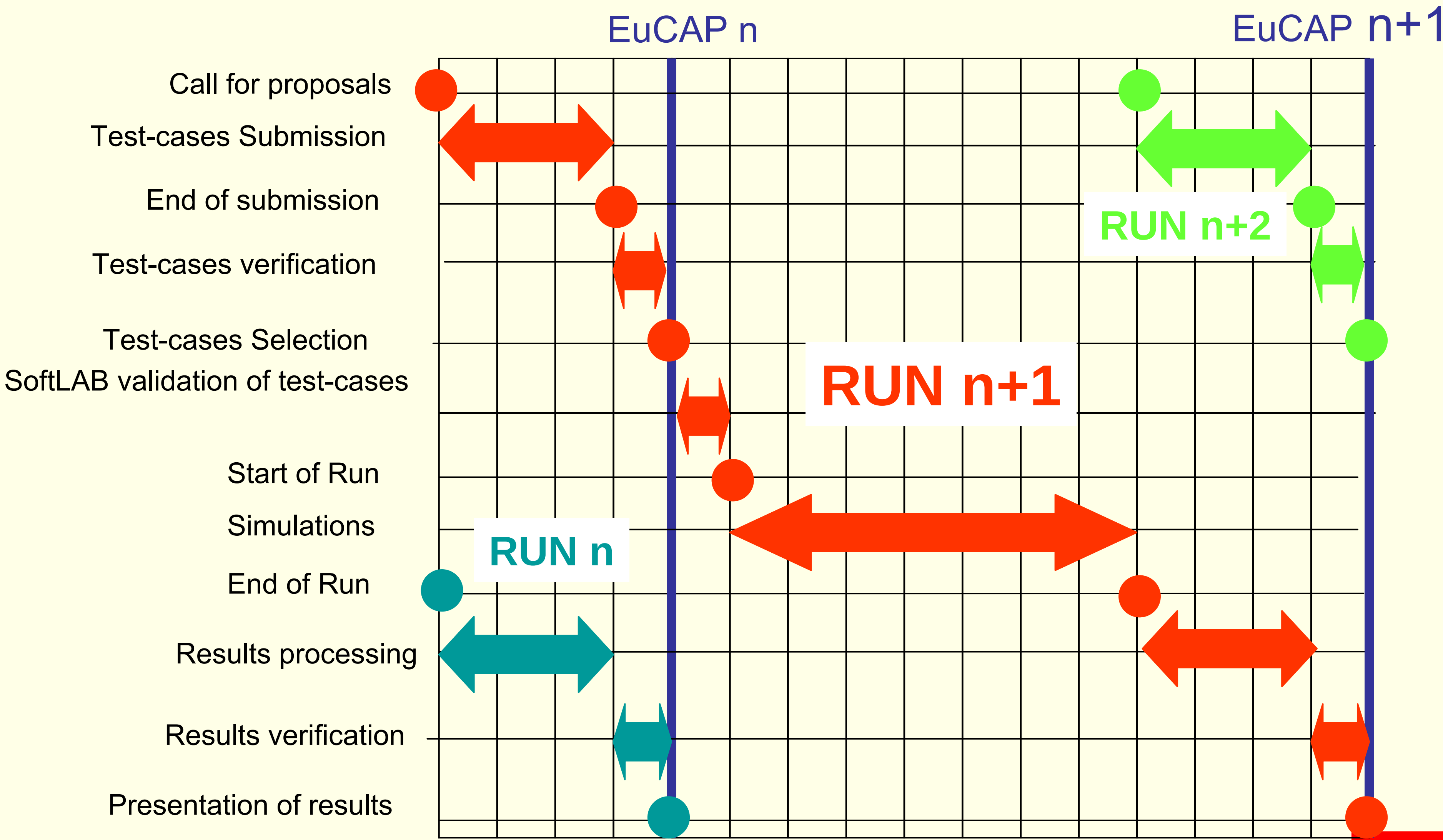
- Blind process

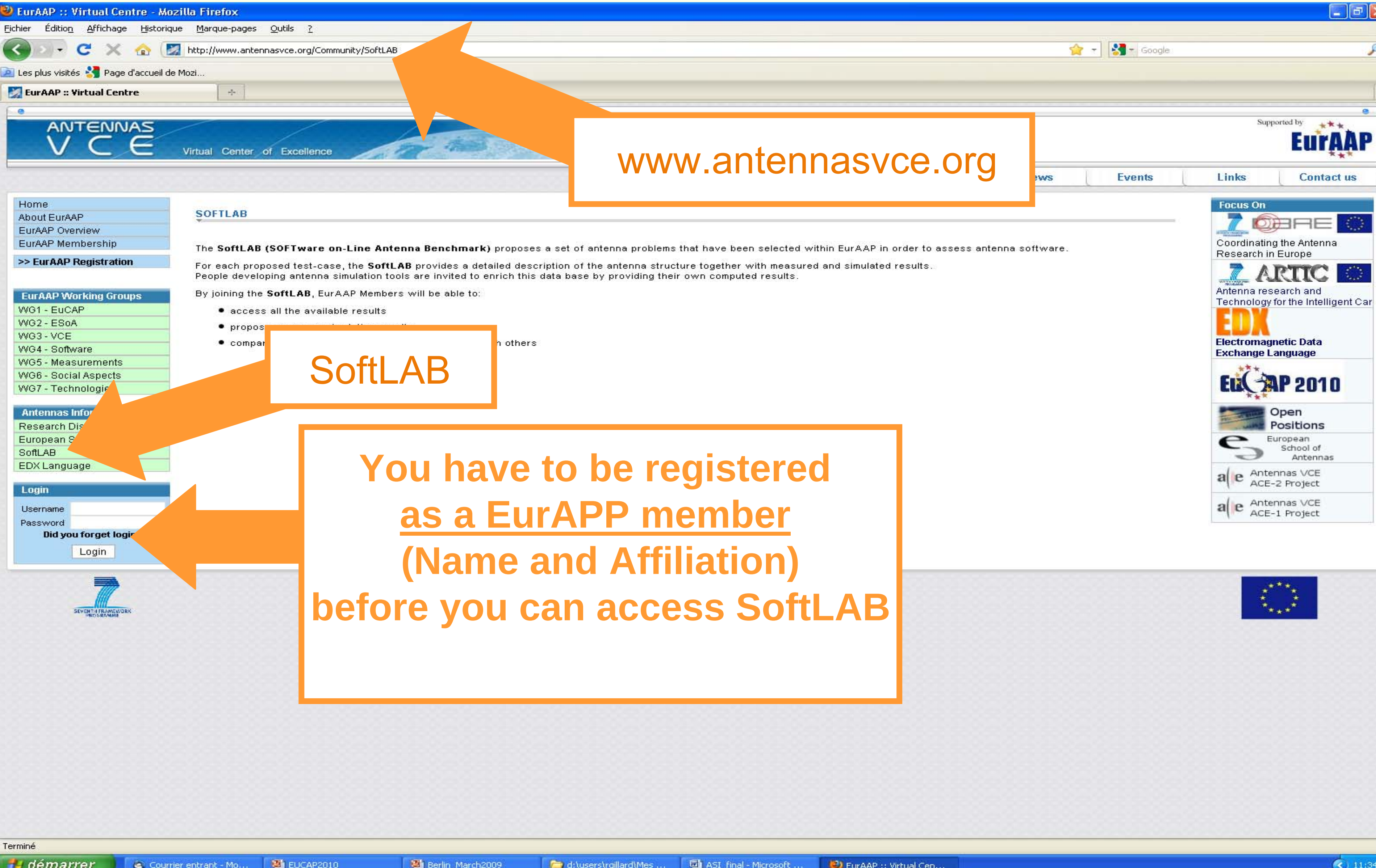
  No results before the end of the current run

- Neutral process

  No biased opinion given about simulation tools. Only raw results.

❑ SoftLAB yearly cycle

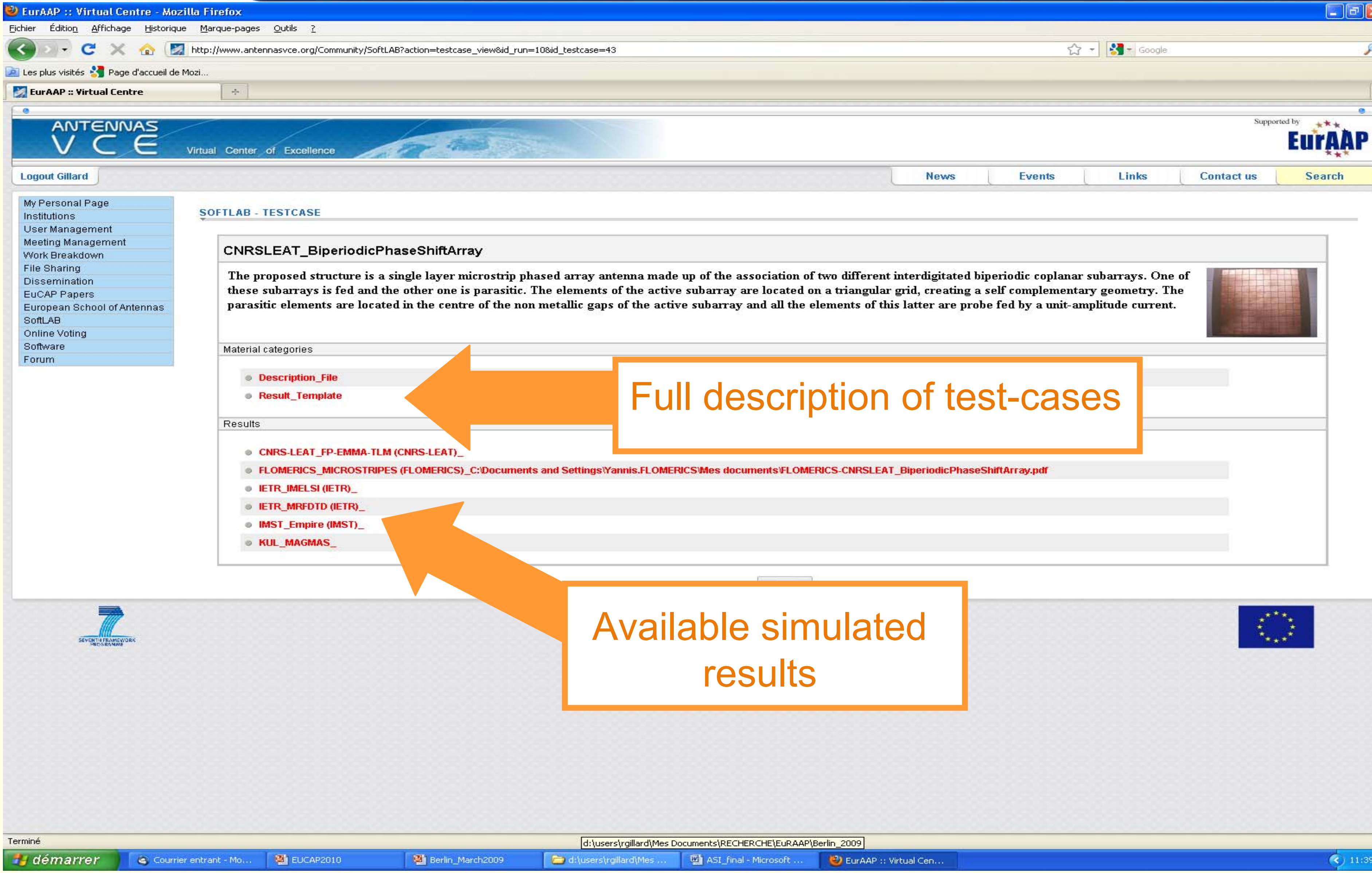




www.antennasvce.org

SoftLAB

You have to be registered
as a EurAPP member
(Name and Affiliation)
before you can access SoftLAB



