Measurement and Simulation Link Applied to Antenna Placement Problems

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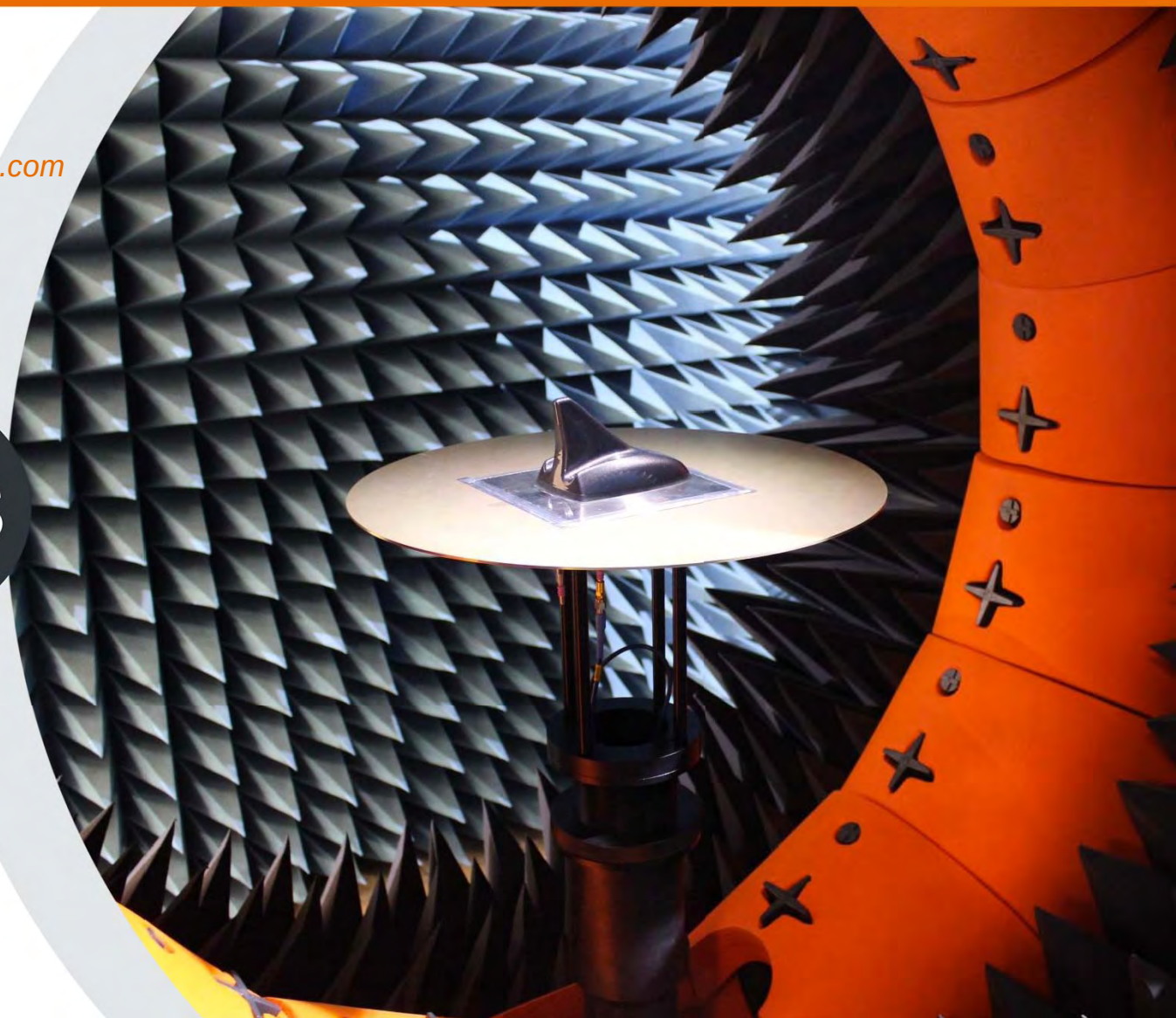


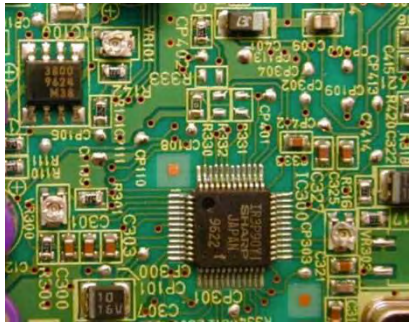
AMS

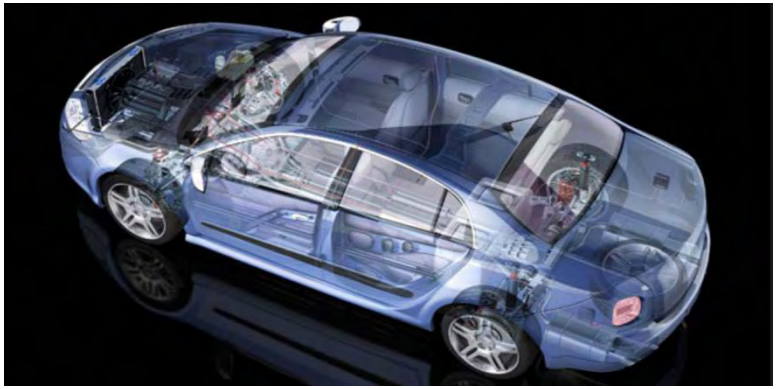
RF & Microwave

AFCEM

Introduction

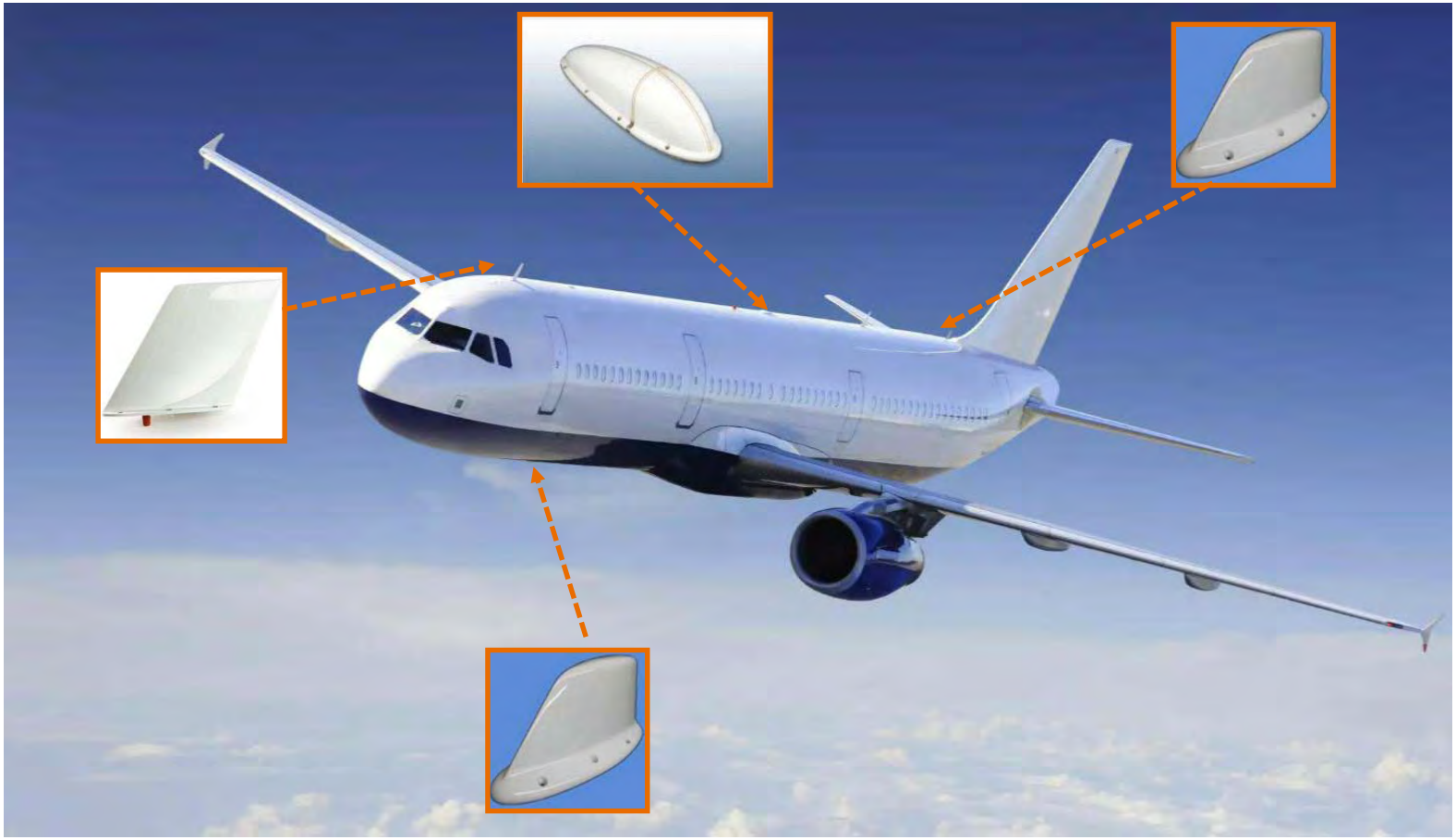
Large and/or complex problems: investigation and optimization of the scenario is necessary…





