

Best practises:

Antenna Software and Measurements

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(with input from ACE activity on measurements)

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The basic questions ...

- ✓ What do we have ?
- ✓ How good is it ?
- ✓ How can we make it better ?

both for antenna software
and antenna measurements



- *to give an overview of what has been reached within the framework of the ACE Network of Excellence*
 - *How did we tackle those questions ?*
- *to make you think, here and now, how you can make use of this, how WE can serve YOUR needs ...*
- *to look how we can continue from here ...*

Software

Who are we ?

software

No.	Full name	Short name	Country
Activity Leaders			
2	Katholieke Universiteit Leuven	KUL	Belgium
13	Institut National des Sciences Appliquées de Rennes	IETR	France
Participants			
1	IDS Ingegneria dei Sistemi Spa	IDS	Italy
2	Katholieke Universiteit Leuven	KUL	Belgium
4	TICRA Fond	TICRA	Denmark
8	France Telecom R&D	FT R&D	France
10	Thales Airborne Systems	TAS	France
12	Centre National de la Recherche Scientifique	CNRS-LEAT	France
13	Institut National des Sciences Appliquées de Rennes	IETR	France
16	IMST GmbH	IMST	Germany
18	Institute of Communication and Computer Systems of the National Technical University of Athens	ICCS/NTUA	Greece
19	Università degli Studi di Roma "La Sapienza"	SAPIENZA	Italy
20	Polytecnico di Torino	POLITO	Italy
22	Università degli Studi di Firenze	UNIFI	Italy
23	Università degli Studi di Siena	UNISI	Italy
26	Universitat Politècnica de Catalunya	UPC	Spain
27	Universidad Politécnica de Madrid	UPM	Spain
28	Universitat Politècnica de Valencia	UPV	Spain
29	Chalmers Tekniska Högskolan	CHALMERS	Sweden
31	Swedish Defence Research Agency	FOI	Sweden
35	École Polytechnique Fédérale de Lausanne	EPFL	Switzerland
39	University of Bristol	UOB	UK
40	The University of Liverpool	LIVUNI	UK

Question 1: What software do we have ?

● *Inventory !!!*

– standardized and detailed description of software tools available on the VCE

» ACE partners

» non-ACE, research

» commercial solvers

Question 2: How good is this software ?

● *benchmarking !!!*

– standardized and detailed procedure for benchmarking

» ACE partners

» non-ACE, research

» commercial solvers

● first run

- elements, open
- 14 partners, 18 tools, 36 simulations

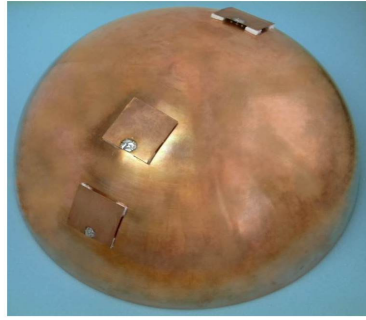
● second run

- finite arrays, blind
- 8 structures, 14 partners + 2 vendors, 17 tools, 28 simulations

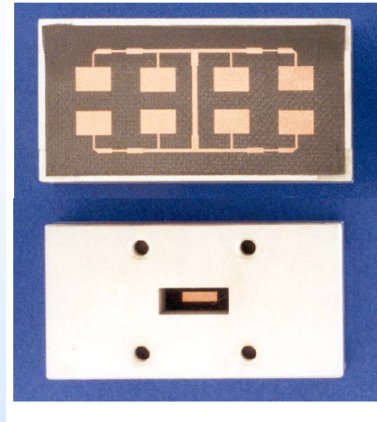
● third run

- environment
- 5 structures

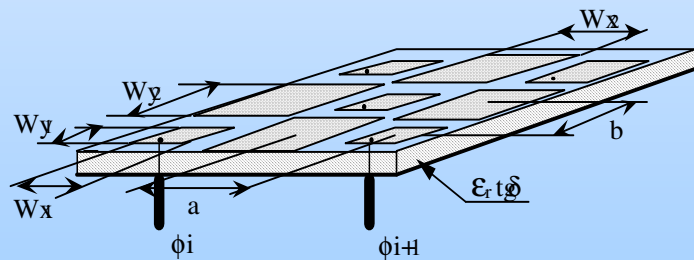
Selected test-cases(1/2)



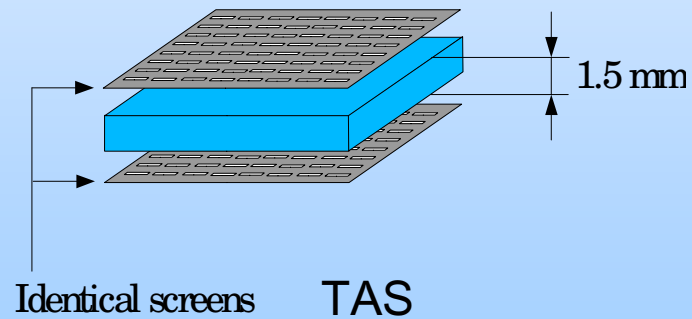
ZAGREB



IMST



CNRS-LEAT



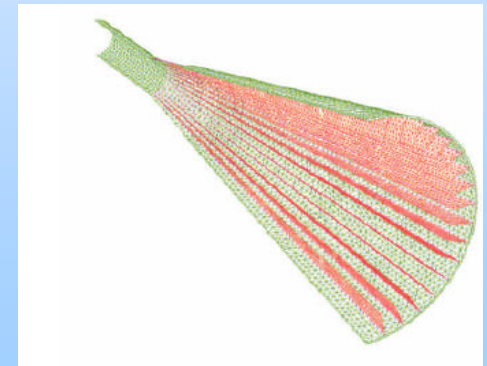
Identical screens TAS

Array structures

Link with A1.2

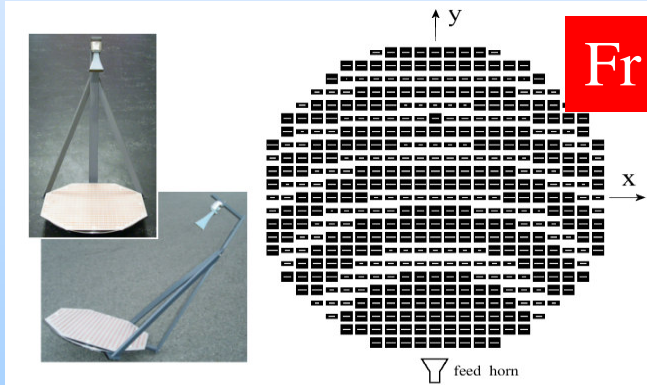


CHALMERS



FT R&D

- ✓ Challenging reflectarray structures (more than 4000 radiating patches for UPM structure)
- ✓ Multilevel approaches are used