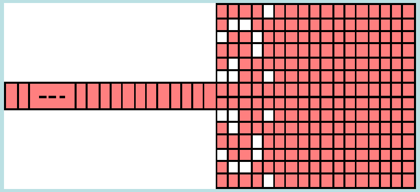
Full description of test-cases

Available simulated results

❑ Run #1 (2005)

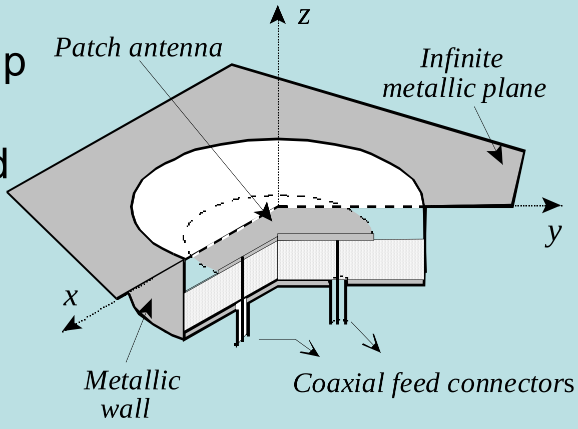
➢ Mainly focused on single elements

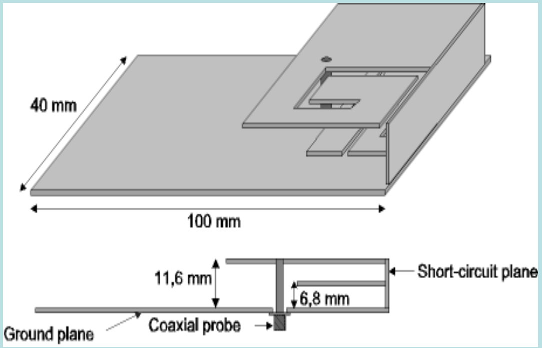
A few examples



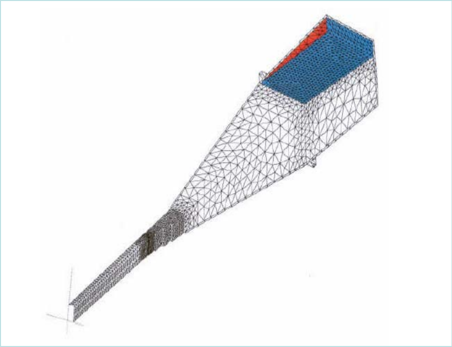
Genetically Optimized Patch
IETR (F)

Cavity-Backed Microstrip Antenna
with Dual Coaxial Feed
UPM (E)





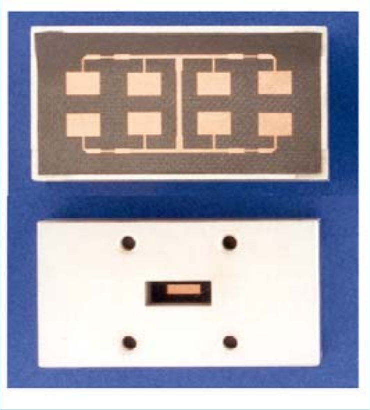
Miniature Multiband Antenna
CNRS LEAT (F)



Pyramidal Horn
With Dielectric
Slab And
Transition
ORANGE LABS (F)

❑ Run #2 (2006)

➢ Mainly focused on antenna arrays



Microstrip array with waveguide excitation
IMST (D)

Spherical array
University of Zagreb (HR)

Planar reflectarray
UPM (E)

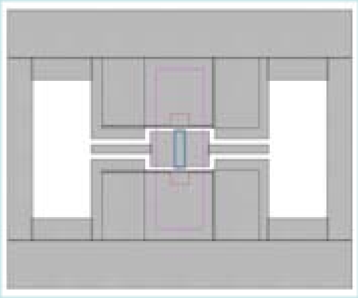
Biperiodic array
CNRS-LEAT (F)

A few examples

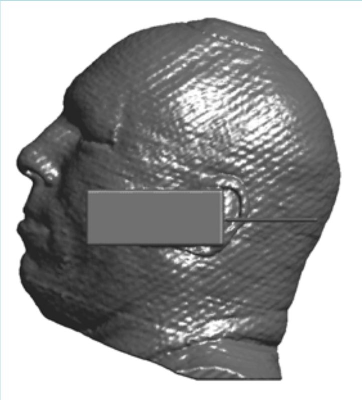
❑ Run #3 (2007)

- Not only antenna problems!

MEMS switch
AMICOM NoE

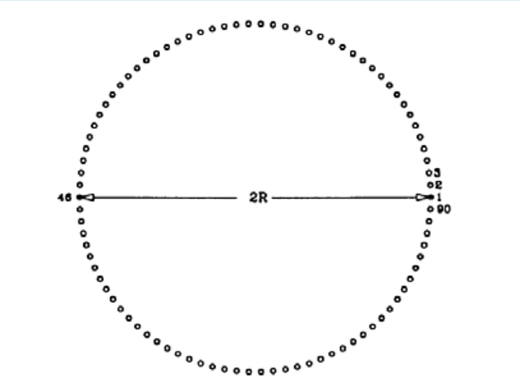


Antenna + Human head
Orange Labs (F)

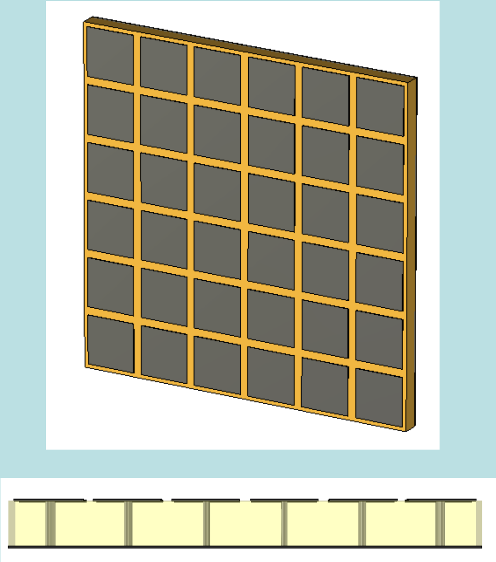


A few examples

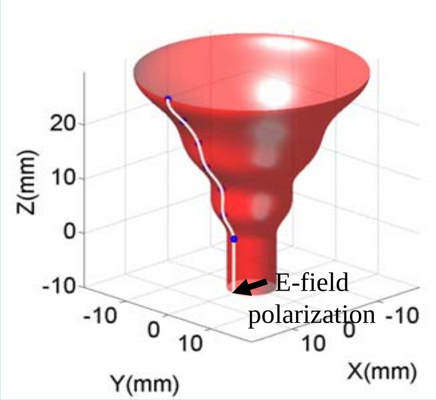
❑ Run #4 (2009)



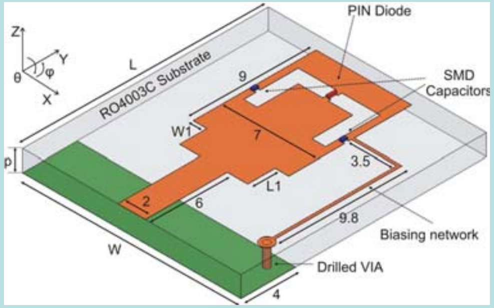
Circular array of dipoles
NTUA (GR)



High Impedance Surface
Telecom Paris Tech (F)

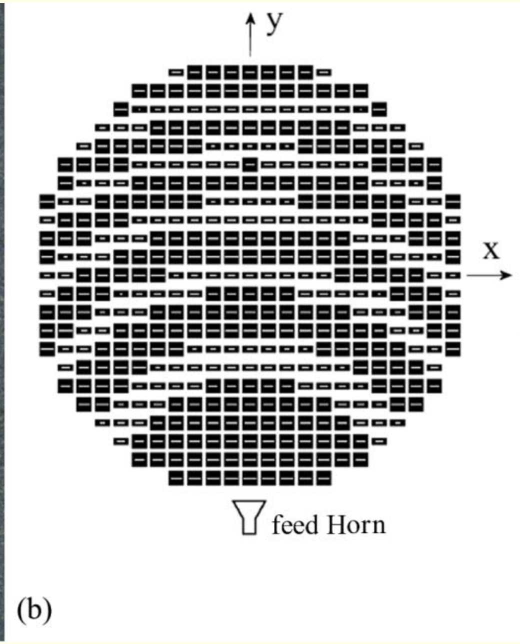


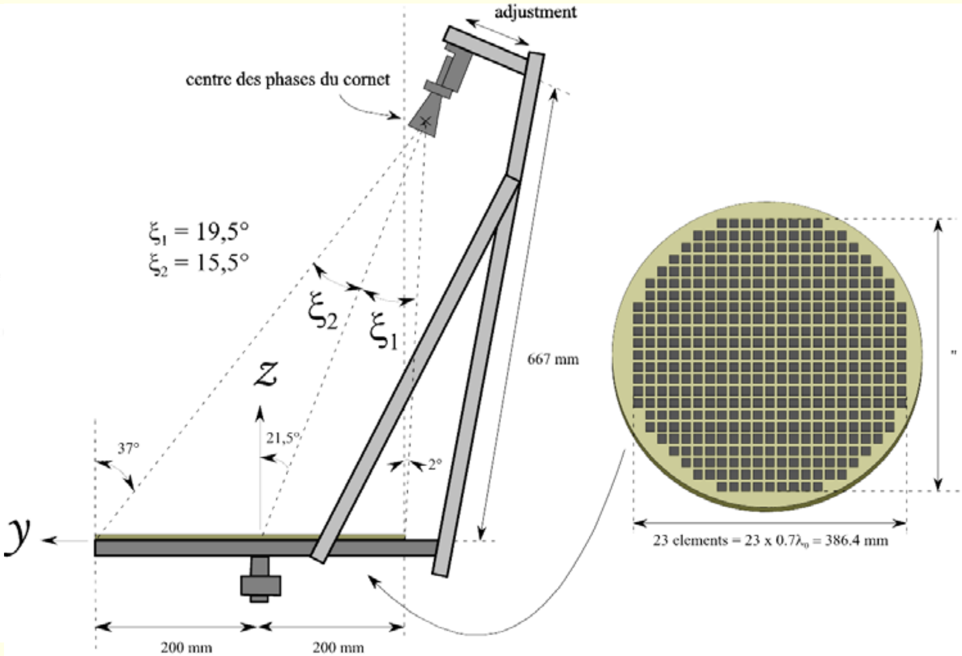
Horn antenna with non intuitive profile
IETR (F)



Switching patch antenna
KUL (B)