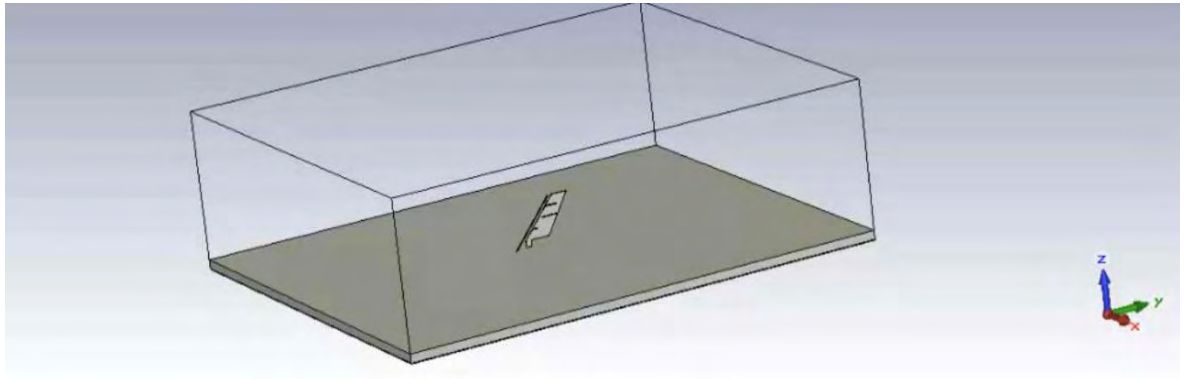
Domain Decomposition Techinque

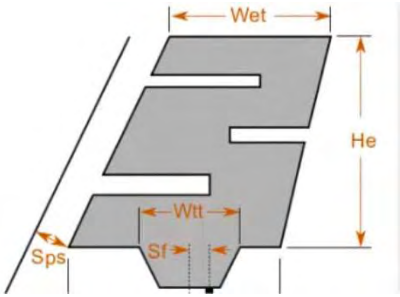
- Simulation of real complex structures => the Domain Decomposition Technique (DDT)

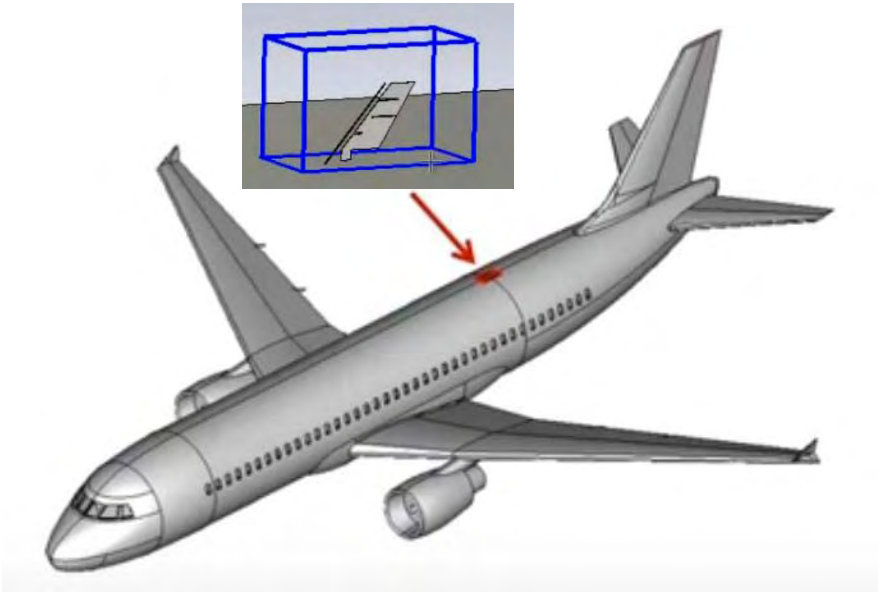


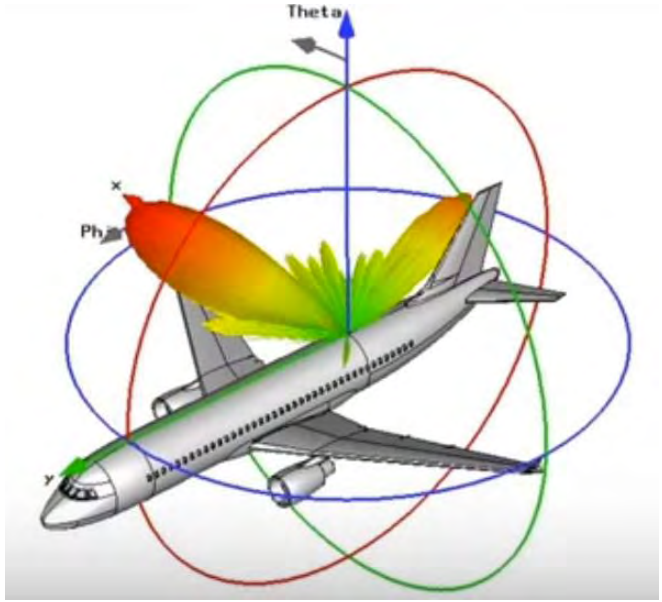
Numerical simulations hybrid methods

- Using numerical CEM tools….





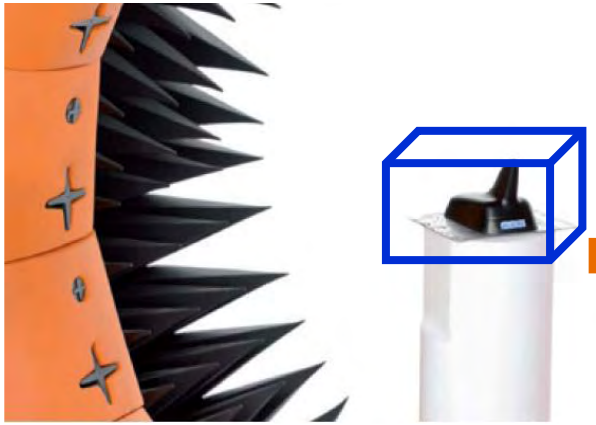




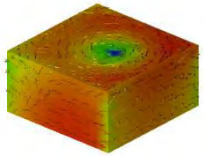
The link between measurements and simulations

- In some cases, when implementing an antenna supplied by a third party, the mechanical and electronic characteristics needed for a full-wave representation of the antenna may be unavailable.