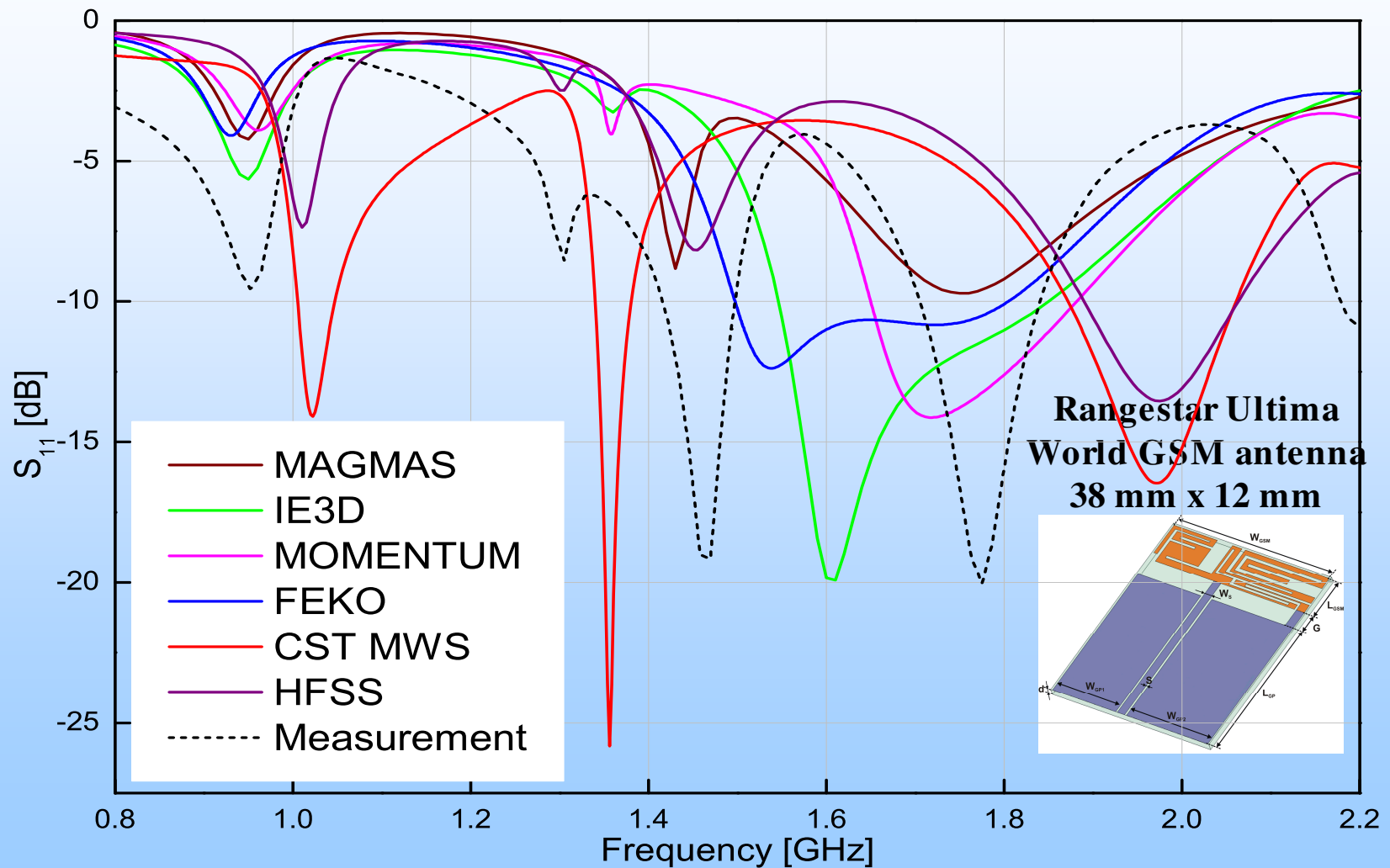


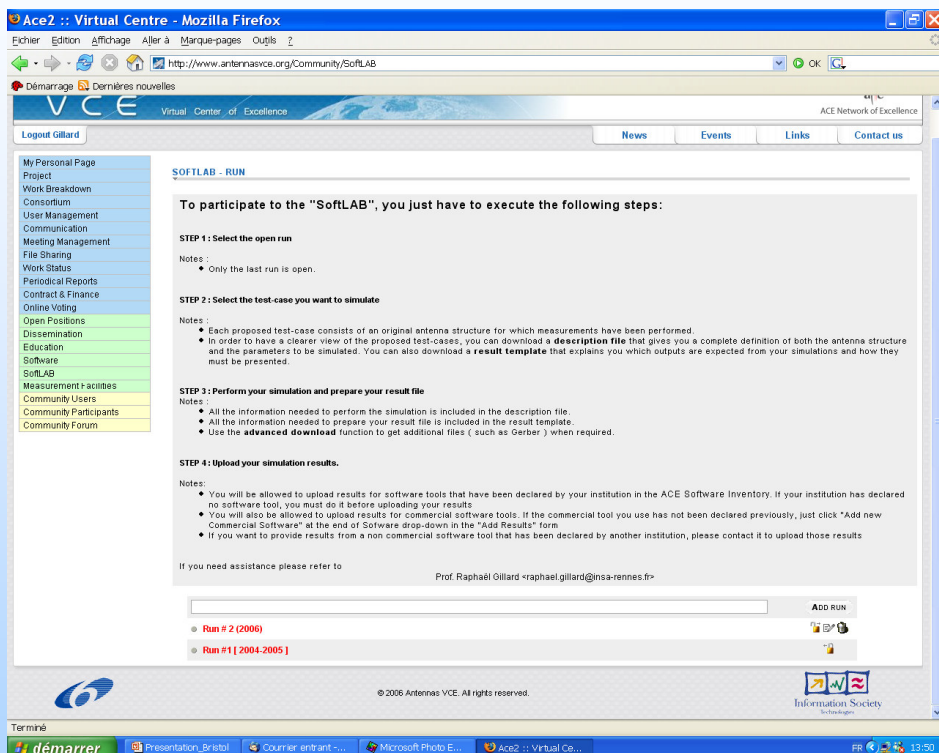
IETR/ALCATEL

From A2.4

UPM

Where do we stand ...