❑ Antenna configuration

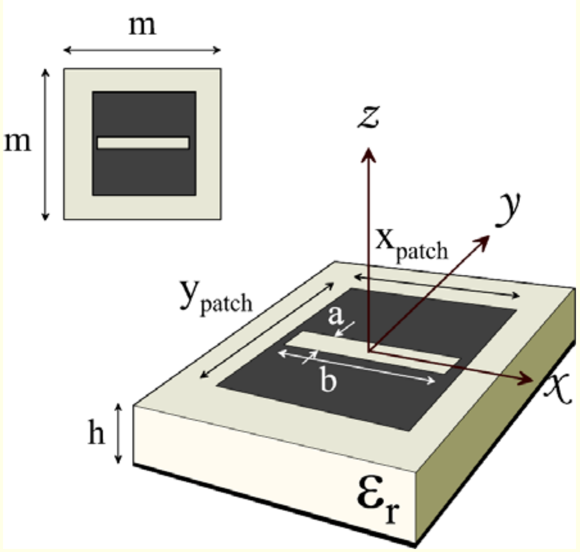




- Microstrip reflectarray
- 437 elements
- Offset horn antenna
- Broadside radiation, linear polarization @ 12.5 GHz
- Rectangular patches loaded with centered slot

❑ Cell geometry

Cell size m	Substrate height h	Patch length y_{patch}	Patch width x_{patch}	ε_r	Slot width a	Slot length b
16.8 mm	3.175 mm	variable from one patch to another, two possible values : 6 or 13 mm	13.5 mm	2.17	1 mm	variable from one patch to another



Phase tuning parameters

❑ Expected results

- radiating patterns (E and H plane @ 12 GHz ,12.5GHz, 13 GHz)
- Simulation time and other computer requirements

❑ Participants and methods

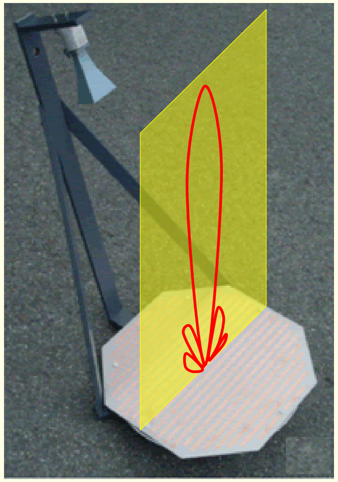
participant	UNIFI+POLITO (University of Florence + Turino)	FT R&D (La Turbie)	IETR (Rennes)
Method	Multiresolution MoM	FEM	FDTD with surrounded-element approach
Main features	2D FD	3D FD	3D TD

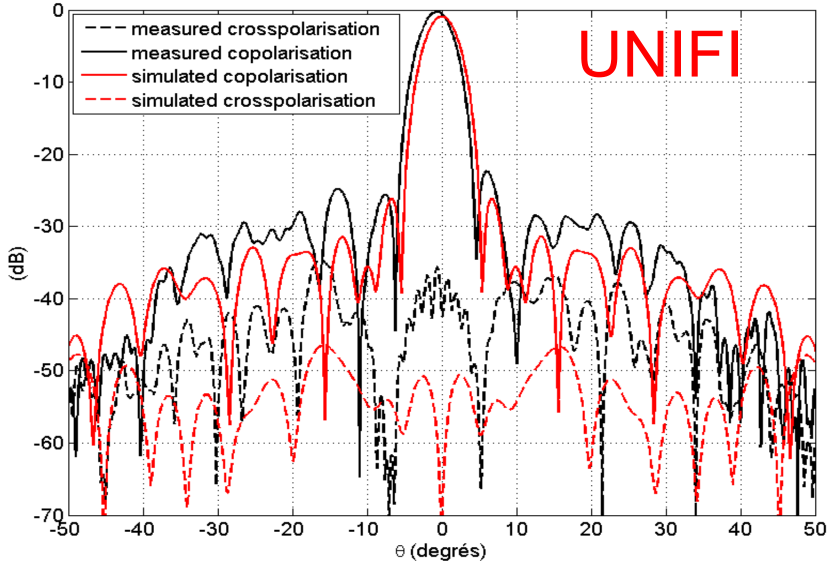
❑ Computer requirements

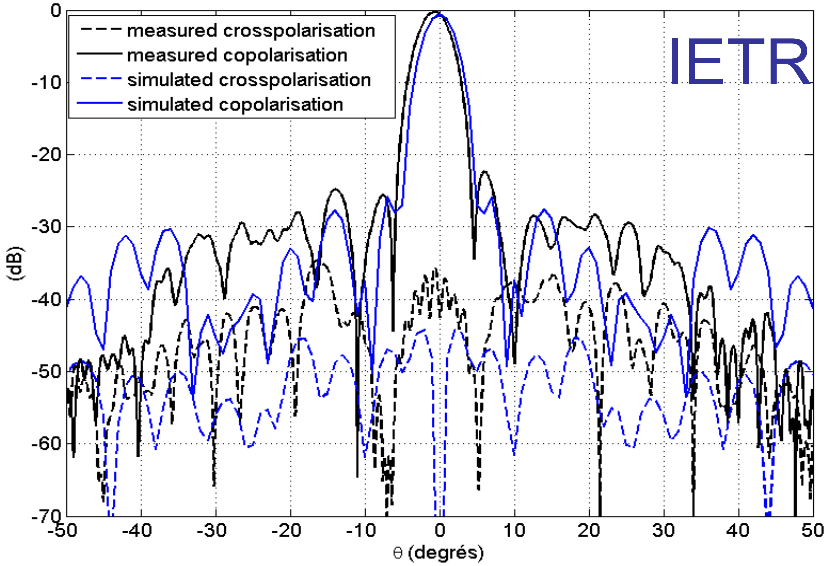
participant	UNIFI	FT R&D	IETR
Computer	Xeon with 2Gb @ 2.8GHz	HP RX7620 with 8 processors and 16 Gb @ 1.5 GHz	AMD Opteron 240 with 2 Gb @ 1.394 GHz
CPU time	1h04 / freq	593 h/freq 97 h/freq	240h (full bandwith)