- To overcome this problem, the radiating antenna can be characterized by a true radiating measurement => INSIGHT

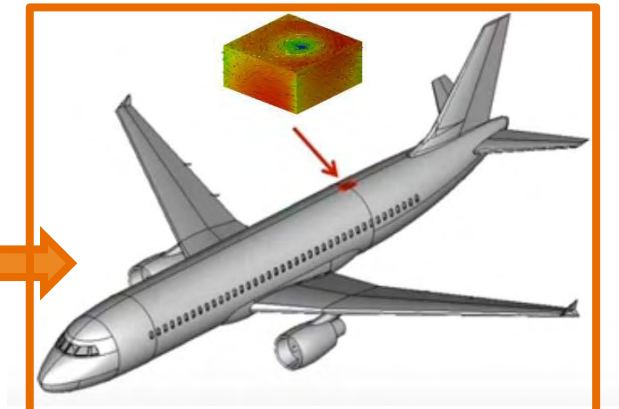


NF radiating measurement



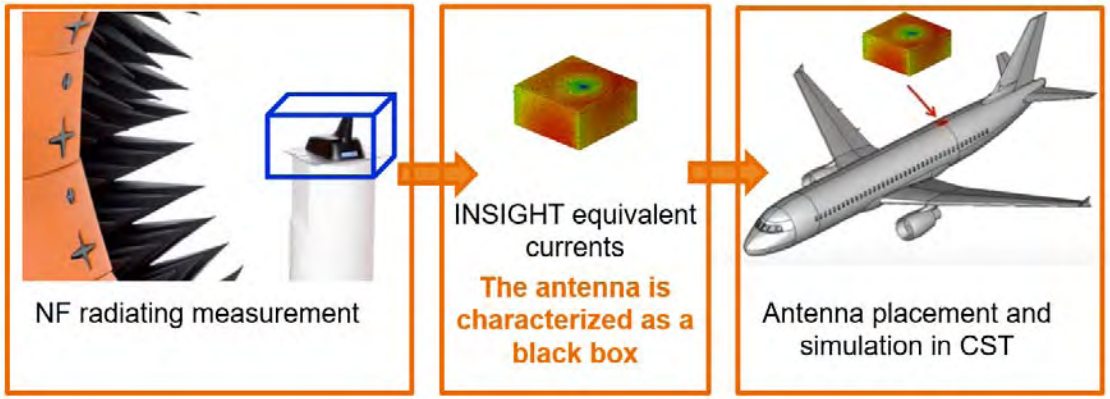
INSIGHT equivalent currents

The antenna is characterized as a black box



Antenna placement and simulation in CST

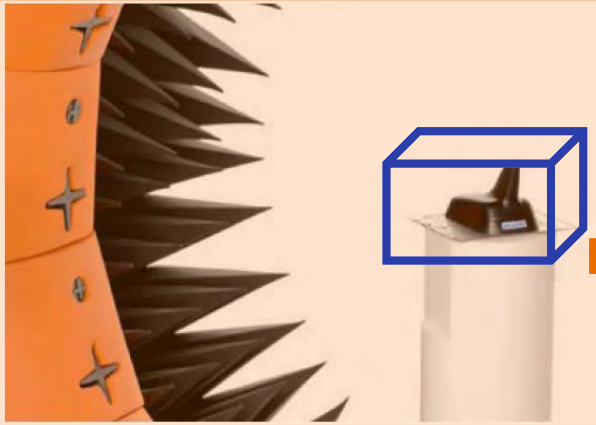
The link between measurements and simulations



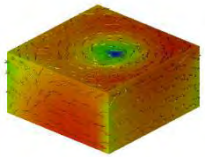
- Advantages of the link:
  - Simulation of antennas in complex scenarios even when mechanical and electronic characteristics needed for a full-wave representation of the antenna may be unavailable;
  - Share antenna data without exposing proprietary data;
  - Use high fidelity measured data as sources for installed antenna performance in CEM tools;
  - Solve enormous, realistic problems, many you may have considered too big to solve before or to measured only before.

The link between measurements and simulations

STEP 1



NF radiating measurement



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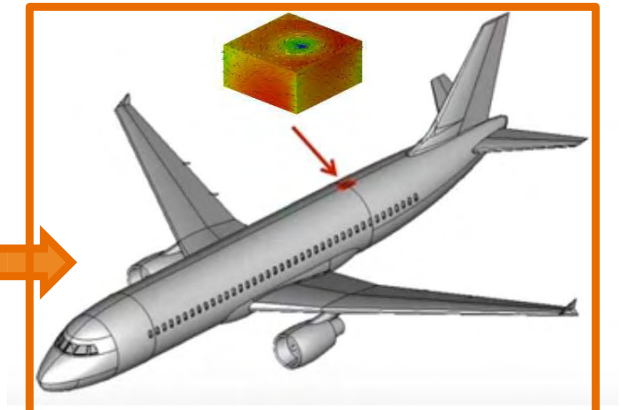
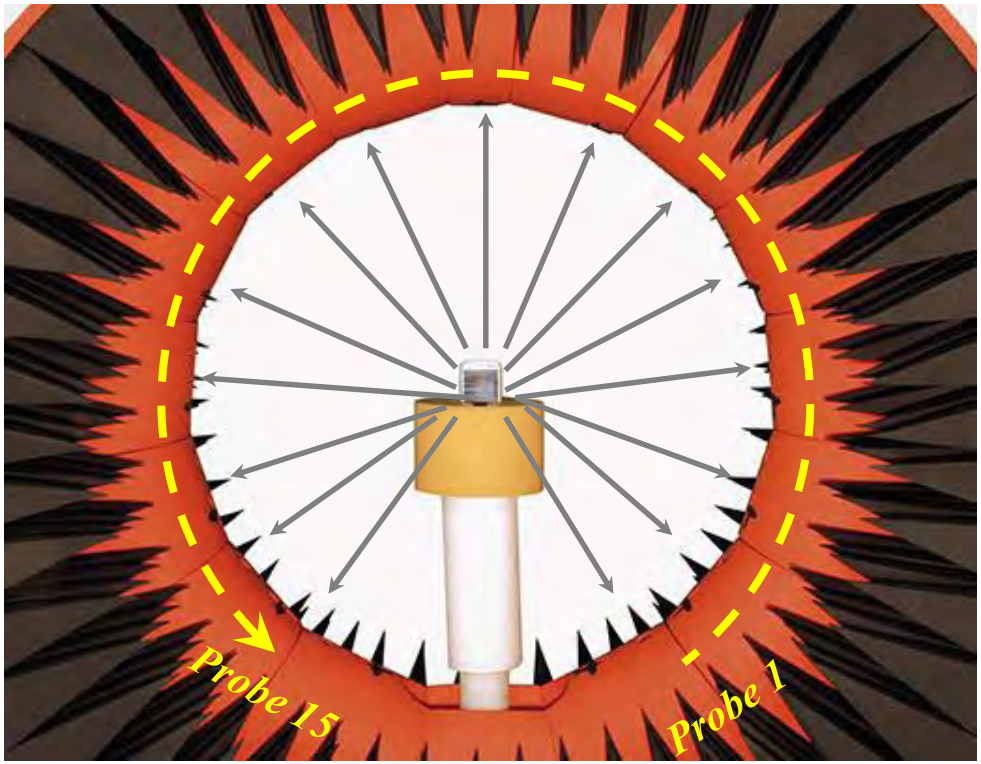


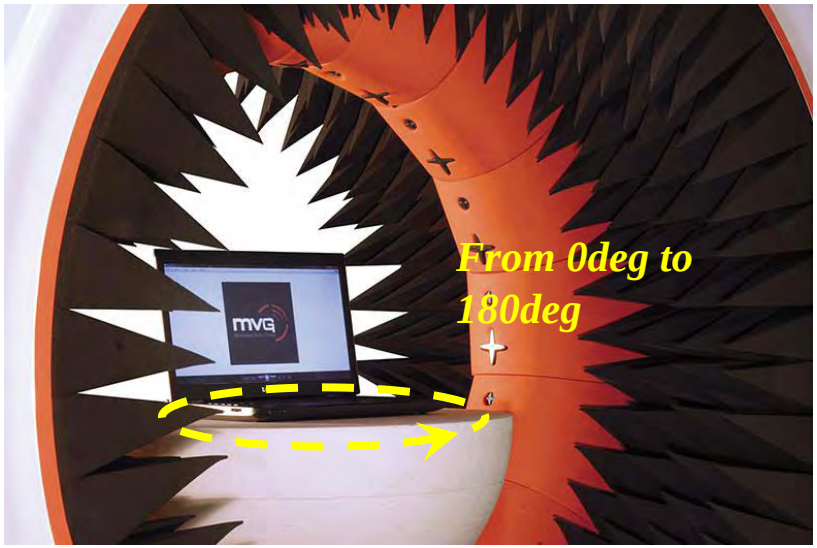
Antenna placement and simulation in CST

SNF Measurement: Multi-probe system

Near field probe array measurements – SNF example

- Elevation Scanned Electronically via Probe Array
- Azimuth Scanned Mechanically via Turntable



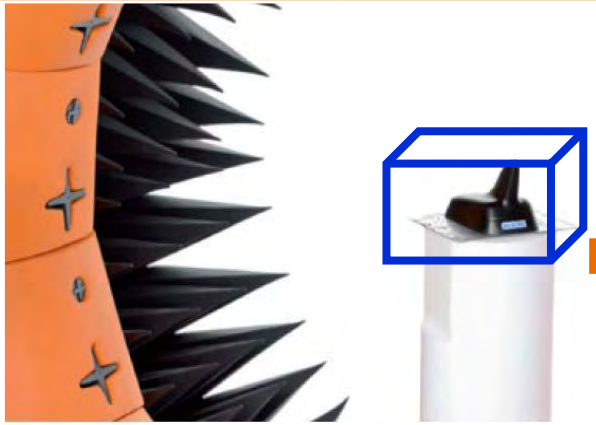


In a few minutes an antenna or other device of diameter ≤10λ can be measured (+20 frequency points).