✓ Online service for benchmarking within VCE

✓ Open to anyone in the antenna community

✓ Possibility to see benchmark results and to participate in

- *duration = 1 year*
- *organized around EuCAP, first meeting was last Tuesday*
- *procedure:*
 - *partners propose through SOFTLAB*
 - *software WG meeting at EuCAP (inaugural meeting 24/03/09)*
 - *democratic selection process (4 structures were selected)*
 - *analysis of structure by partners*
 - *reports are uploaded to SOFTLAB*
 - *discussion of results at next meeting*
 - *each structure = paper proposal in session of software WG*

alle *Question 3: how can we make better software ?*

Is it this what we are doing ?

● *Cylindrical structure: (z, φ, r)*

$$E_z(r, \varphi, z) = \iint_{z' \varphi'} K_z^e(\varphi', z') \cdot G_z^{E, K, e} d\varphi' \cdot dz' + \frac{d}{dz} \iint_{z' \varphi'} (\vec{\nabla}_t \vec{K}^e) \cdot G_z^{E, \sigma, e} d\varphi' \cdot dz'$$

$$E_\varphi(r, \varphi, z) = \iint_{z' \varphi'} K_\varphi^e(\varphi', z') \cdot G_\varphi^{E, K, e} d\varphi' \cdot dz' + \frac{1}{r} \frac{d}{d\varphi} \iint_{z' \varphi'} (\vec{\nabla}_t \vec{K}^e) \cdot G_\varphi^{E, \sigma, e} d\varphi' \cdot dz'$$

$$G(z - z', \varphi - \varphi')$$

functions of 2 variables

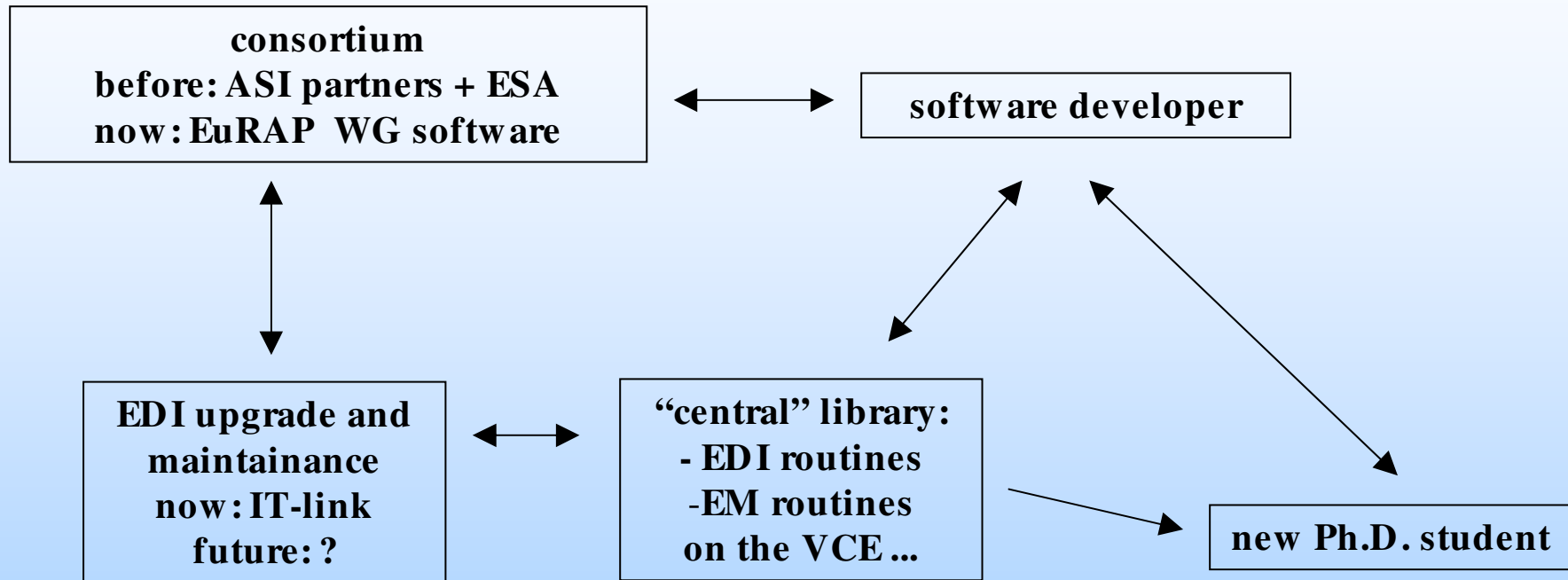
No, not at all ... it is this:

NOW:

- *use of commercial monolithic software tools*
- *software development at a research level*
 - *only exchange of scientific information*
 - *no standardized exchange of software routines*

This is a waste of effort, time, ... and thus money

- *the new Ph.D. student ...*
- *low efficiency ... few users ...*



**ACE has provided the means to start-up this process and
to lay the technical foundations
EurAAP has the duty to continue this effort**

- *EDI (Electromagnetic Data Interface)*
 - *definition DD/EDI*
 - *implementation EDI*
 - *testing EDI*
 - *EDI in software*
- *integration projects: integration of software coming from different partners*
 - *multiresolution*
 - *large and infinite arrays*
 - » *periodic Green's functions*
 - » *large systems of equations*
 - *large reflector antennas*
 - *IE-FEM using modes*

- *The Electromagnetic Data Interface (EDI)*

- *6 Data Dictionaries (DD) completed*

- » *near fields, far fields, currents and meshes: full agreement in a wider European group of partners, not only ACE*
 - » *Green's functions, modes: agreement at ACE level*
 - » *S-parameters: easiest, already some "standardization"*

- *EDI routines implemented for 3 DDs in Matlab, Fortran, and C*

- *implementation inside software of 10 ASI partners*

- *establishment of the EDX working group*

- *European library of routines*

- *through integration projects between partners*

- *new analysis schemes: SIG on Structures and Structuring:*

- » *based on available library*

- *PROBLEM: at this moment: **DISTRIBUTED LIBRARY***

- **an already committed group**
 - (KUL, IDS, SATIMO, THALES, TICRA) + (ERICSSON + ESA-ESTEC + IT-Link)
 - open for other partners
- **plan organized around 4 topics will be implemented**
 - short term evolution: TICRA
 - standardization: SATIMO
 - user community: KUL
 - long-term management: IDS
- **two meetings**
 - Noordwijk, October 2008: kick-off (under the ACE umbrella)
 - Rome, February 2008: first technical meeting
 - Berlin, March 2009: first meeting under EuRAAP umbrella