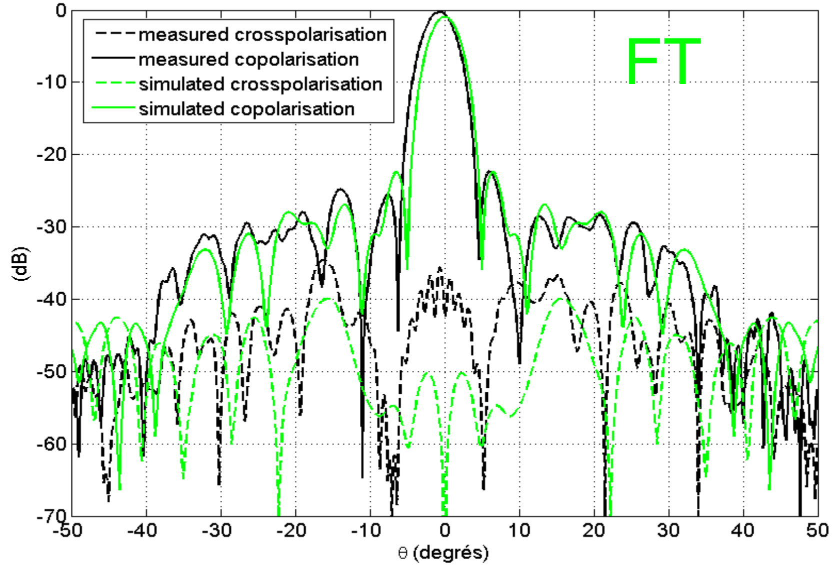
Test-case #1 : Reflectarray

12 GHz, H plane

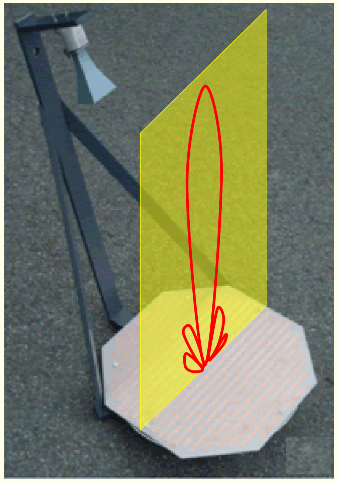


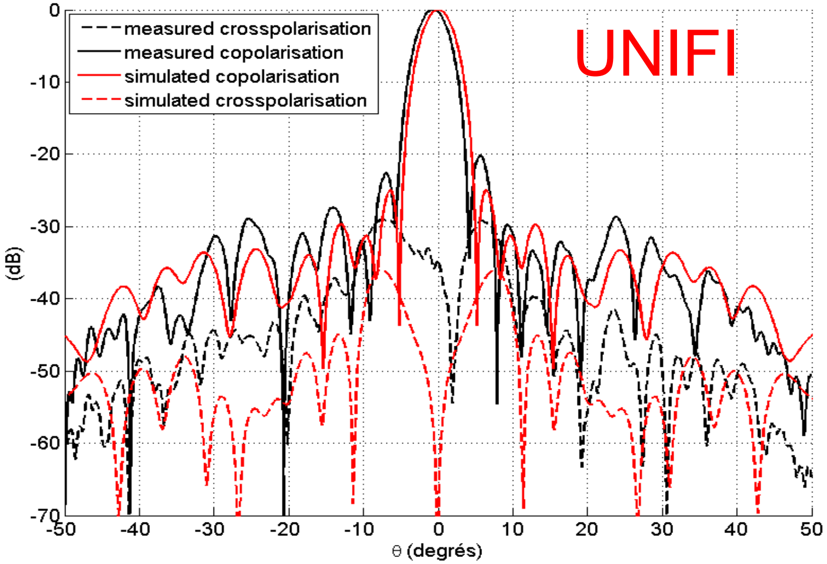


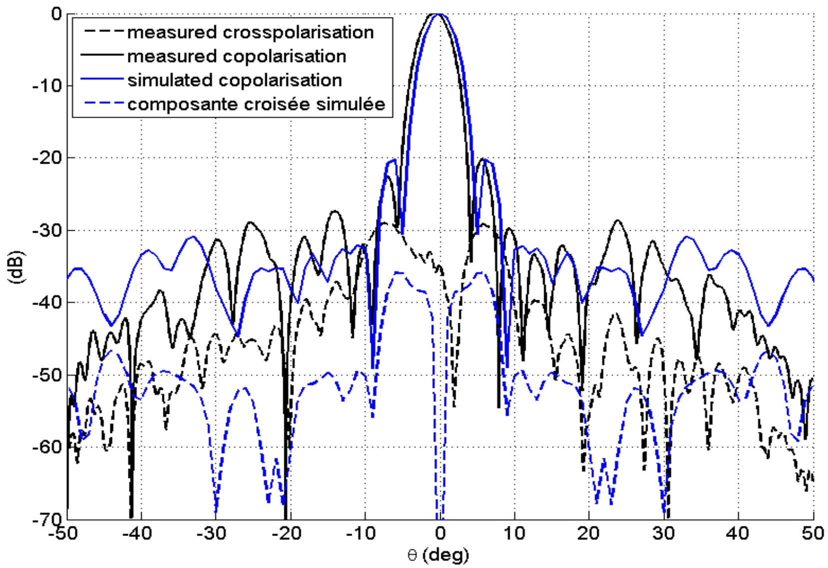


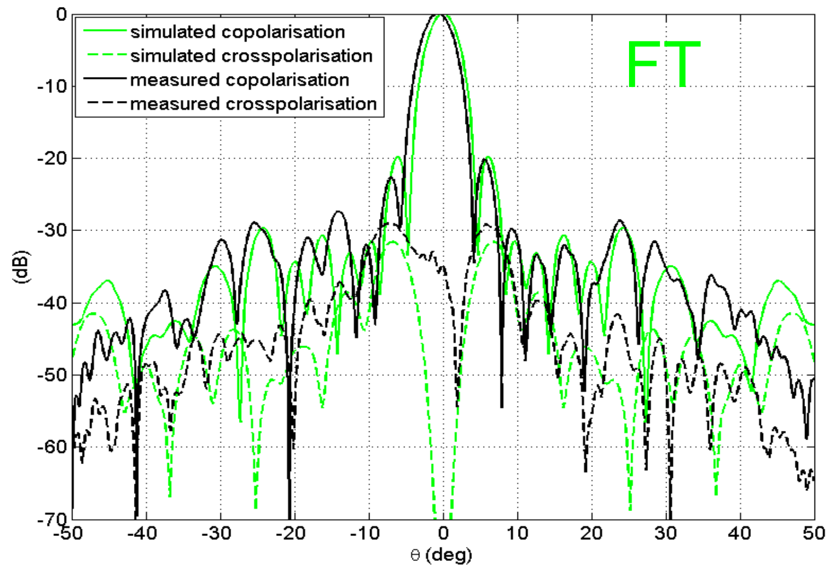


12.5 GHz, H plane

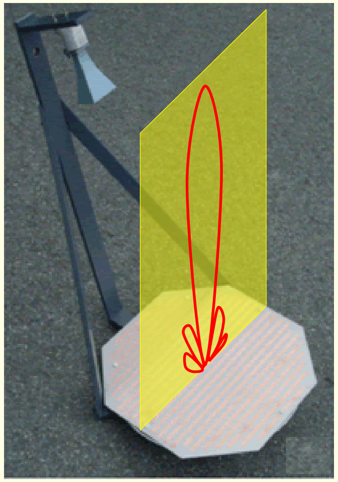


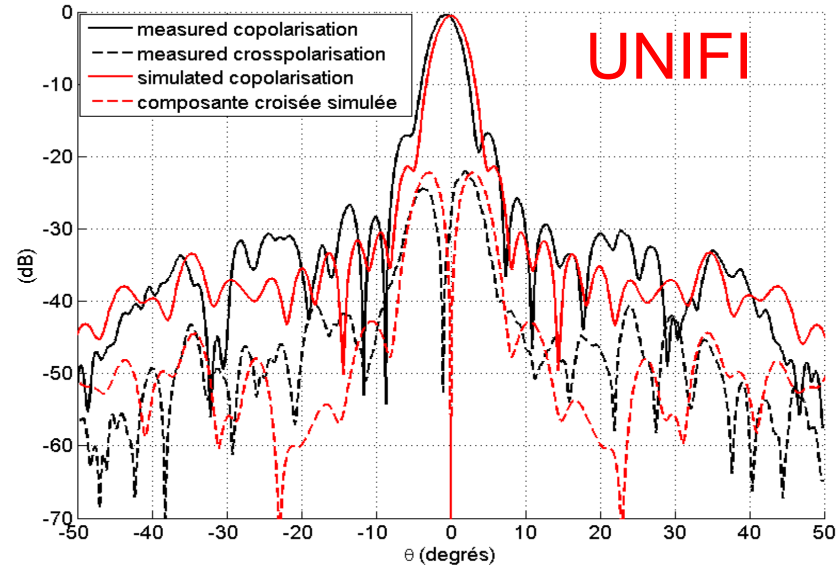


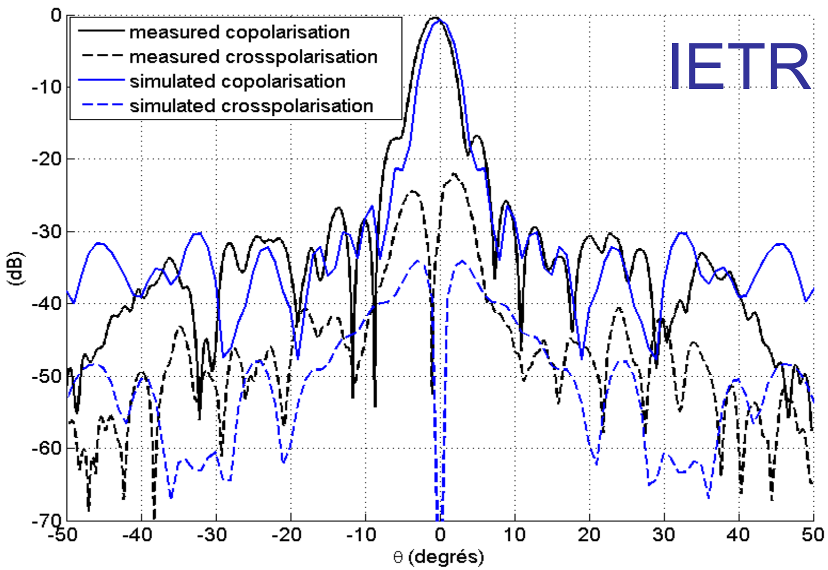


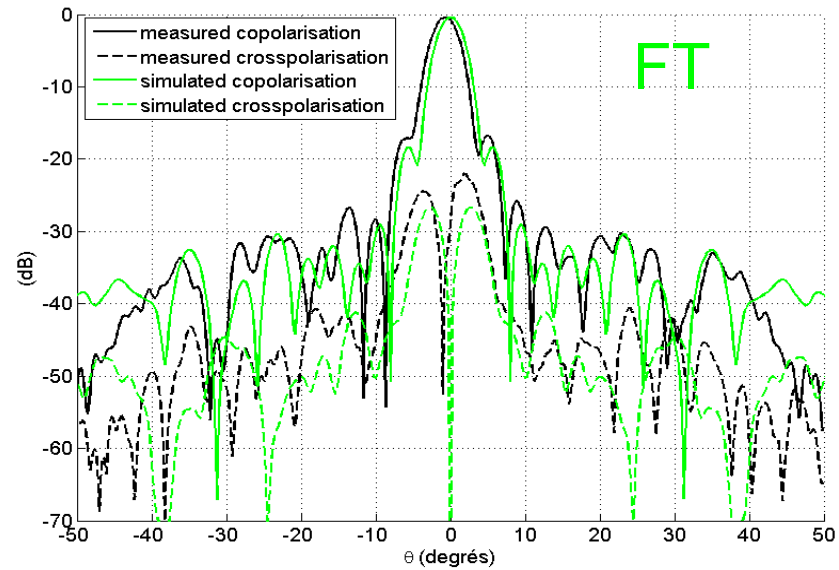


13 GHz, H plane





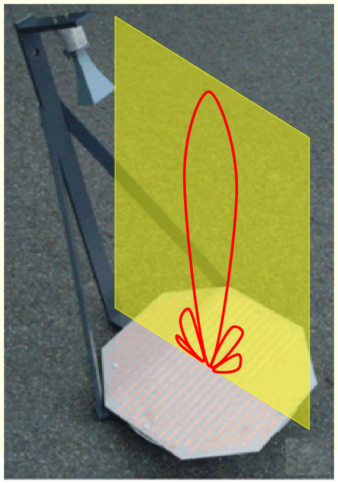




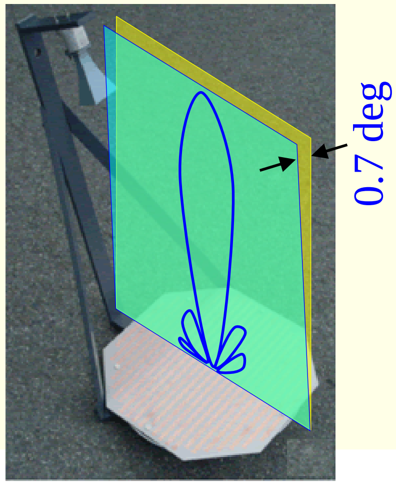
Test-case #1 : Reflectarray

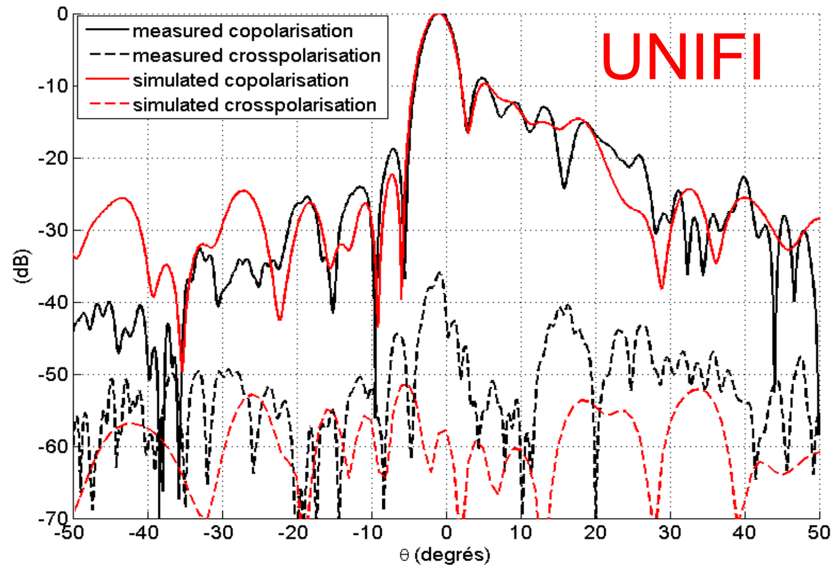
12 GHz, E plane

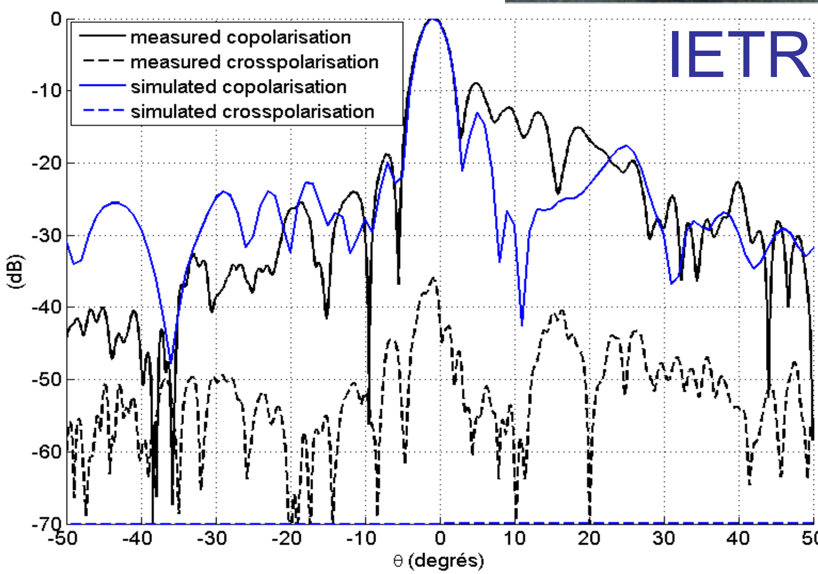