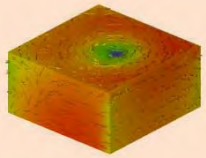
IEEE Recommended Practice for Near-Field Antenna Measurements. IEEE Std 1720-2012

The link between measurements and simulations

STEP 2



NF radiating measurement



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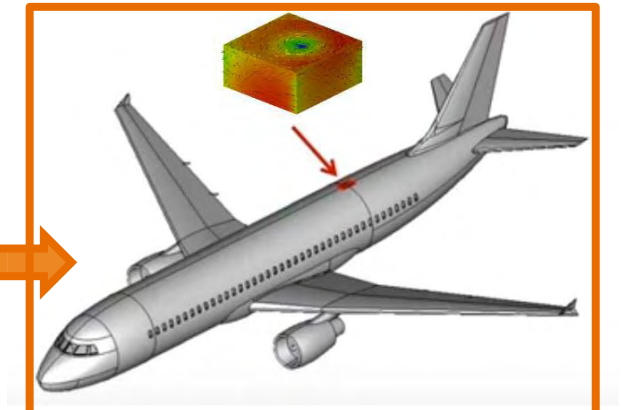
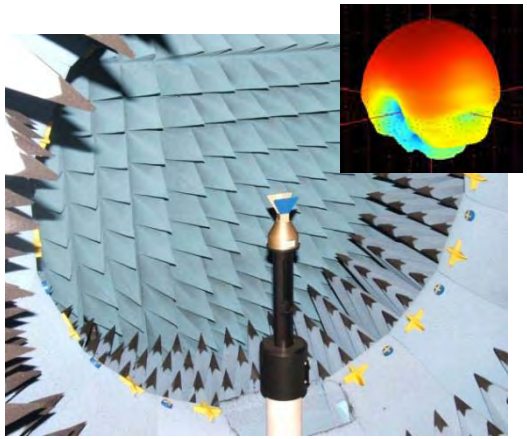


Antenna placement and simulation in CST

MVG INSIGHT software

- **INSIGHT is a unique and advanced measurement post processing tool for antenna analysis, diagnostics and as link between measurements and commercial computational electromagnetic (CEM) tools.**
  - INSIGHT is able to reconstruct authentic equivalent electromagnetic current distributions and extreme near fields on the antenna under test from antenna measurement data.



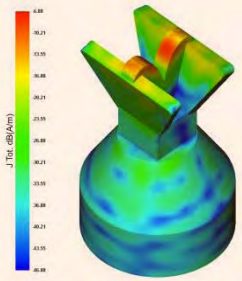
Antenna measurement in the StarLab measurement system

3D reconstruction geometry

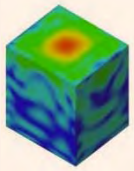
Insight

Equivalent electromagnetic current distribution (J and M currents)

Antenna analysis and diagnostics

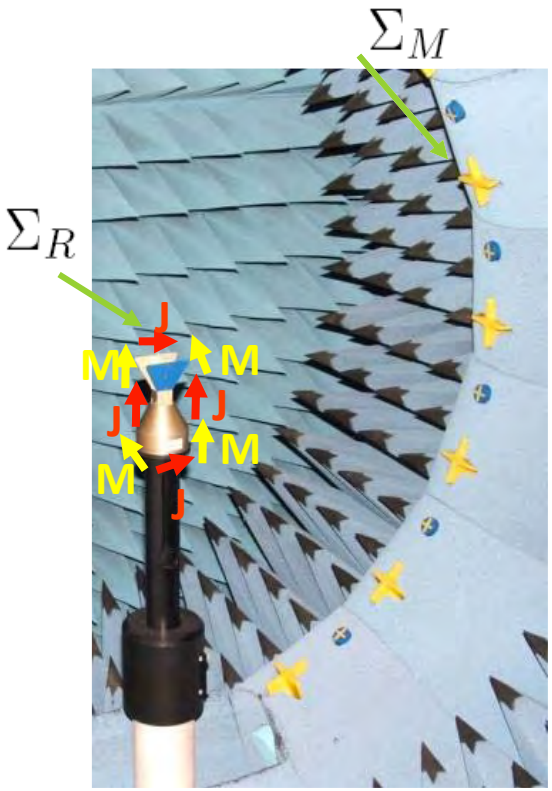


Link between measurements and CEM tools



Equivalent currents (INSIGHT)

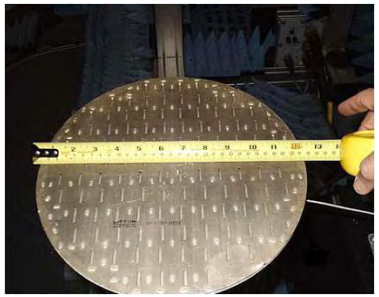
- INSIGHT implements the inverse source technique.
- Equivalence principle: all sources/scatterers within a closed volume conformal to the antenna can be substituted by a distribution of equivalent electric and magnetic currents (J, M) lying on an enclosing surface ΣR, radiating the same fields at ΣM.

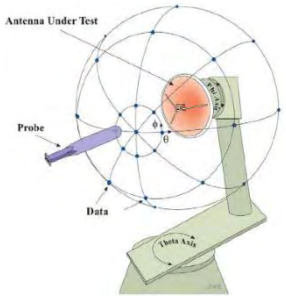


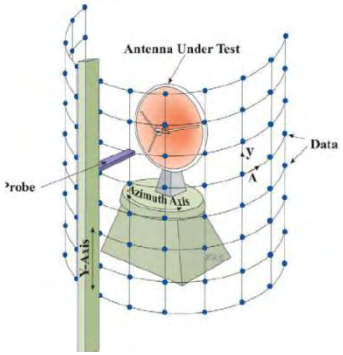
- Dual integral equation enforcing the boundary condition of zero internal field to determine the two unknown currents J/M on the surface conformal to the antenna.
- The system of equations can be solved very efficiently with Method Of Moment (MOM) techniques.

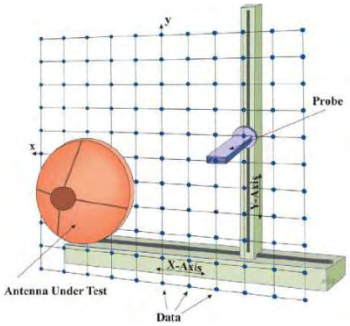
Equivalent currents (INSIGHT)

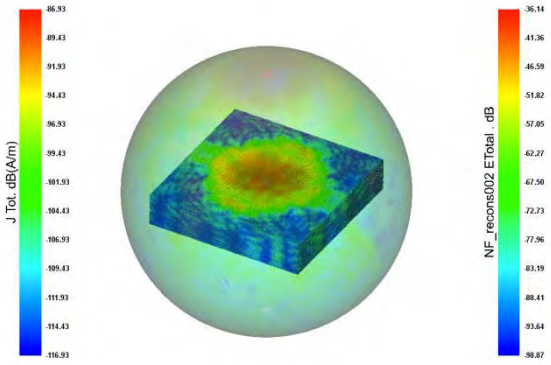
- Application ranges: spherical, cylindrical and planar near field geometries and corresponding far field;
- Ex: Passive slotted array operating in X band.