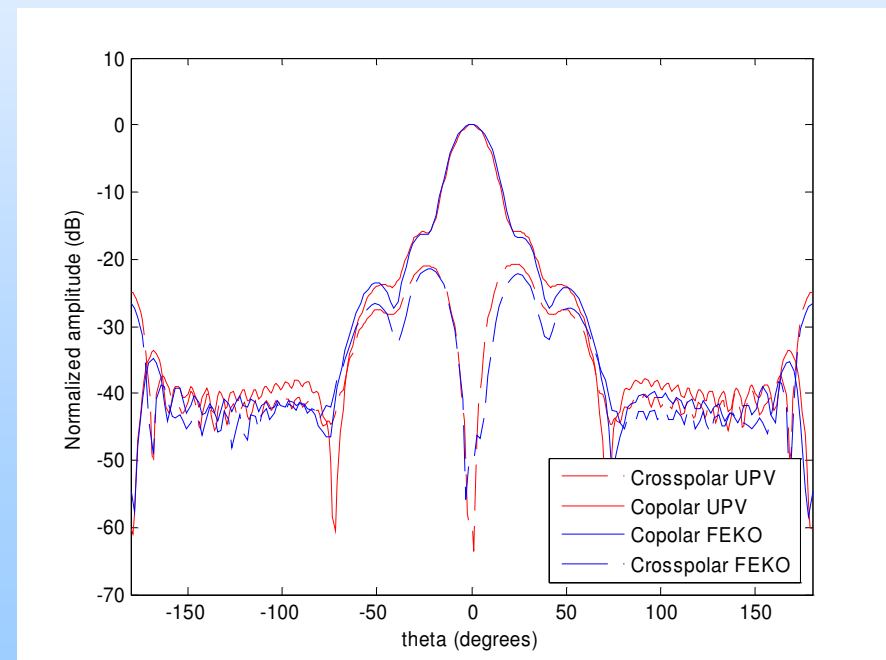
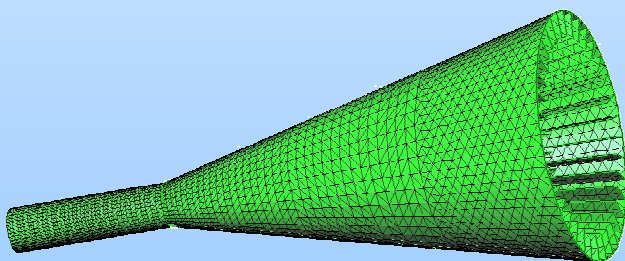
a||e *Large systems of equations (UPC – KUL – UPM – UPV)*

- *MoM problem with $N \approx 70,000$ unknowns (without symmetries)*

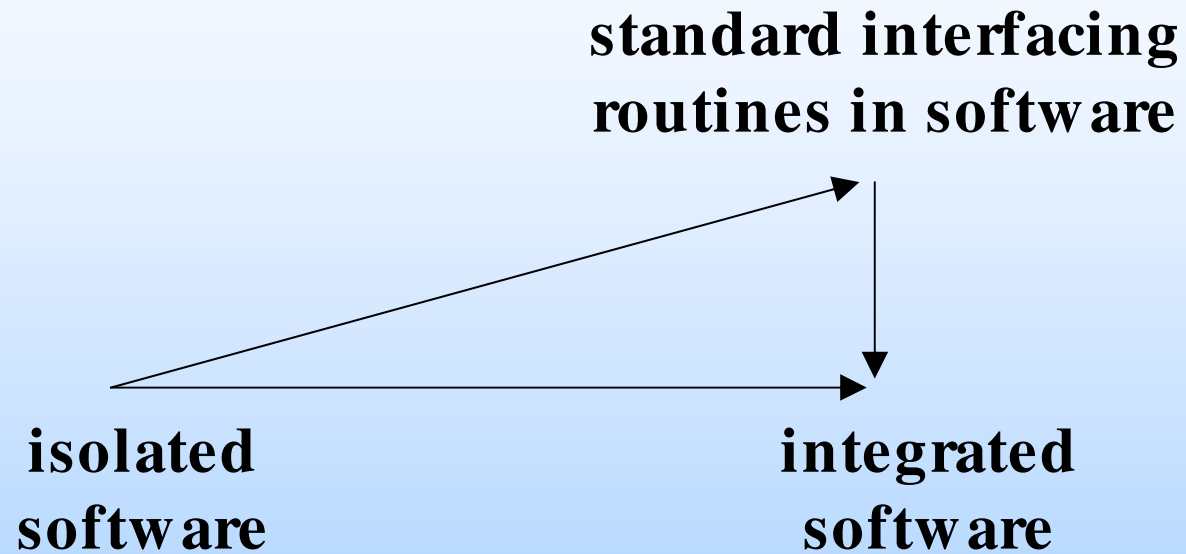
<i>Solver</i>	<i>CPU time</i>	<i>Error in J</i>	<i>CPU</i>	<i>Mem</i>
<i>Solver 1: HD-BLU (direct)</i>	<i>150h (extrapolated)</i>	<i>0%</i>	N^3	N^2
<i>Solver 2: EFIE-TM 2D CBLU (direct)</i>	<i>1h 35min</i>	<i>0.0011%</i>	N^2	$N^{3/2}$
<i>Solver 3: EFIE 3D MDA-SVD (direct)</i>	<i>1h 33min</i>	<i>1.3%</i>	N^2	$N^{3/2}$
<i>Solver 3: EFIE 3D MDA-SVD (iterative)</i>	<i>16min 20sec Planar: 7min</i>	<i>2.0% Planar: 0.1%</i>	$N \log N$ <i>x it</i>	$N \log N$ <i>x it</i>
<i>For comparison: MLFMA (iterative)</i>	<i>17min 22sec</i>	<i>7.2%</i>	$N \log N$ <i>x it</i>	$N \log N$ <i>x it</i>

AMD Opteron CPU at 2.2 GHz (MATLAB single threaded) with 8GB RAM

integration of UPC solver in codes of other partners



Triangle of effort



Conclusions

- *ASI has given the European antenna software community an identity, a profiled structure where things can be discussed ...*
- *ASI has initiated a software harmonization and standardization process within Europe*
- *ASI has intensified considerably the interaction in between universities, and between universities and industry*
- *ASI has produced a considerable number of cooperative publications and has triggered a lot of bilateral cooperations*

DOW: Task 2.1 Software Best Practices

- Collection of the current requirements in vehicles communication software
- Distribution of the current Electromagnetic Data Interface software library to the automotive industries and related research centres.
- Implementation of the antenna software interfaces in complex simulation of vehicles communication.

1. What antenna software is used in the automotive industry ?
 - in-house developed or commercial ?
2. What are the challenges there at the moment ?
 - presence of complicated environment ...
 - size of the problem and computation speed ...
 - ...
3. How does it interact with other software ?
 - structural analysis: geometry description
4. ...