IETR and FT

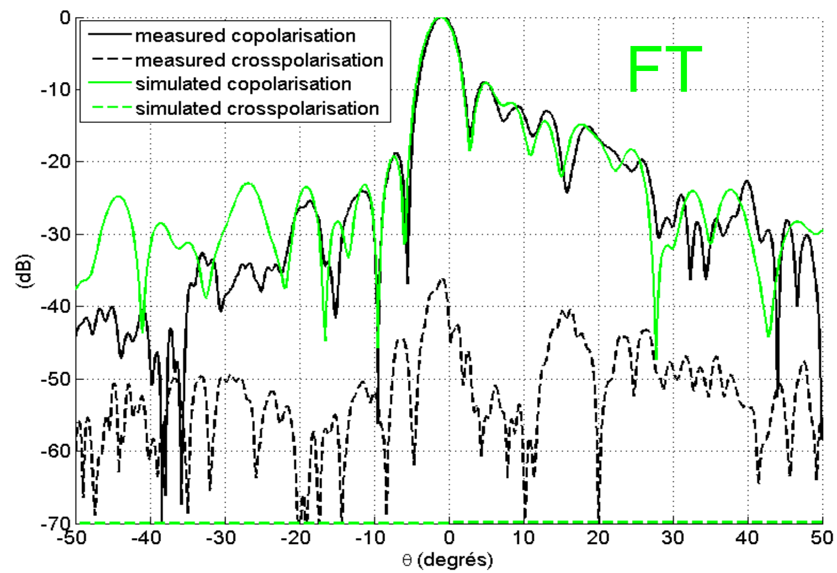


UNIFI



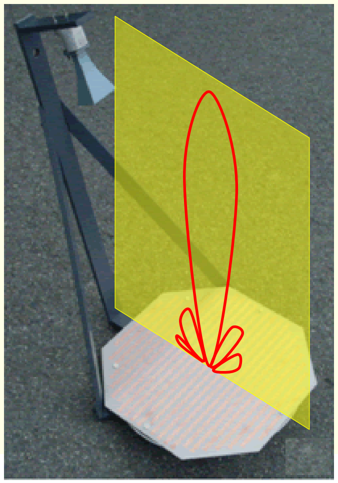






12.5 GHz, E plane

IETR and FT



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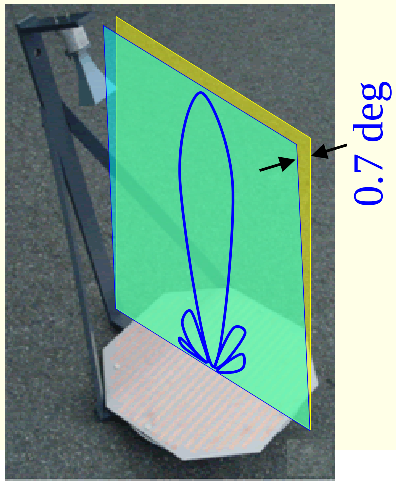
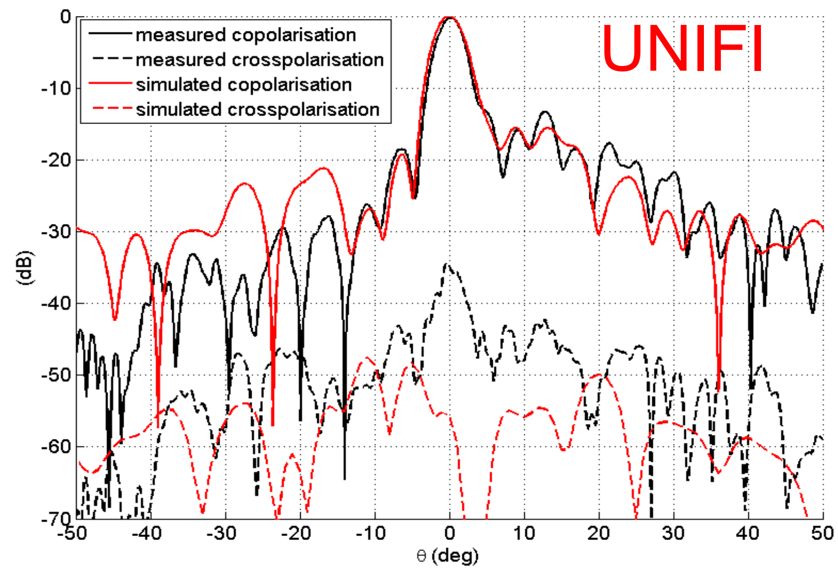
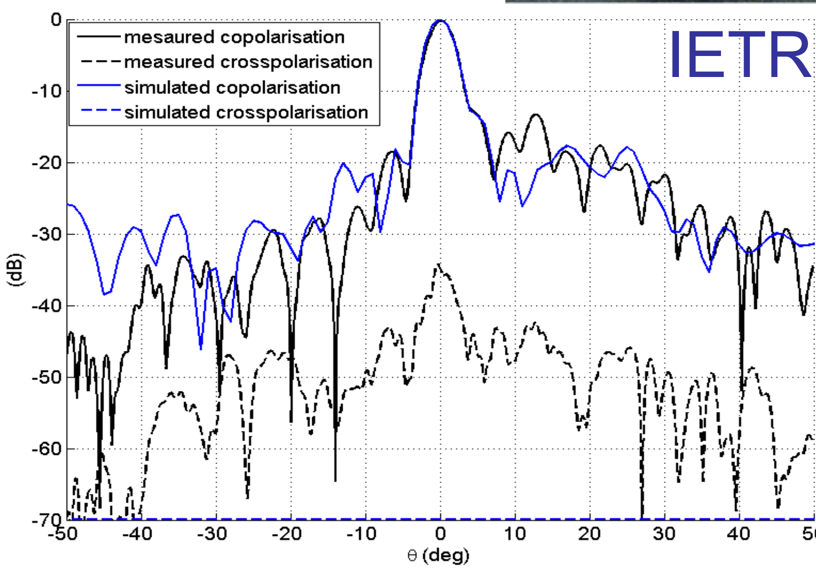
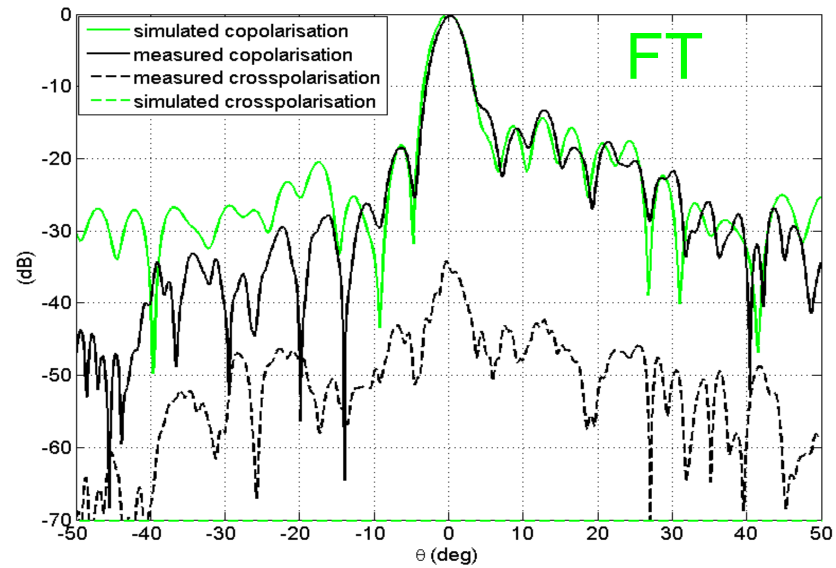


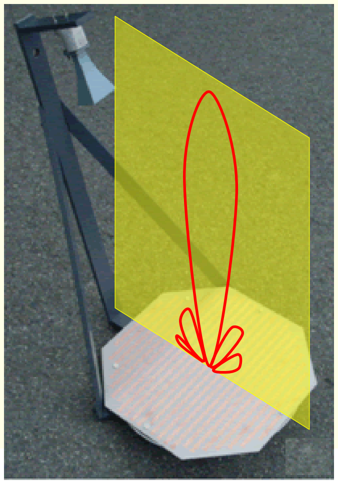






13 GHz, E plane

IETR and FT



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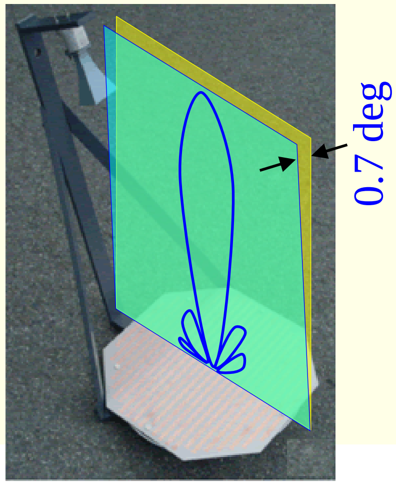
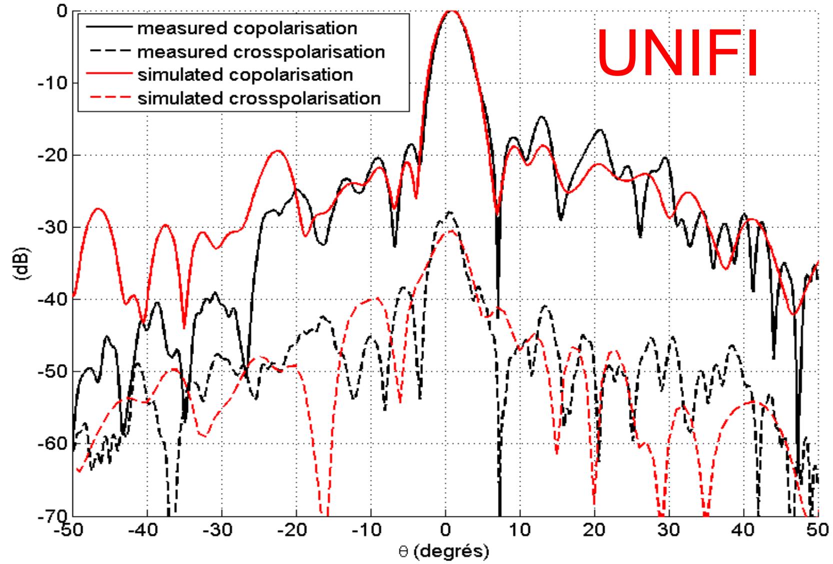
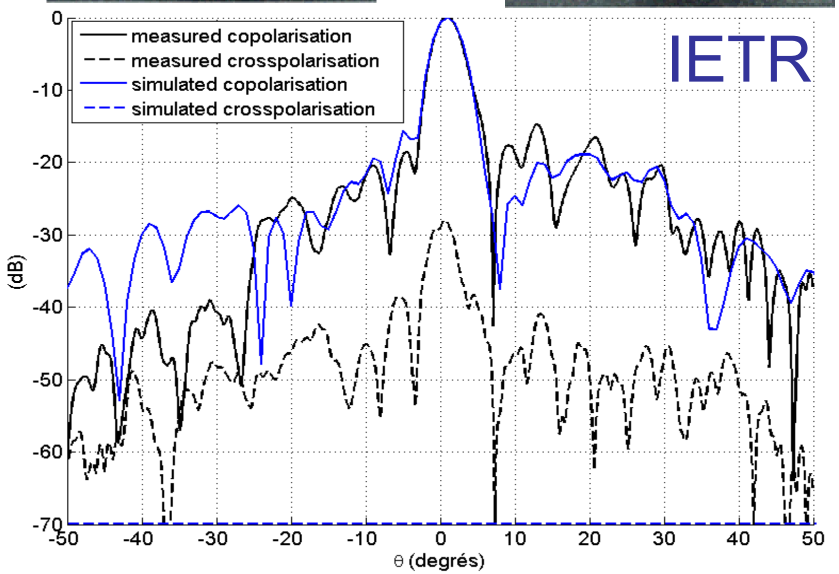
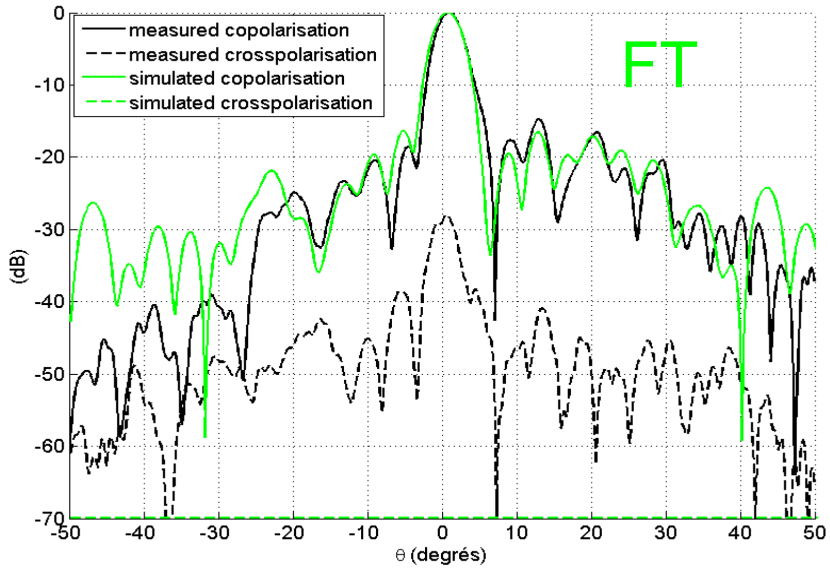