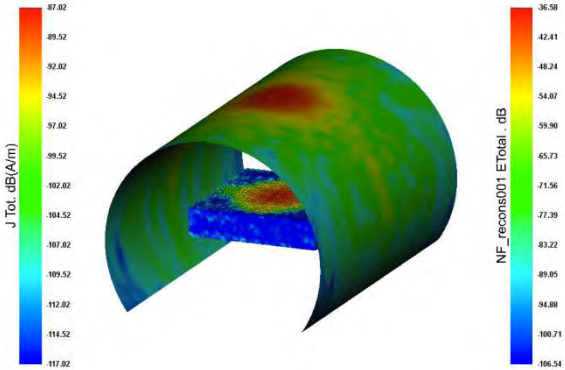


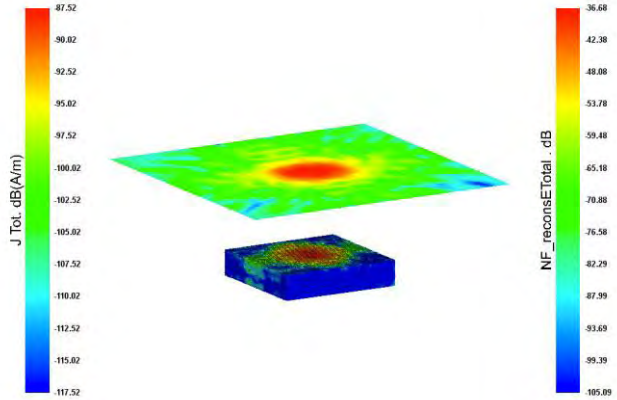






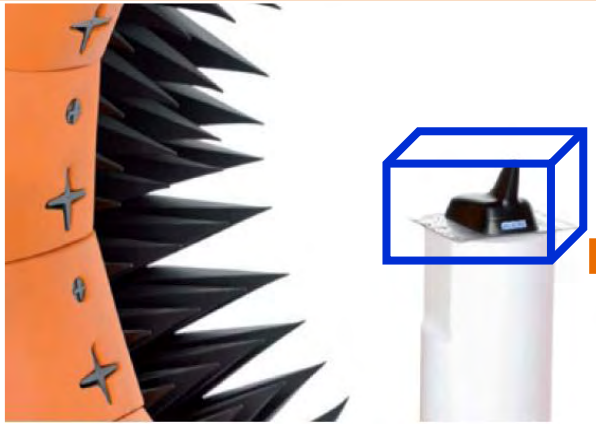




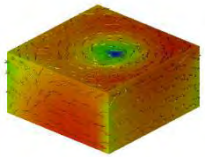


The link between measurements and simulations

STEP 3



NF radiating measurement



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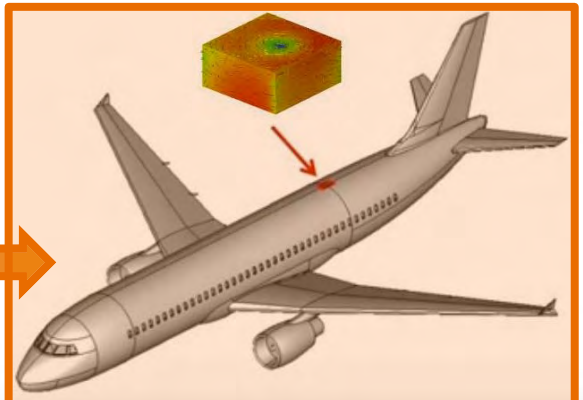
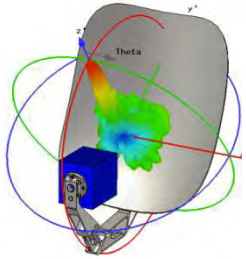


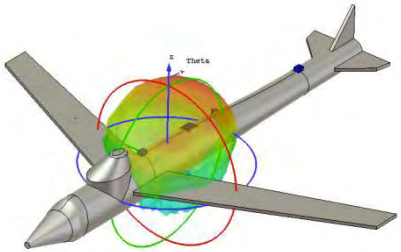
Antenna placement and simulation in CST

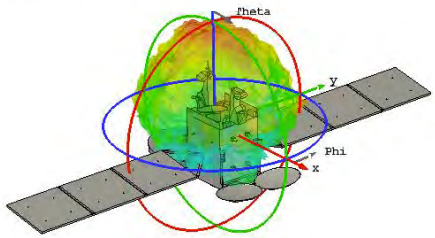
The applications of the link

- Antenna design

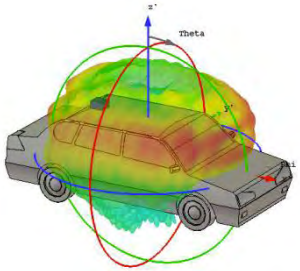


- Aerospace

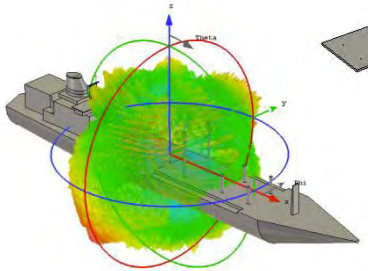




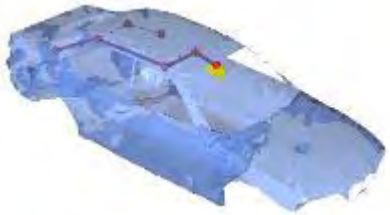
- Automotive



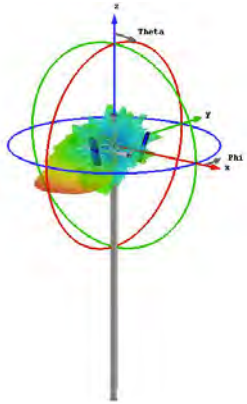
- Naval



- EMC



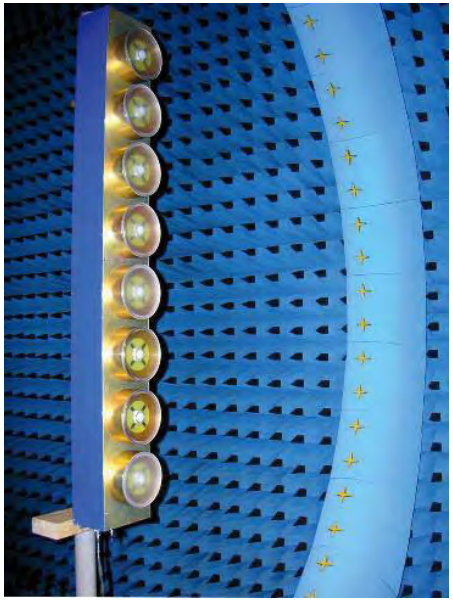
- Telecommunication

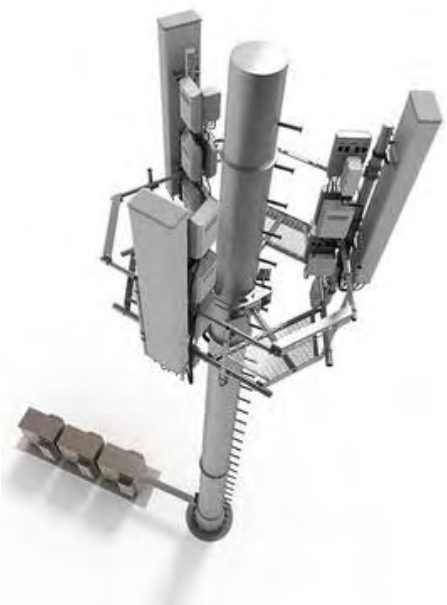


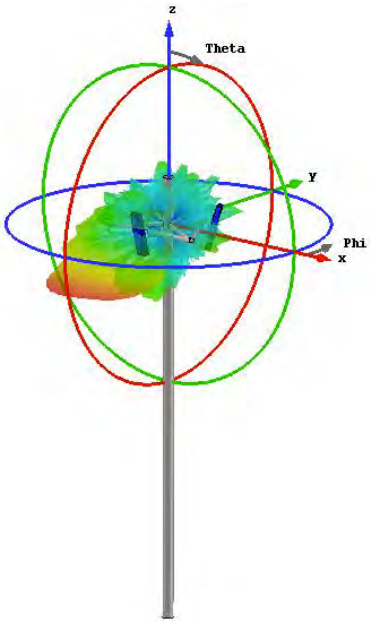
Application examples

Complex Environment

- Base Transceiver Station (BTS)

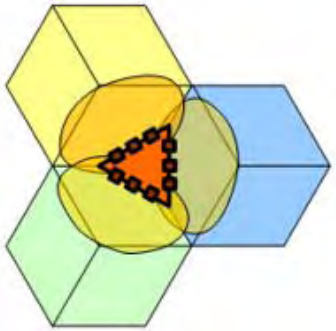


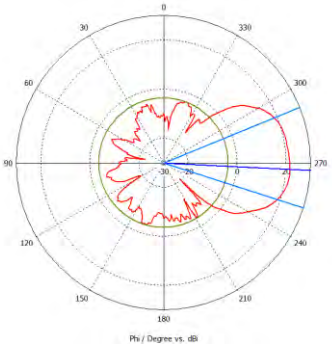




Base Transceiver Station (BTS)

- Base Transceiver Station (BTS) is a telecoms infrastructure used to facilitate wireless communication between subscriber device and telecoms operator network. The subscriber device can be mobile phone, wireless internet devices while the operator network could be 2G, 3G and 4G.
- A BTS consists of an antenna and the radio equipment necessary to communicate by radio with a Mobile Station (MS). Each BTS covers a defined area (cell).
- The antenna should have a high gain in the direction facing cellular sector being illuminated.