Possible actions ...

- *upgrade of inventory*
- *inclusion of benchmarking structures from automotive industry*
- *incorporation of EDI within software used in automotive industry*
- *set up list of modeling needs typical for automotive industry*
- ...

Measurements

Who are we ?

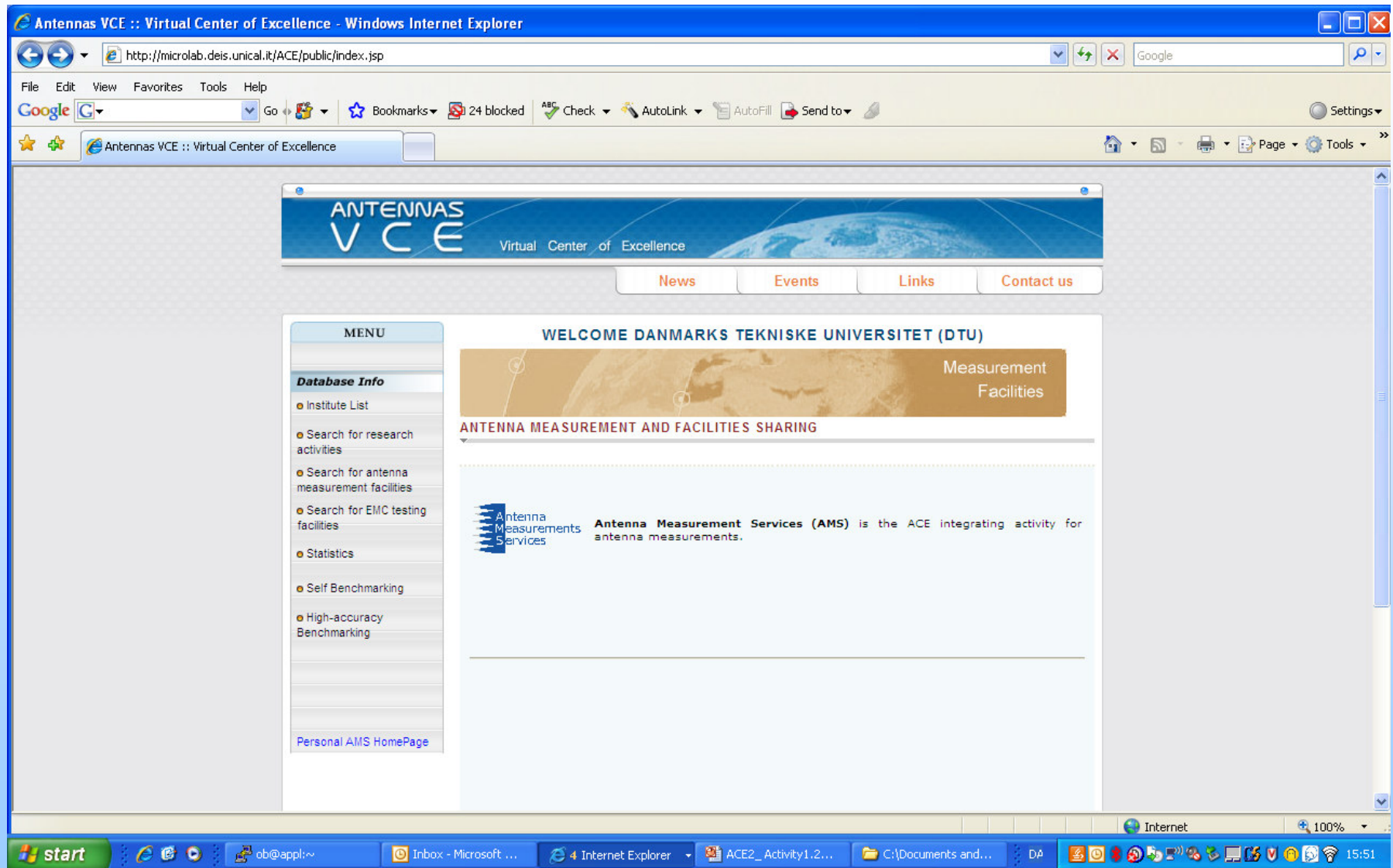
measurements

17 ACE Partners

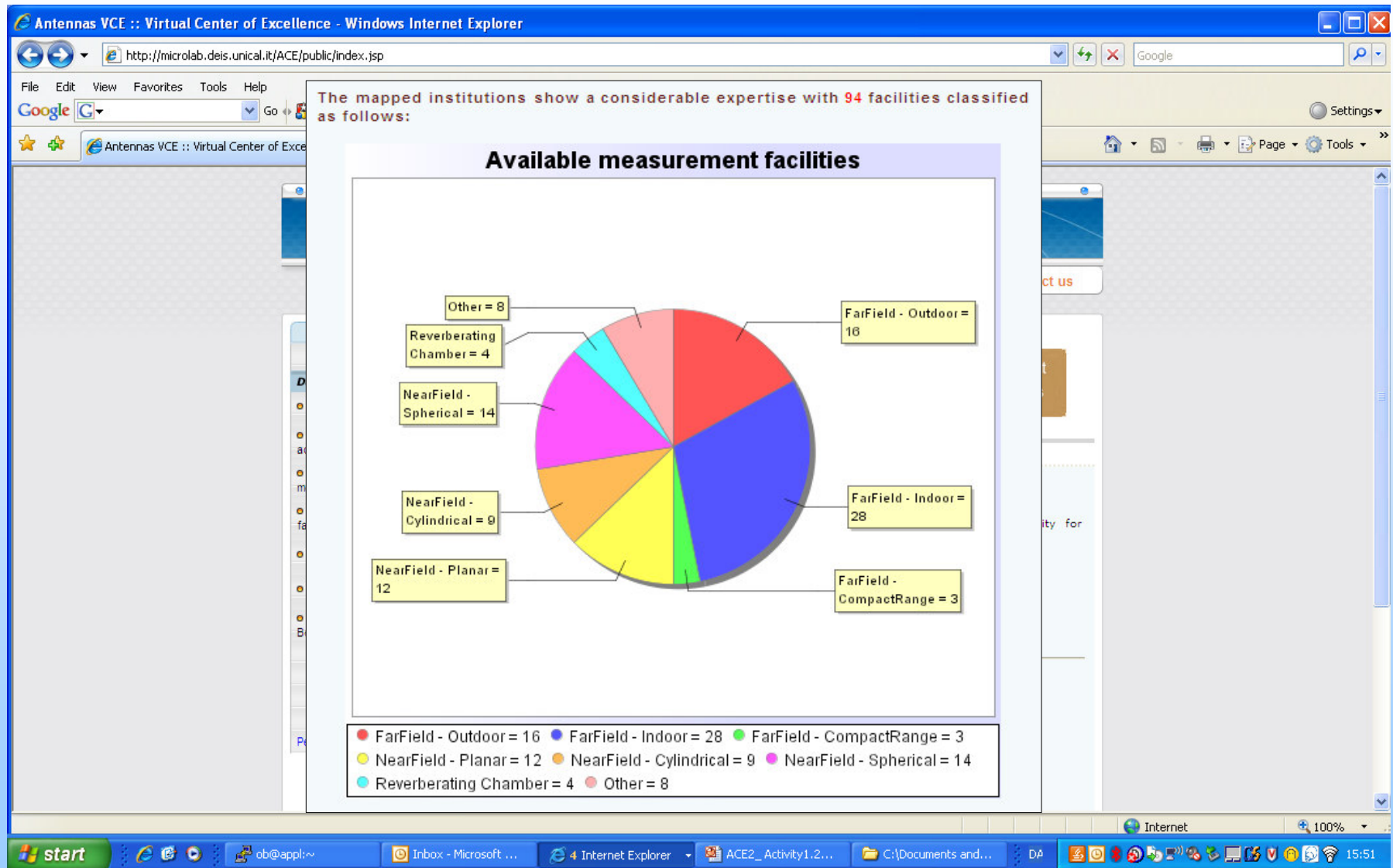
- | | | |
|---------------|-----------------|--------------|
| • DTU | • <i>LIVUNI</i> | • UNICAS |
| • EMW | • NSCRD | • UNIOVI |
| • FTRD | • <i>SATIMO</i> | • <i>UPC</i> |
| • HUT | • SES | • <i>UPM</i> |
| • <i>IETR</i> | • <i>TICRA</i> | • TUD |
| • <i>IMST</i> | • UNICAL | • WUT |