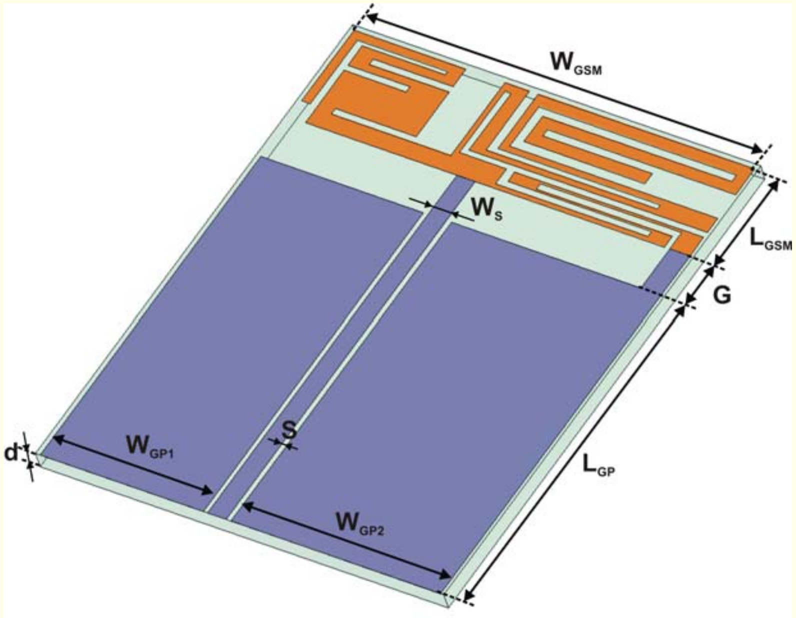




- Challenging test-case
- Very good performance for MR-MoM software
- 3D software tools more time consuming but can handle actual 3D structures (finite substrate, horn, …)

Antenna configuration

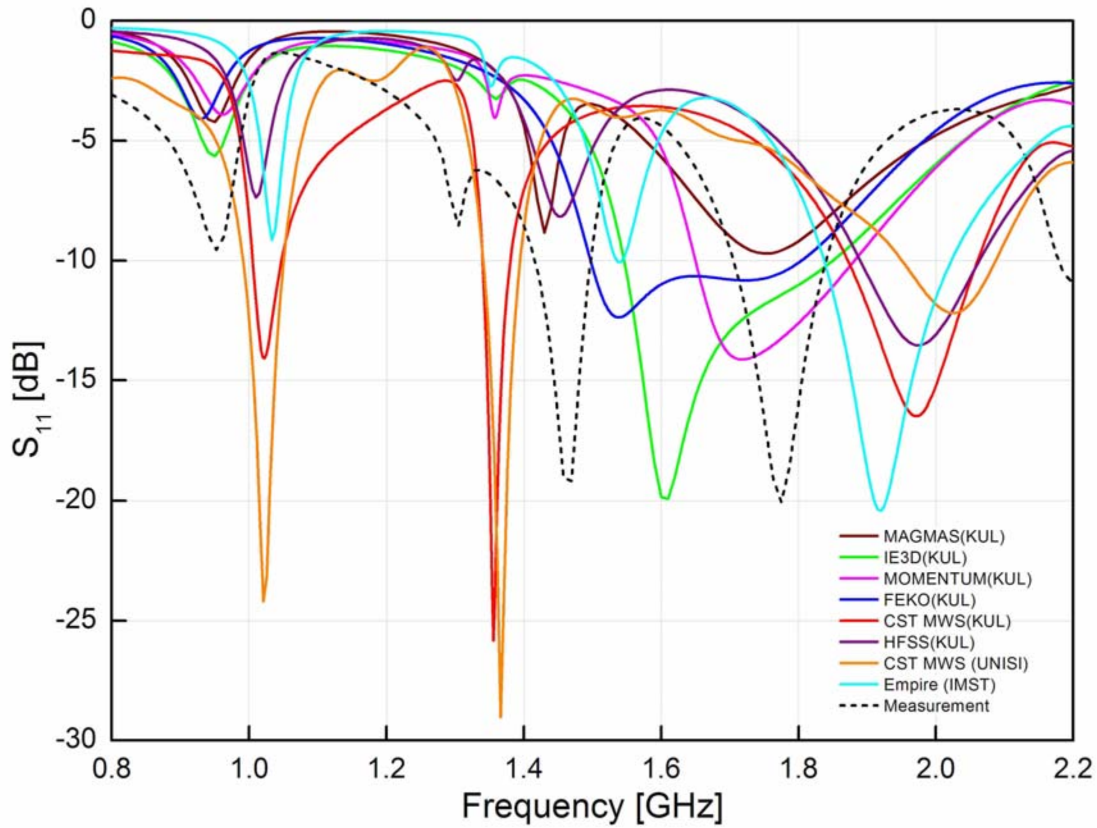
- Commercial RangeStar UltimaTM 'World GSM antenna'
- 3 GSM frequency bands
- FR4 substrate (εg = 4.4, tanδ=0.02, d = 1.57 mm)
- Finite dimensions (37.6 x 46.275 mm^2)
- Coplanar feeding line



WGSM x LGSM =36.88 x 9.42 mm^2
WGP1 x LGP =15.2 x 32.2 mm^2
WGP1 x LGP =19.541 x 32.2 mm^2
S = 0.218 mm
Ws = 1.7 mm G = 2.2 mm

❑ Participants and methods

- ➢ KUL (University of Leuven – Belgium)
- ➢ IMST (Germany)
- ➢ UNISI (University of Sienna, Italy)



- ➢ Large dispersion
- ➢ Checked by vendors

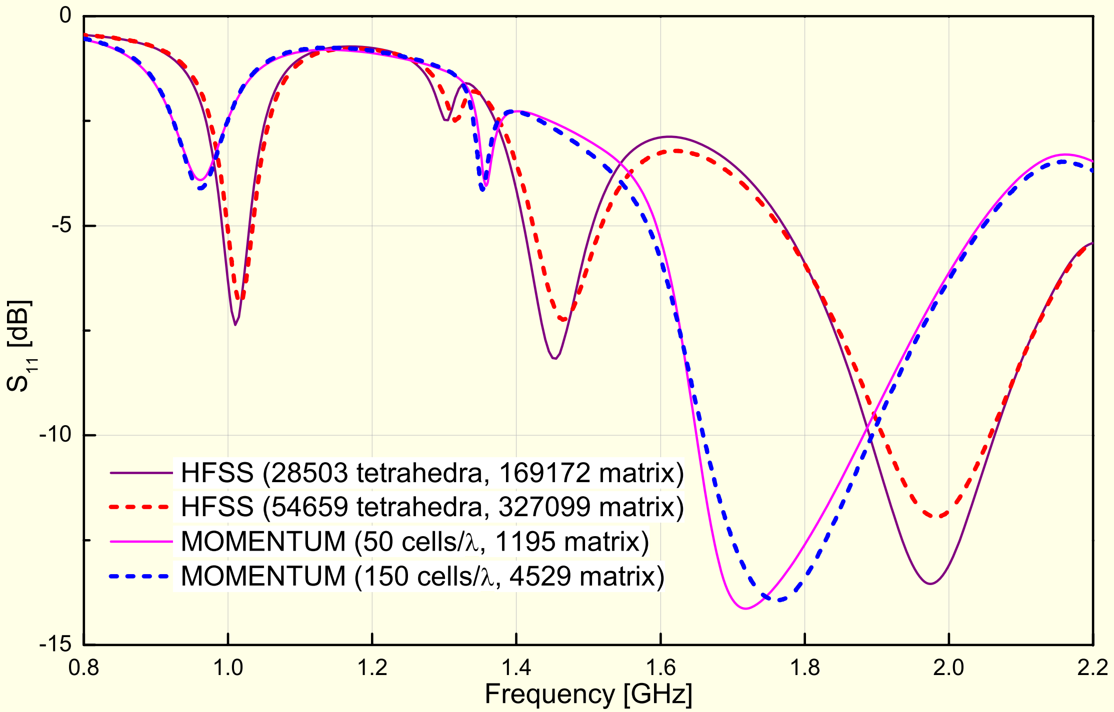
Computer requirements

	MAGMAS(1)	IE3D(2)	FEKO	Momentum	CST	HFSS
Unknowns	6076	740	3879	1195	1724225	169172
CPU time /freq (sec)	367	5	433	15.2	_	126
Total CPU time (sec)	26077	76	6062	350	5664	2144