Base Transceiver Station (BTS)

- BTS are mounted on very high masts and due to the large dimensions of the scenario, this cannot be entirely measured in a measurement system.

- Thanks to the link between measurements and simulations, the user can initially measure the antennas stand alone in a NF or FF measurement system. Then starting from the measured data, the simulations of the antennas in the BTS (final scenario) can be performed to predict how the antennas will radiate in the final scenario.

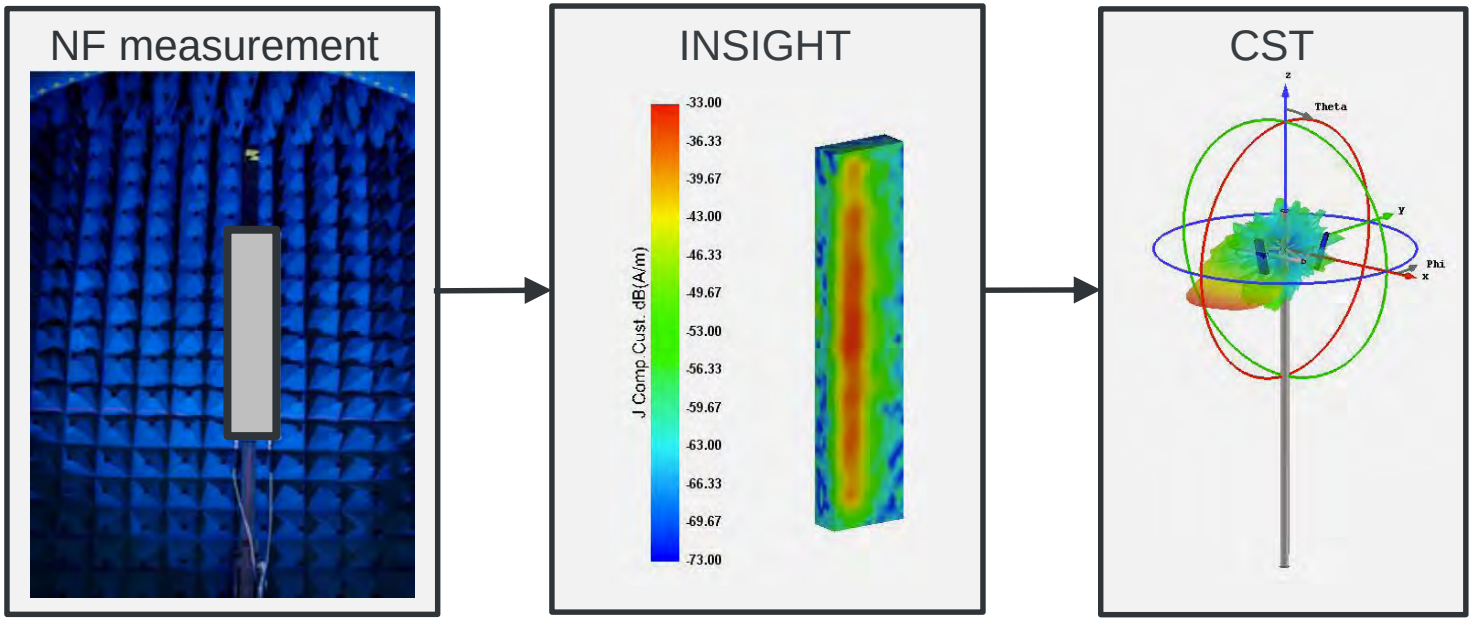
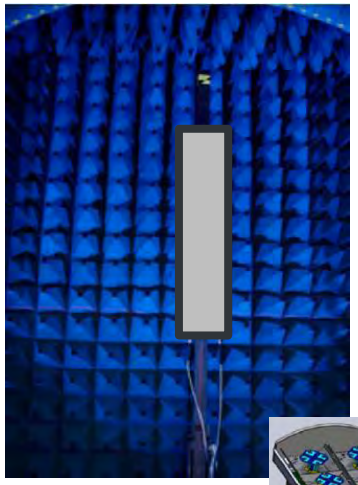


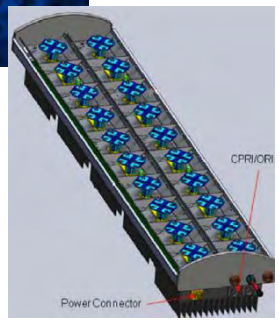
Image of the real antenna is confidential

Antenna measurement and preparation of the Huygens box by INSIGHT

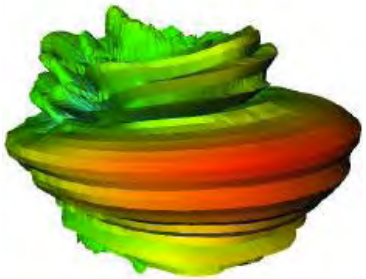
- Equivalent currents are calculated on a box enclosing the antenna and representing the antenna in the measurement system.

SG128 NF multi-probe measurement system

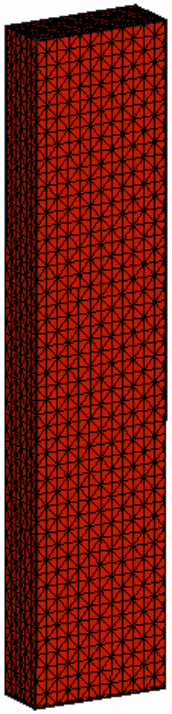




NF radiation patterns @2620MHz (+45° port)



Equivalent geometry/ triangular mesh



Equivalent currents/ Huygens box

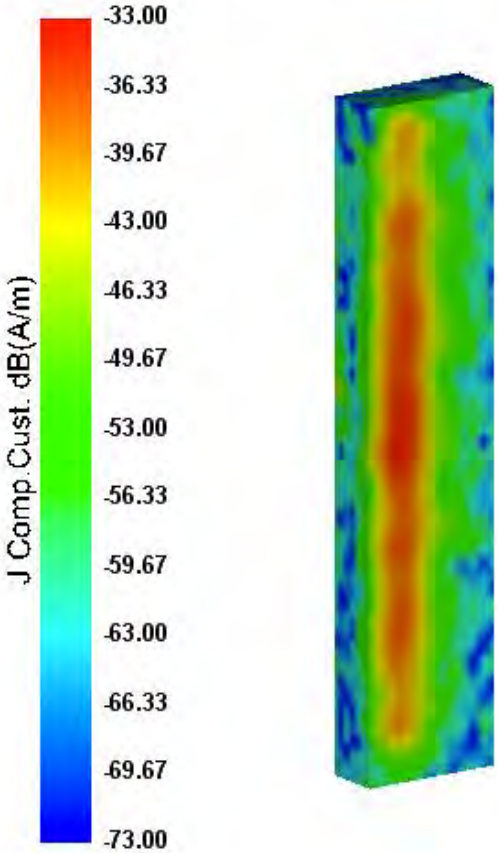
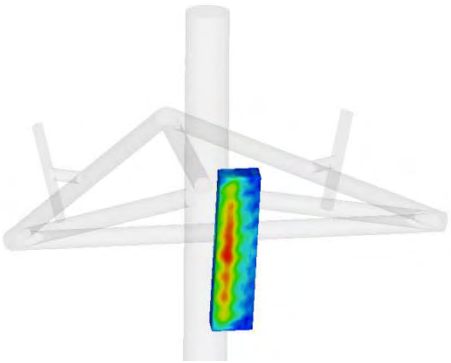


Image of the real antenna is confidential

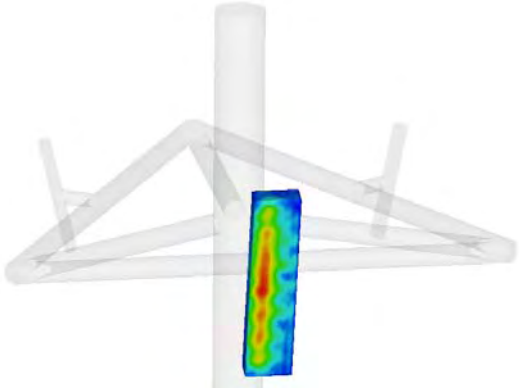
Use of the Huygens box (measured data) in CST

- The computed Huygens box (measured data) is positioned in the simulation final scenario.