Question 1: What infrastructure do we have ?



Question 1: What infrastructure do we have ?



- offered to the Antenna Community
- through the ACE Virtual Center of Excellence

Question 2: How good are they ?

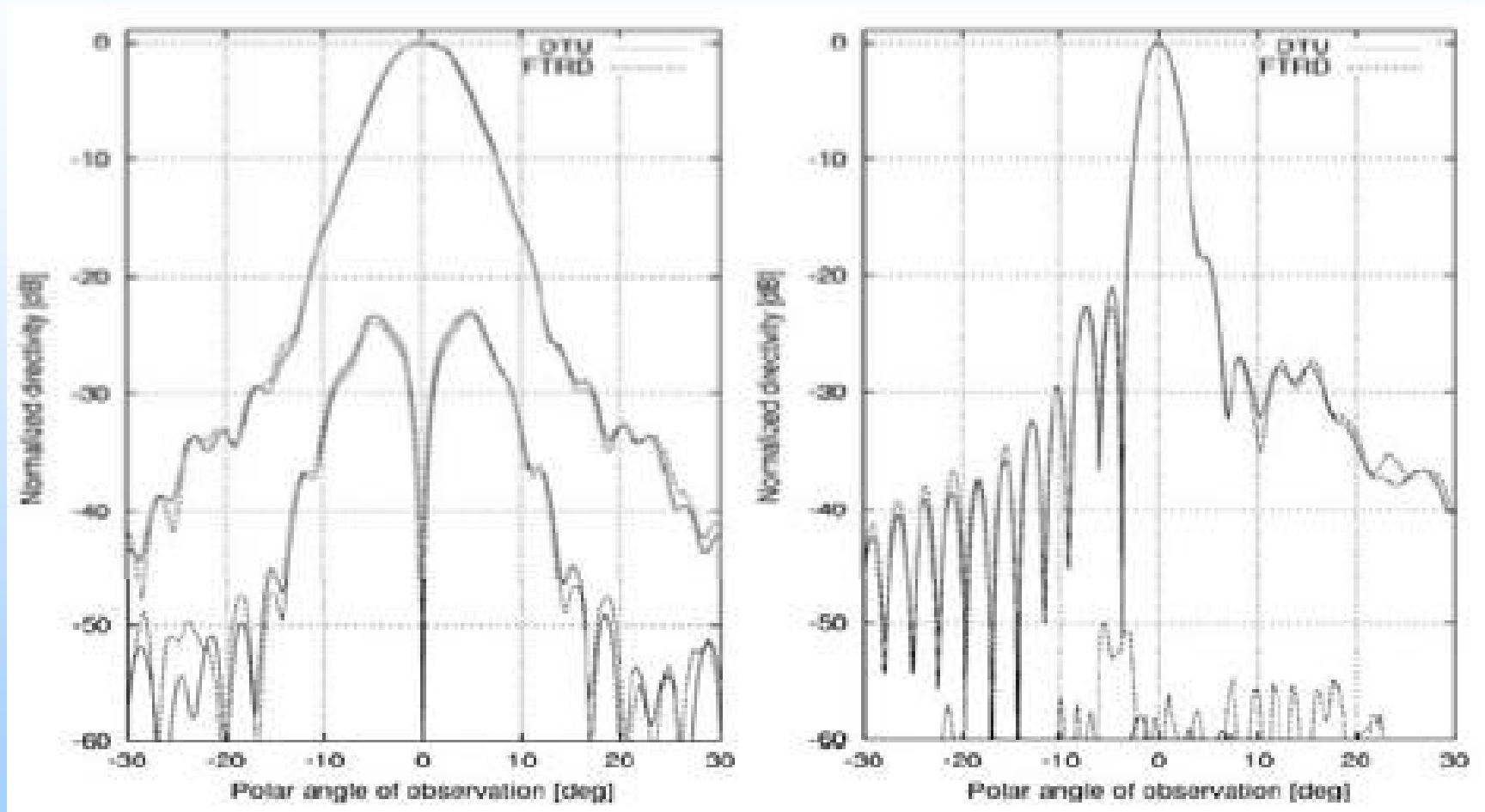
● *comparison campaign*

- DTU-ESA 12GHz Validation Standard Antenna (VAST)
- SATIMO, SH800 0.8-12GHz Dual Ridge Horn (DRH) in the 1.5-6GHz band
- SATIMO SH2000 2-32 GHz Dual Ridge Horn
- set of calibrated Standard Gain Horns (SGH) covering the 1.5- 40 GHz range from the DTU-ESA Spherical Near-Field Antenna Test Facility