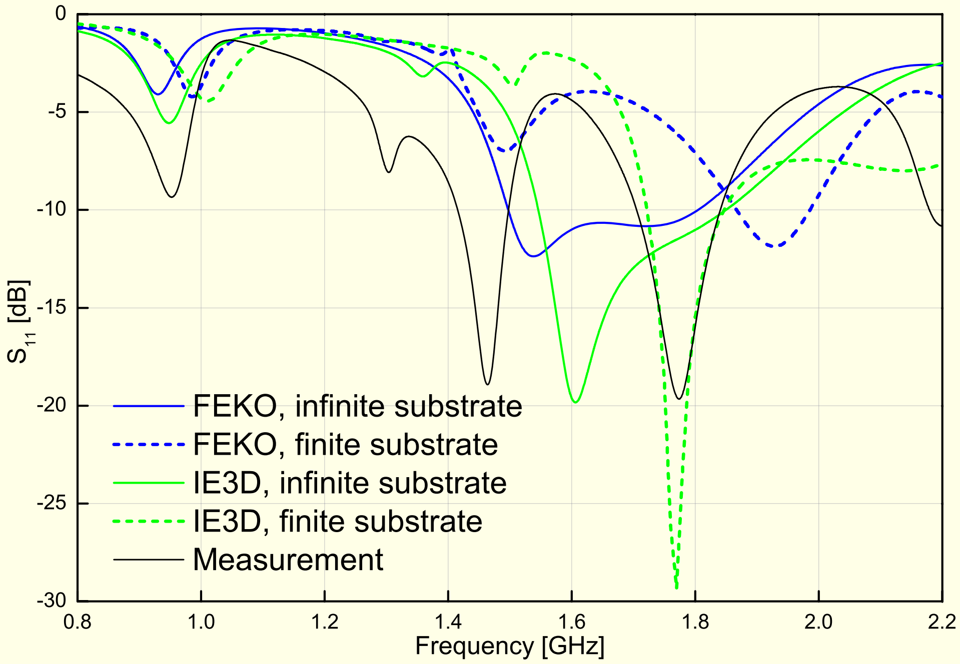
(1) Large number of unknowns as the reference
(2) With a specific "solver version" dedicated to the specific Win64 architecture of the processor used provided by the Zeland company

Software package	CPU type	RAM
MAGMAS 3D	Intel Xeon ™ 2.66 GHz	2 Gb
IE3D ver. 12.22	Intel Xeon ™ 2.8 GHz	4 Gb
FEKO Suite 5.3	AMD Athlon ™ 64 3800+	3.5 Gb
ADS 2006A.400 Momentum	2 x AMD Opteron ™ 250 (2.4 GHz) 64 bit	4 Gb
CST MWS 2006B.03	Intel Xeon ™ 2.8 GHz	4 Gb
Ansoft HFSS ver. 10.1	2 x Dual-Core AMD Opteron ™ 285 (2.6 GHz) 64 bit	8 Gb
Empire XCcel	2 x Intel Xeon ™ 5472 3 GHz	4 Gb

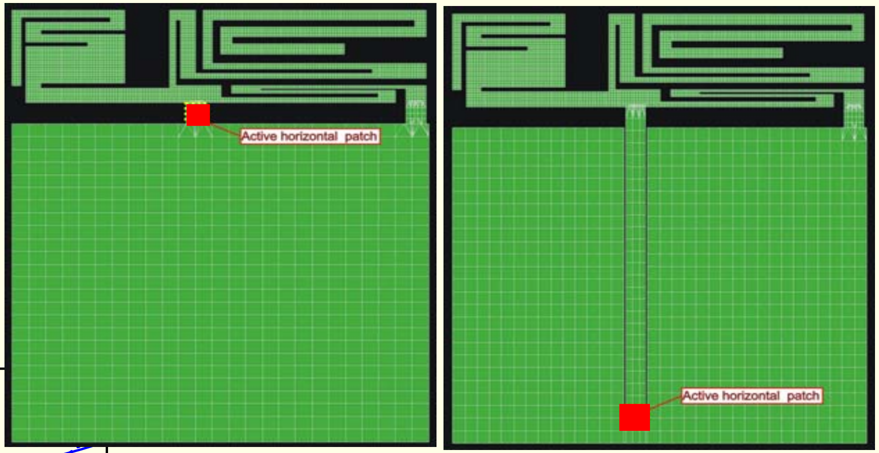
❑ Effect of meshing



❑ Effect of finite substrate

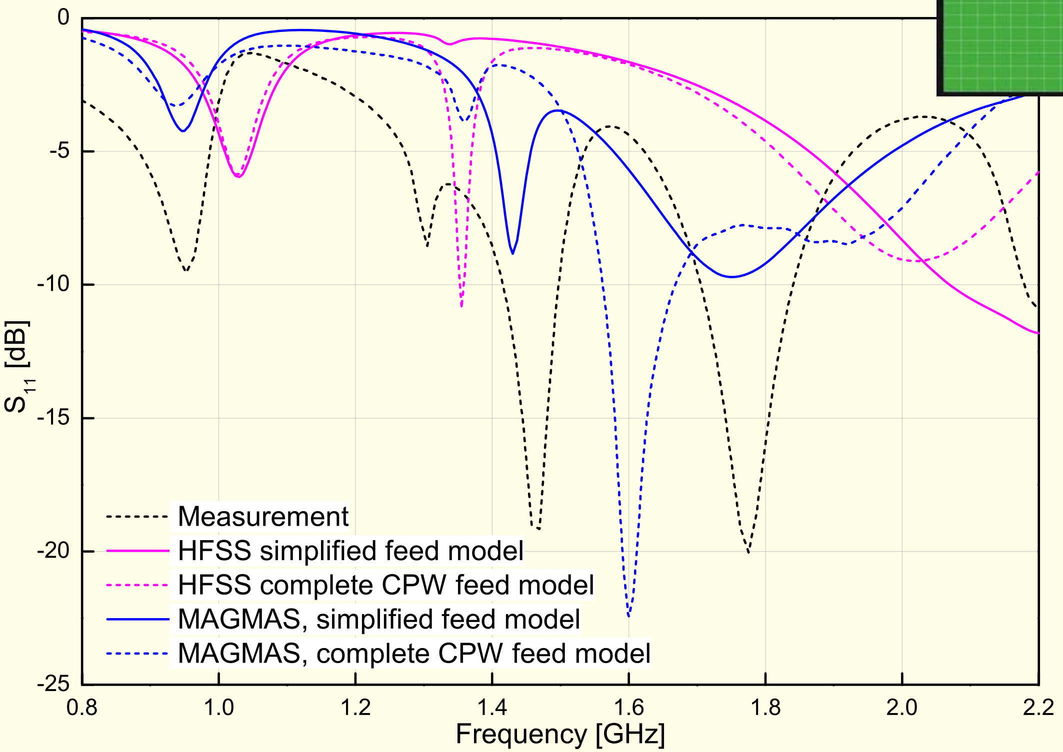


❑ Effect of feed modelling (1/2)

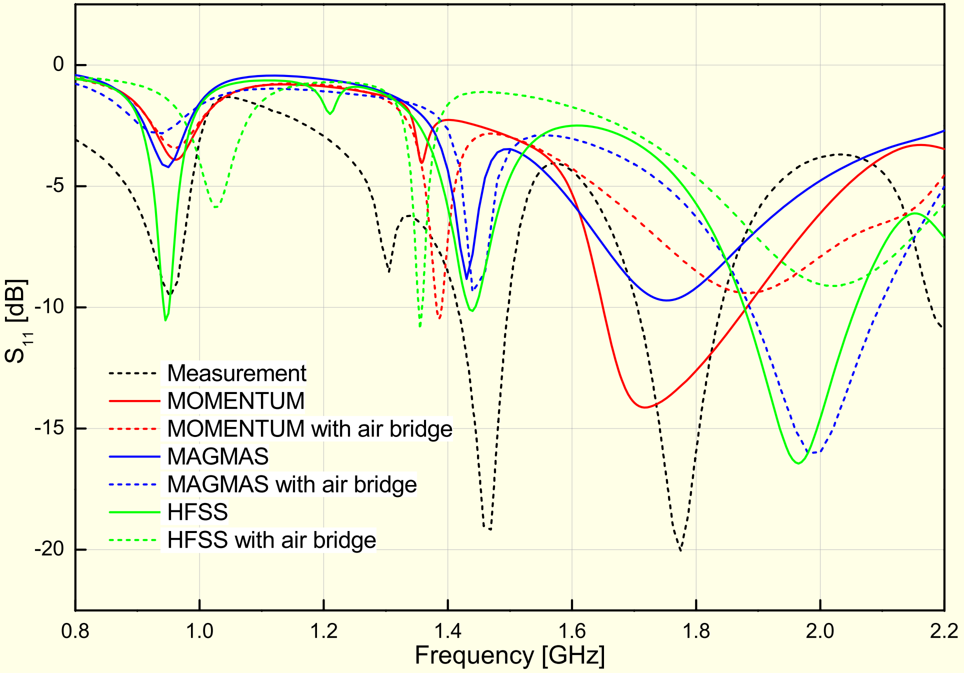


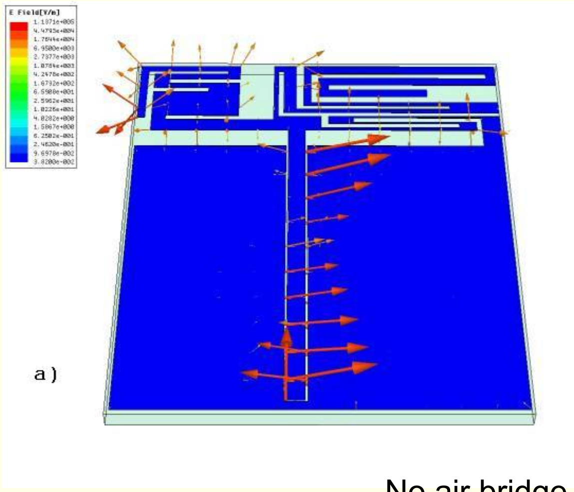
Simplified model

Complete CPW model

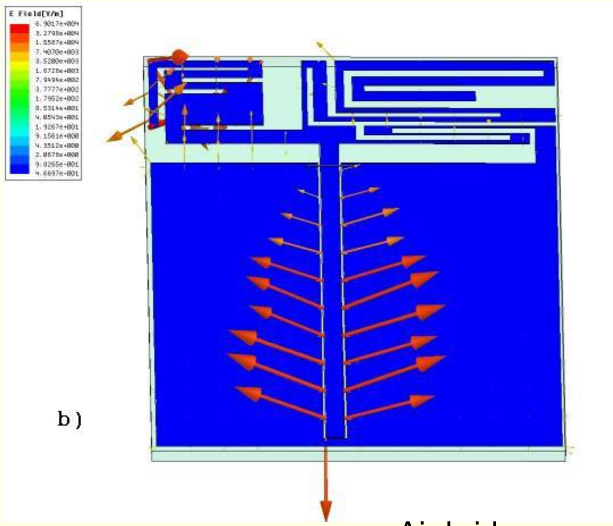


❑ Effect of feed modelling (2/2)





No air bridge



Air bridge

- Challenging test-case
- Importance of accurate feed modelling
- Importance of finiteness

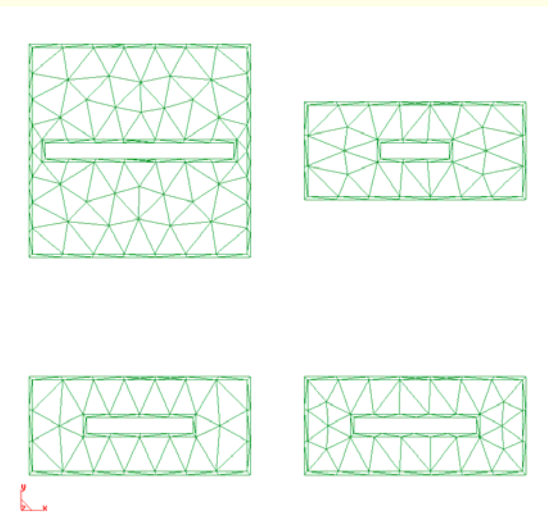
- SoftLAB is open to all EurAAP members
- Run #5 is expected soon
- A call for benchmark test-cases will be launched
- Feel free to submit your challenging antenna test-cases!