Equivalent currents/ Huygens box

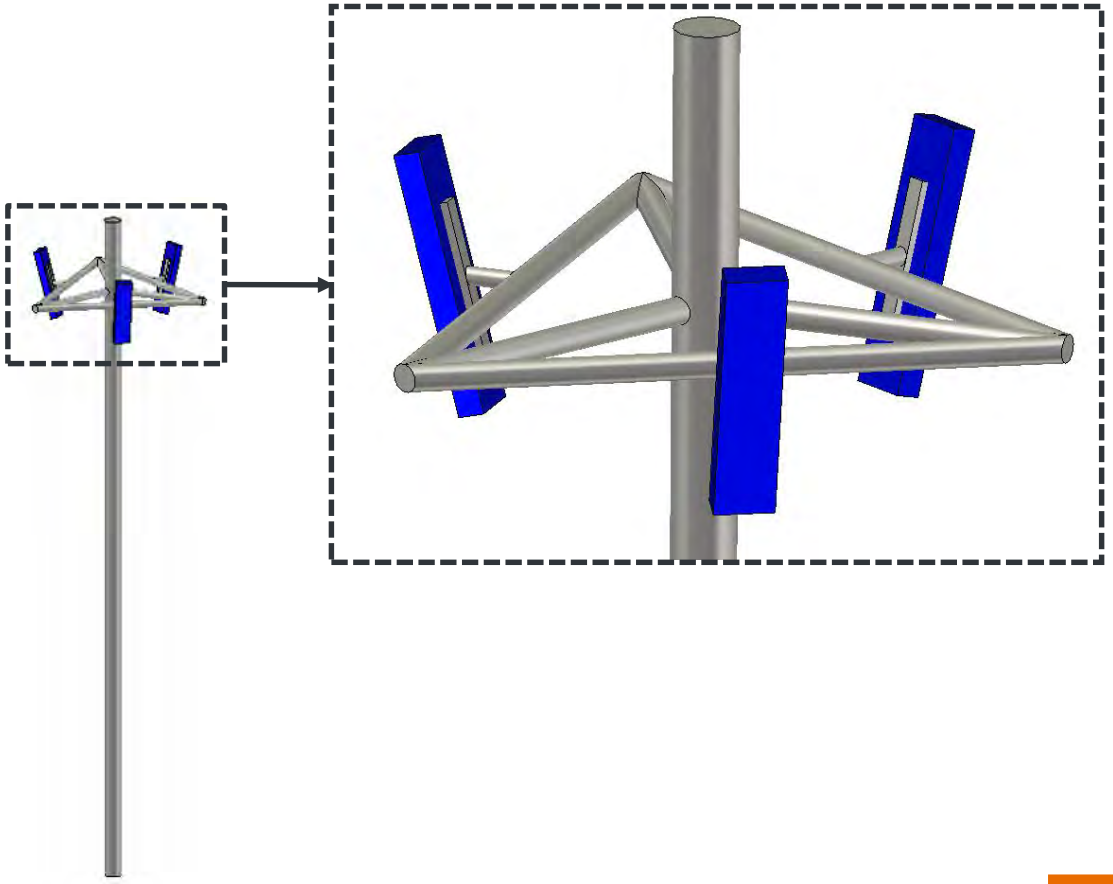


E-field (dB)



H-field (dB)

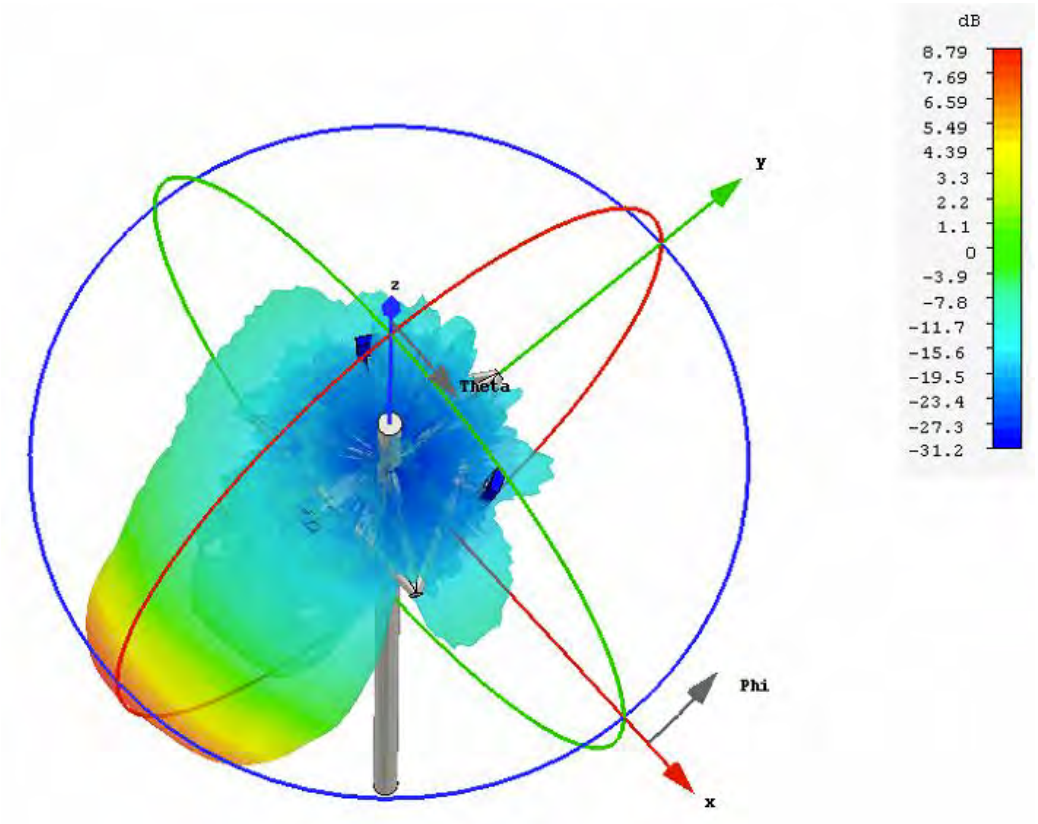
Final scenario: 3 identical antennas



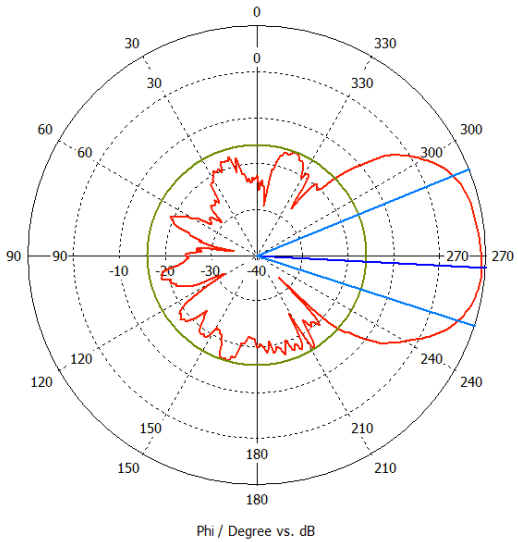
Use of the Huygens box (measured data) in CST

- Simulation of the radiation pattern at 2620MHz with the Integral Equation Solver
- **Only one antenna is radiating.**

Directivity ABS @2620MHz
3D radiation pattern



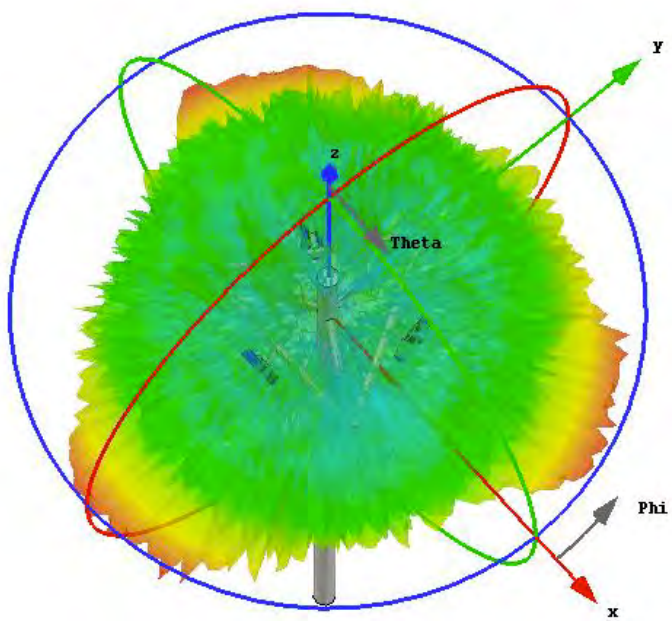
Directivity ABS @2620MHz
Azimuth scan plane
Theta = 105 deg