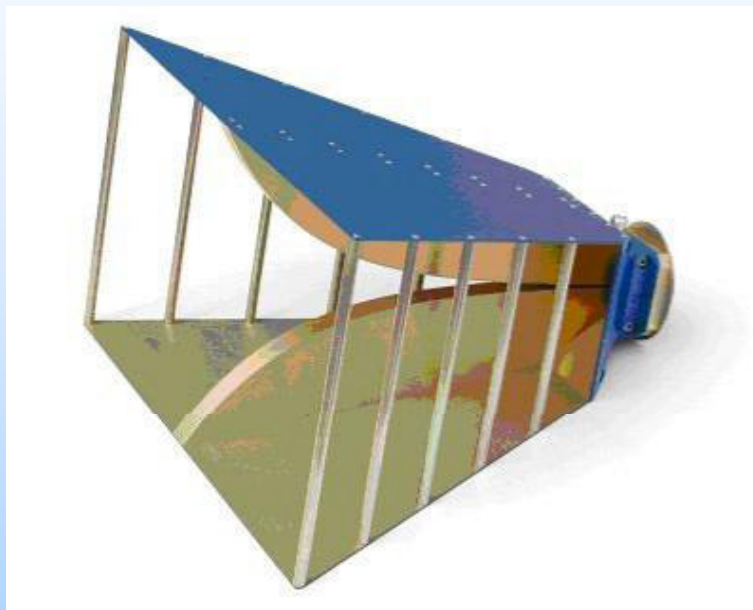
DTU-ESA VAST antenna



Comparison VAST:DTU – France Telecom

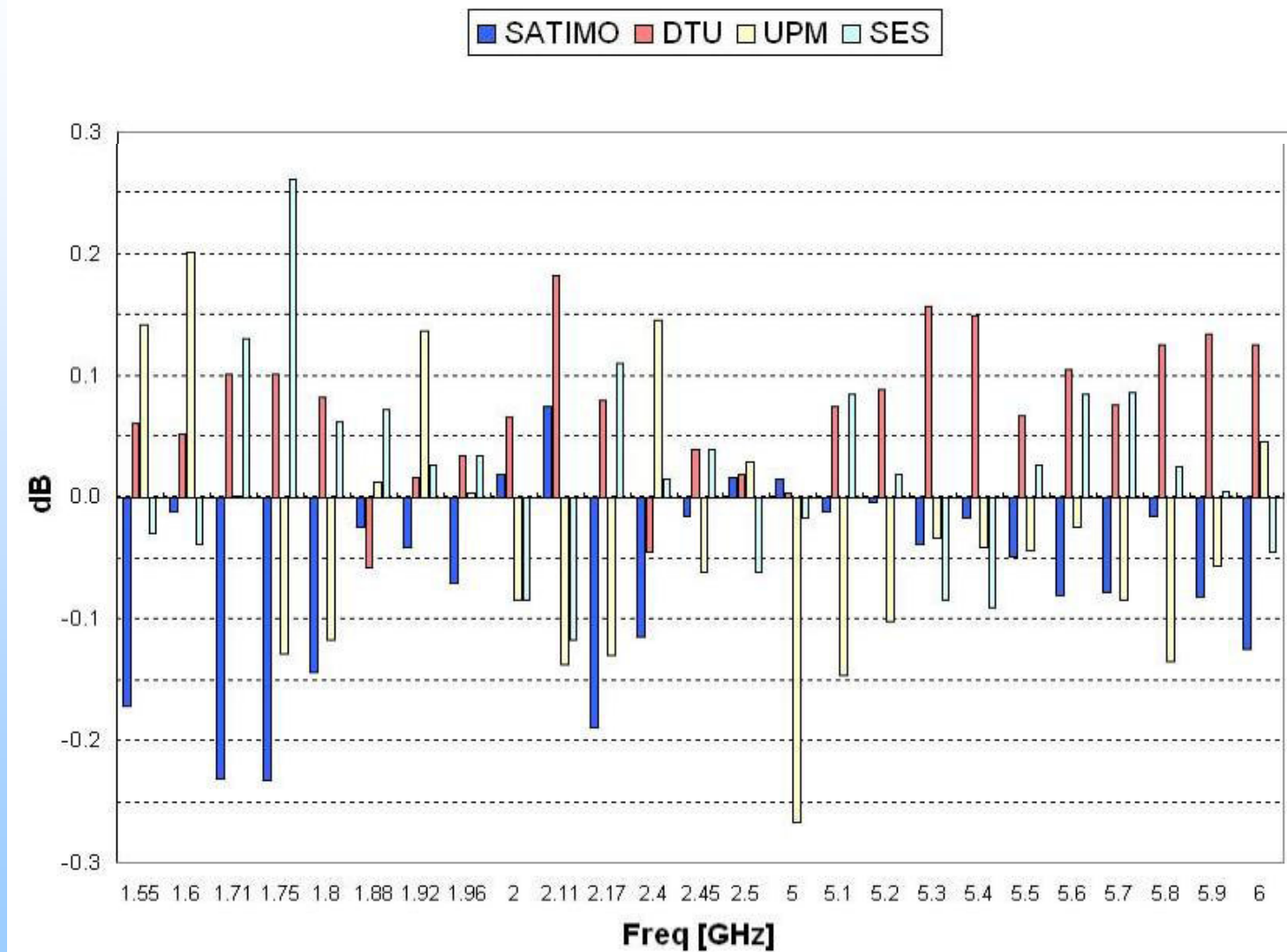


a||e *Comparison DTU – SATIMO – UPM - SES*



Freq	DTU		SATIMO		UPM		SES	
	Dir	Gain	Dir	Gain	Dir	Gain	Dir	Gain
1.55	9.97	9.93	9.78	9.70	10.01	10.01	9.87	9.84
1.60	10.22	10.04	10.06	9.98	10.33	10.19	10.05	9.95
1.71	10.73	10.67	10.43	10.34	10.56	10.57	10.89	10.7
1.75	10.8	10.72	10.48	10.39	10.57	10.49	10.85	10.88
1.80	10.49	10.4	10.26	10.17	10.3	10.2	10.49	10.38
1.88	9.41	9.32	9.45	9.35	9.35	9.39	9.65	9.45
1.92	9.35	9.26	9.29	9.20	9.23	9.38	9.43	9.27
1.96	9.67	9.57	9.56	9.47	9.36	9.54	9.55	9.57
2.00	9.86	9.74	9.79	9.69	9.63	9.59	9.72	9.59
2.11	10.14	10.05	10.03	9.94	10.24	9.73	9.82	9.75
2.17	10.44	10.38	10.20	10.11	10.37	10.17	10.37	10.41
2.40	11.1	11	11.03	10.93	11.1	11.19	11.07	11.06
2.45	11.15	11.06	11.10	11.01	11.17	10.96	11.13	11.06
2.50	11.21	11.11	11.21	11.11	11.23	11.12	11.17	11.03
5.00	12.39	12.32	12.49	12.33	12.23	12.05	12.45	12.3
5.10	12.66	12.55	12.62	12.46	12.54	12.33	12.71	12.56
5.20	12.85	12.74	12.80	12.65	12.75	12.55	12.93	12.67
5.30	13.03	12.93	12.89	12.74	12.9	12.74	12.91	12.69
5.40	12.96	12.86	12.84	12.69	12.92	12.67	12.86	12.62
5.50	12.66	12.56	12.60	12.44	12.7	12.45	12.77	12.52
5.60	12.65	12.54	12.51	12.36	12.68	12.41	12.78	12.52
5.70	12.7	12.6	12.60	12.45	12.61	12.44	12.88	12.61
5.80	12.77	12.66	12.67	12.52	12.65	12.4	12.82	12.56
5.90	12.76	12.64	12.58	12.42	12.63	12.45	12.77	12.51
6.00	12.69	12.57	12.48	12.32	12.65	12.49	12.67	12.4