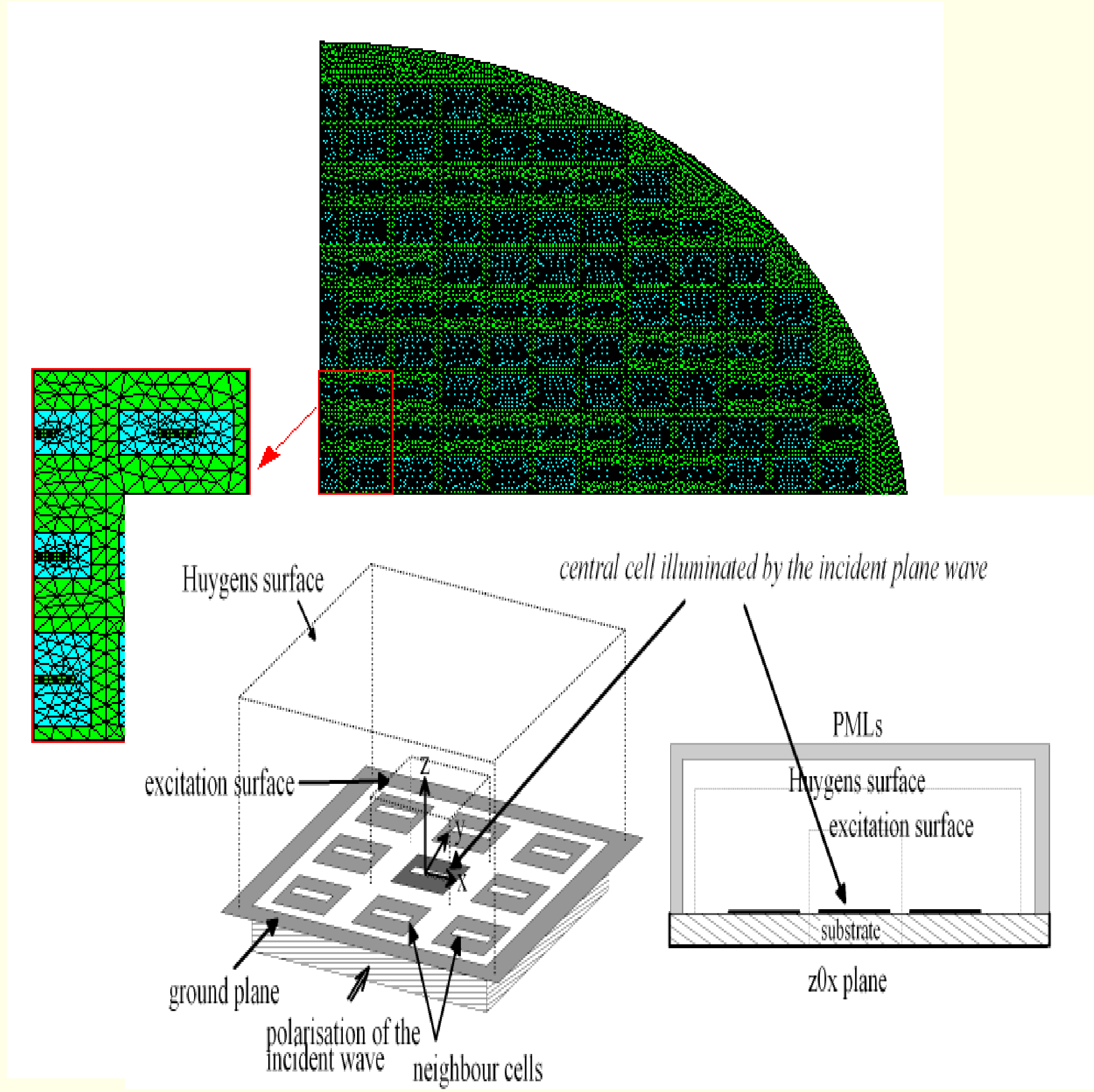
Software Package	2nd resonance					
	Fmin (GHz)	Fmax (GHz)	Fc (GHz)	Fc-shift (%)	BW (GHz)	FcD2 (%)
MAGMAS	1.404	1.457	1.431	1.96	0.053	0.53
IE3D	NA	NA	NA	NA	NA	NA
FEKO	NA	NA	NA	NA	NA	NA
MOMENTUM	NA	NA	NA	NA	NA	NA
HFSS	1.41	1.505	1.458	3.88	0.095	2.42
CST MWS	1.325	1.437	1.381	-1.57	0.112	-2.95
Measurement	1.271	1.535	1.403	0.0	0.264	-1.41

Software Package	3rd resonance					
	Fmin (GHz)	Fmax (GHz)	Fc (GHz)	Fc-shift (%)	BW (GHz)	FcD3 (%)
MAGMAS	1.577	1.986	1.782	0.39	0.409	-2.75
IE3D	1.493	2.04	1.767	-0.45	0.547	-3.57
FEKO	1.44	1.982	1.711	-3.58	0.542	-6.6
MOMENTUM	1.596	2.033	1.815	2.25	0.437	-0.95
HFSS	1.77	2.19	1.98	11.58	0.42	8.09
CST MWS	1.737	2.138	1.938	9.19	0.401	5.77
Measurement	1.622	1.927	1.775	0.0	0.305	-3.13

Table 4: Nominal frequency values for GSM antenna at -5 dB power level

Software Package	1st resonance					
	Fmin (GHz)	Fmax (GHz)	Fc (GHz)	Fc-shift (%)	BW (GHz)	FcD1 (%)
MAGMAS	NA	NA	NA	NA	NA	NA
IE3D	0.932	0.963	0.948	1.45	0.031	-5.80
FEKO	NA	NA	NA	NA	NA	NA
MOMENTUM	NA	NA	NA	NA	NA	NA
HFSS	0.99	1.029	1.01	8.08	0.039	0.36
CST MWS	0.986	1.135	1.061	13.54	0.149	5.43
Measurement	0.882	0.986	0.934	0.0	0.104	-7.14




Huygens surface
central cell illuminated by the incident plane wave
excitation surface
ground plane
polarisation of the incident wave
neighbour cells
PMLs
Huygens surface
excitation surface
substrate
z0x plane

many bends = coupling among the two monopoles. FR4 substrate = high loss tangent = differences in loss modeling

commercialRangeStar UltimaTM ‘World GSM antenna’
three GSM frequency bands
2.5:1 VSWR in the frequency bands 880–960 MHz and 1710–1990 MHz.
FR4 substrate $\varepsilon g = 4.4$ and $\tan\delta=0.02$.
ground plane and coplanar feeding line
PCB outer dimensions 37.6 x 46.275 mm2
substrate thickness is d = 1.57 mm
antenna outer dimensions 36.88 x 9.42 mm2 (WGSM x LGSM)
(15.2 x 32.2 mm2 (WGP1 x LGP) for GP1
19.541 x 32.2 mm2 (WGP2 x LGP) for GP2
with S = 0.218 mm
Ws = 1.7 mm width
The left-hand part is a short monopole resonates in the upper frequency band, the right-hand part is longer and resonates in the lower frequency band. On the lower right of the antenna there is a little short circuit to match the antenna to a 50 Ω feed.
the feed gap G = 2.2 mm.

It is seen that the curves of all MoM-based solvers agree quite well for the lower resonance. FEKO outlines the middle resonance dissimilar to other solvers, completely merging it with the higher resonance. Among the IE-based software packages, the -5 dB power level in the lower GSM band (900 MHz) was attained by IE3D only (Table 4). In case the -5 dB criterium was not reached NA is used in Table 4. The volumetric mesh refinement available in CST MWS and Ansoft HFSS helped to uncover the low band resonance. HFSS like CST MWS shows a resonance shift to higher frequencies.

The fabricated structure has a coax to coplanar waveguide transition and utilizes the right-angle SMA connector (R125680000 by Radial®) in the measurement setup. Such a feeding setup inevitably induces unwanted parasitics, which affect the characteristics of the antenna.

It has to be emphasized that only in the Empire simulation the connector feeding the fabricated structure was modeled in more detail. There a coaxial feed model was used similar to this connector. The concentrated port impedance of this coaxial feed was set to 50 Ω. The other simulations used the implemented feeding techniques embedded within the solvers, which is the standard practice in most designs reported in literature. These simulations with Empire showed that ***the connector feeding the antenna has a strong influence on the results***.

If the mere presence of the connector indeed alters the results beyond expectation for this type of complicated antenna, this means that it has to be taken into account always in the analysis. This is not possible up to now with the IE solvers and would lead to much larger calculation times for HFSS and CST. Even the slightest difference between the feed model defined by software user and the actual setup can lead to radical differences in results [66].

Two different feed models were studied in MAGMAS (Fig. 15). Both of them apply the horizontal current source, which consist of a user-defined electric current imposed on a so called active patch. The first topology has the active patch placed between the antenna feeding point and its ground plane (Fig. 14a). The second topology fully models the CPW feed with the active patch set on the actual feeding point of the SMA connector in the measurements setup (Fig.14b). Simulated S11 results highlight the substantial importance of the feed modeling (Fig. 15).

Excitation of the slotline mode in the CPW

The ground planes on the test PCB are connected only at the side of the SMA connector. Inevitably, the slotline mode will appear along with the coplanar mode at the antenna side. The vector E-field plot in Fig. 16a obviously shows the asymmetric slotline mode dominantly launched by a lumped port in HFSS, whereas the use of the air bridge in Fig. 16b suppresses the parasitic slotline mode and gives rise to the symmetric CPW mode. Does this contribute to the observed discrepancy? In theory, it should not. The reason is that as long as a unique and identical topology is inserted in several solvers, the user has the theoretical right to expect identical output. However, it is a fact that the presented EM solvers use different theoretical techniques to derive the scattering parameters of CPW fed structures. It is clear that this may considerably contribute to the simulation results diversity. This is also clearly confirmed by simulations, which exhibit a significant difference when the transversal air bridge is added at the end of the CPW line (Fig. 17). The air bridge was modeled as a bond wire whose ends were soldered to both ground planes in order to equalize their potentials. The position and length of the bond wires have a big influence on the resonant frequency of the two lowest resonances. Normally, the power leaking to the slotline mode can be identified as the main contribution to the losses of the CPW feeding line [64].