Comparison boresight gain



Question 3: how can we measure better ?

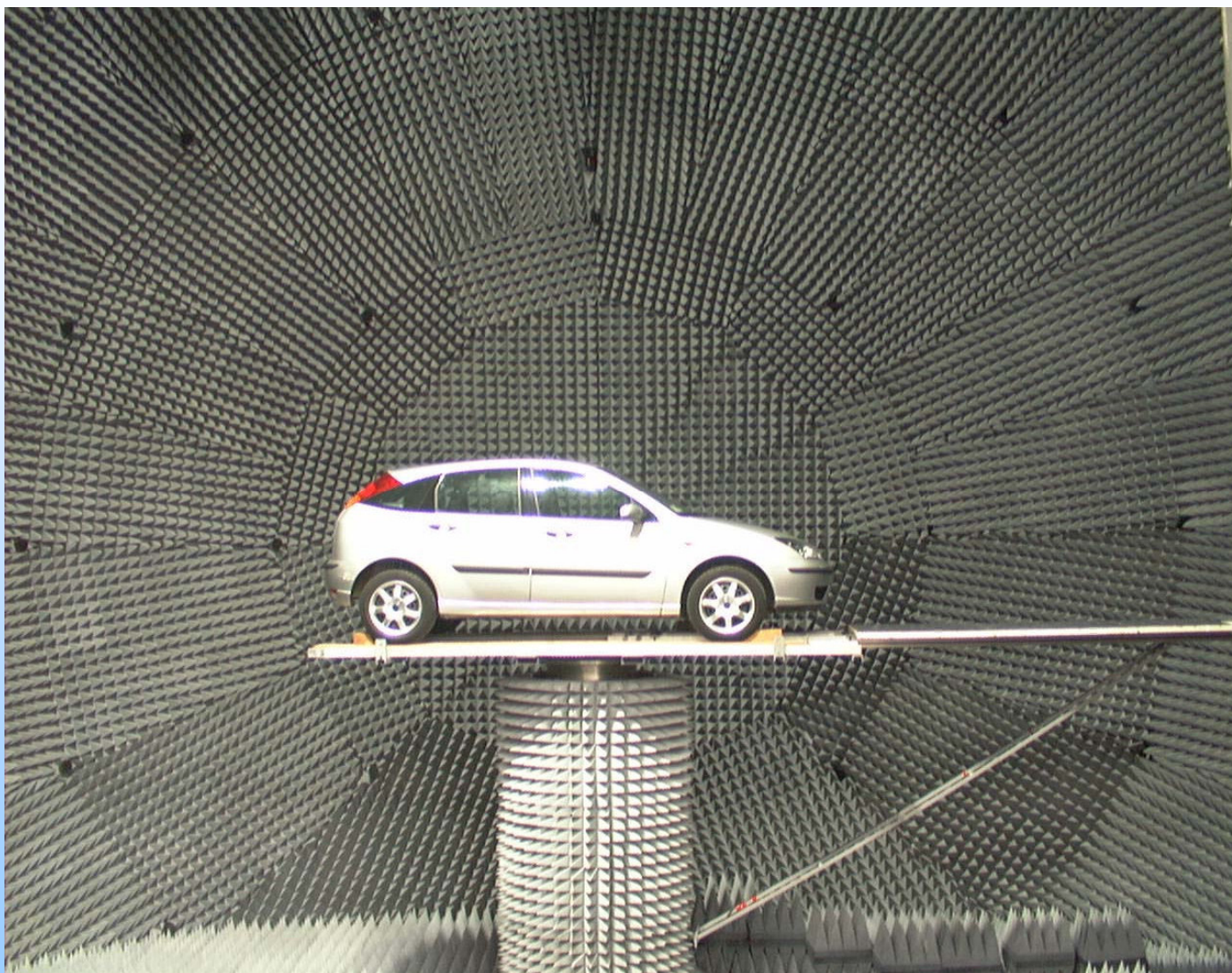
- standardization of primarily near field antenna measurement techniques in order to eliminate measurement inaccuracies due to the practical implementation of the measurement

Question 3: how can we measure better ?

- Development of measurement techniques and procedures for new and emerging antenna technologies within the 5 vertical research activities of ACE
 - » millimetre and sub-millimetre wave integrated antennas
 - » small antennas
 - » wideband and multi-band antennas
 - » planar and conformal arrays
 - » smart antennas

DOW: Task 2.2 Measurement Best Practices

- Collection of existing experience and knowledge on measurements of vehicle-based wireless system – including specifications for measurement results (which parameters should be measured and to which accuracy/ precision).
 - Comparative investigation between different techniques, procedures, and instrumentation.
-
1. What facilities are used in the automotive industry ?
 - in-house or external ?
 2. What are the challenges there at the moment ?
 - presence of “large”, complicated environment ...
 - size of the structures to measure and accuracy ...
 - ...
 3. ...



Possible actions ...

- *upgrade of Antenna Measurement Services in VCE*
- *inclusion of benchmarking antennas from automotive industry*
- *set up list of measuring needs typical for automotive industry*
- ...

Conclusions

- *ACE has given the European antenna community an identity, a profiled structure where things can be discussed*
- *ACE has initiated a harmonization and standardization process within Europe*
- *ACE has intensified considerably the interaction in between universities, and between universities and industry*
- *ACE has produced a considerable number of cooperative publications and has triggered a lot of bilateral cooperations ... both for software and measurements*

These efforts will be continued within the COST-ASSIST and EuRAAP frameworks