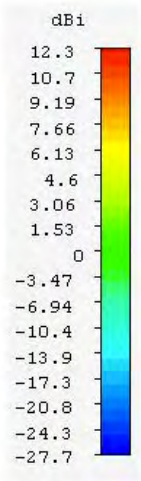


Use of the Huygens box (measured data) in CST

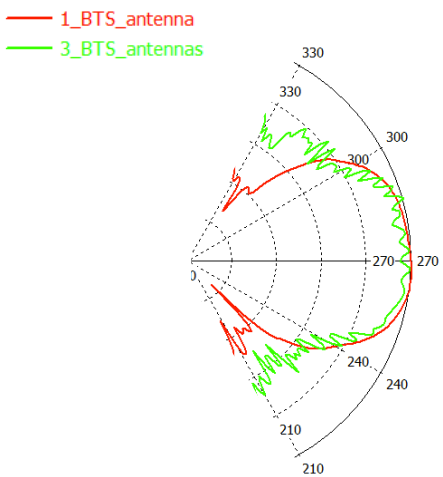
- Simulation of the radiation pattern at 2620MHz with the Integral Equation Solver
- **Combining antennas for azimuth coverage.**

Directivity ABS @2620MHz
3D radiation pattern





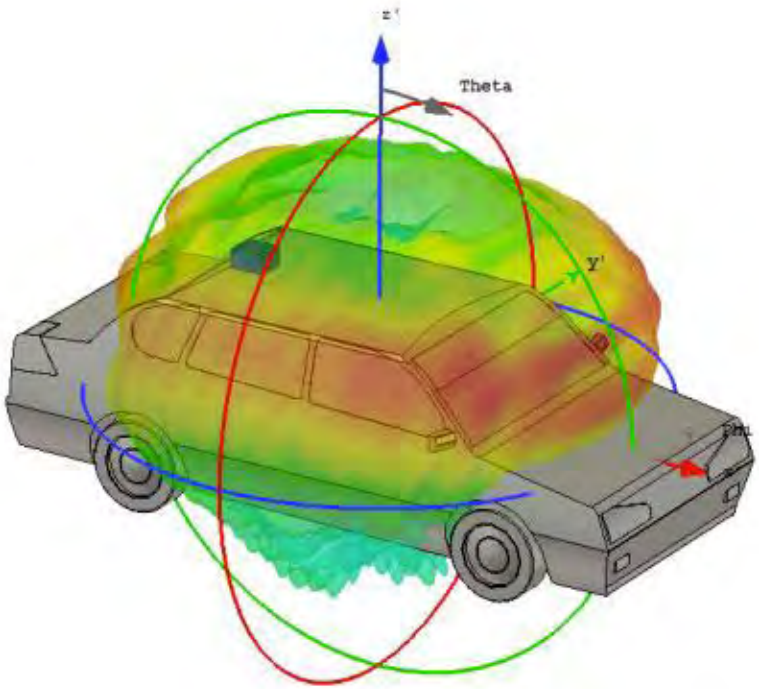
Directivity ABS @2620MHz
Azimuth scan plane
Theta = 105 deg



Application examples

Antenna placement

- Shark fin antenna from Calearo installed on a car model



Shark fin antenna from Calearo

- The shark fin antenna has been measured in the GSM, LTE and UMTS frequency bands from 698MHz to 2690MHz.
- Preparation of the measured Huygens box has been performed starting from the antenna measurement on a circular plate of 40cm diameter in the MVG StarLab measurement system.
- Huygens boxes at 925MHz, 1850MHz and 2530MHz have been computed. No instructions are provided to the CEM tool about the car model.

Preparation of a flush mounted antenna

Preparation and use of the measured source

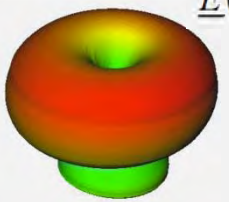
- If the antenna is "**flush mounted**" on the structure - we have to measure the antenna with a minimum of representative ground plane to impose the correct local boundary condition.
- We then need to extract the edge scattering from the ground plane in an additional post processing step.
- This processing can be performed with the procedure shown in the following slides.

Measurement of the shark fin antenna on a circular ground plane

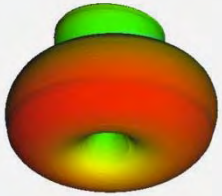
Preparation of a flush mounted antenna

- Preparation and use of the measured source.
- A virtual infinite ground-plane field can be created from the finite ground-plane measurements by “mirroring” the measured field in Z=0. Source edge Diffraction Extraction (SDE).

$\underline{E}(\theta,\phi)$



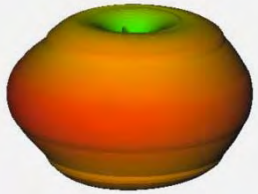
“Mirrowing” the field in Z=0 we create a virtual infinite ground plane.



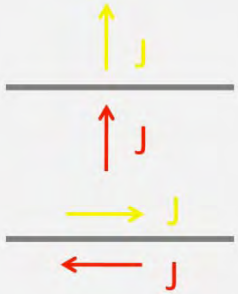
$\underline{E}(\pi-\theta,\phi)$

Add the mirrored version of the field

$$E_\theta^C(\theta,\phi)=E_\theta(\theta,\phi)+E_\theta(\pi-\theta,\phi)$$
$$E_\phi^C(\theta,\phi)=E_\phi(\theta,\phi)-E_\phi(\pi-\theta,\phi)$$
$$E_r^C(\theta,\phi)=E_r(\theta,\phi)-E_r(\pi-\theta,\phi)$$



We obtain the same infinite ground plane field above and below Z=0.



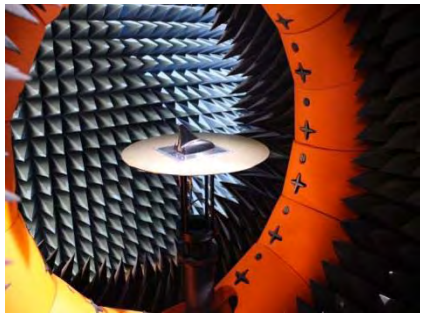
$\underline{E}^C(\theta,\phi)$

L.J. Foged, F. Mioc, B. Bencivenga M. Sabbadini, E. Di Giampaolo, “Accurate infinite groundplane antenna measurements”, AMTA, Salt Lake City, Utah, November 2009.

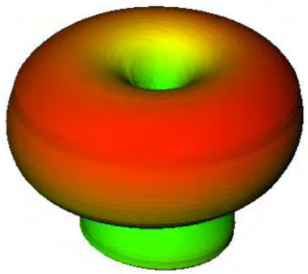
Link between measurements and simulations

From measurement to simulation: the workflow.

Shark fin antenna with limited ground plane measured in the MVG StarLab system



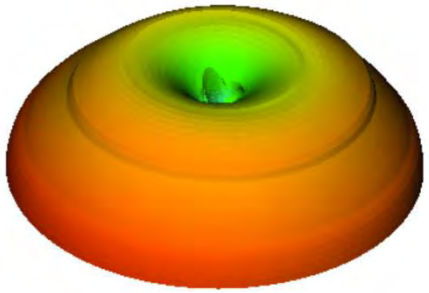
NF pattern @925MHz



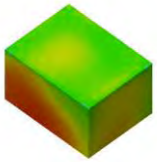
(*) L.J. Foged, F. Mioc, B. Bencivenga M. Sabbadini, E. Di Giampaolo, "Accurate infinite groundplane antenna measurements", AMTA, Salt Lake City, Utah, November 2009.

(*) Infinite Ground Plane Boundary Condition

Source Edge Diffraction Extraction (SDE)

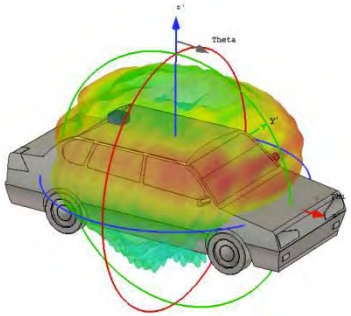


Insight



Electric currents

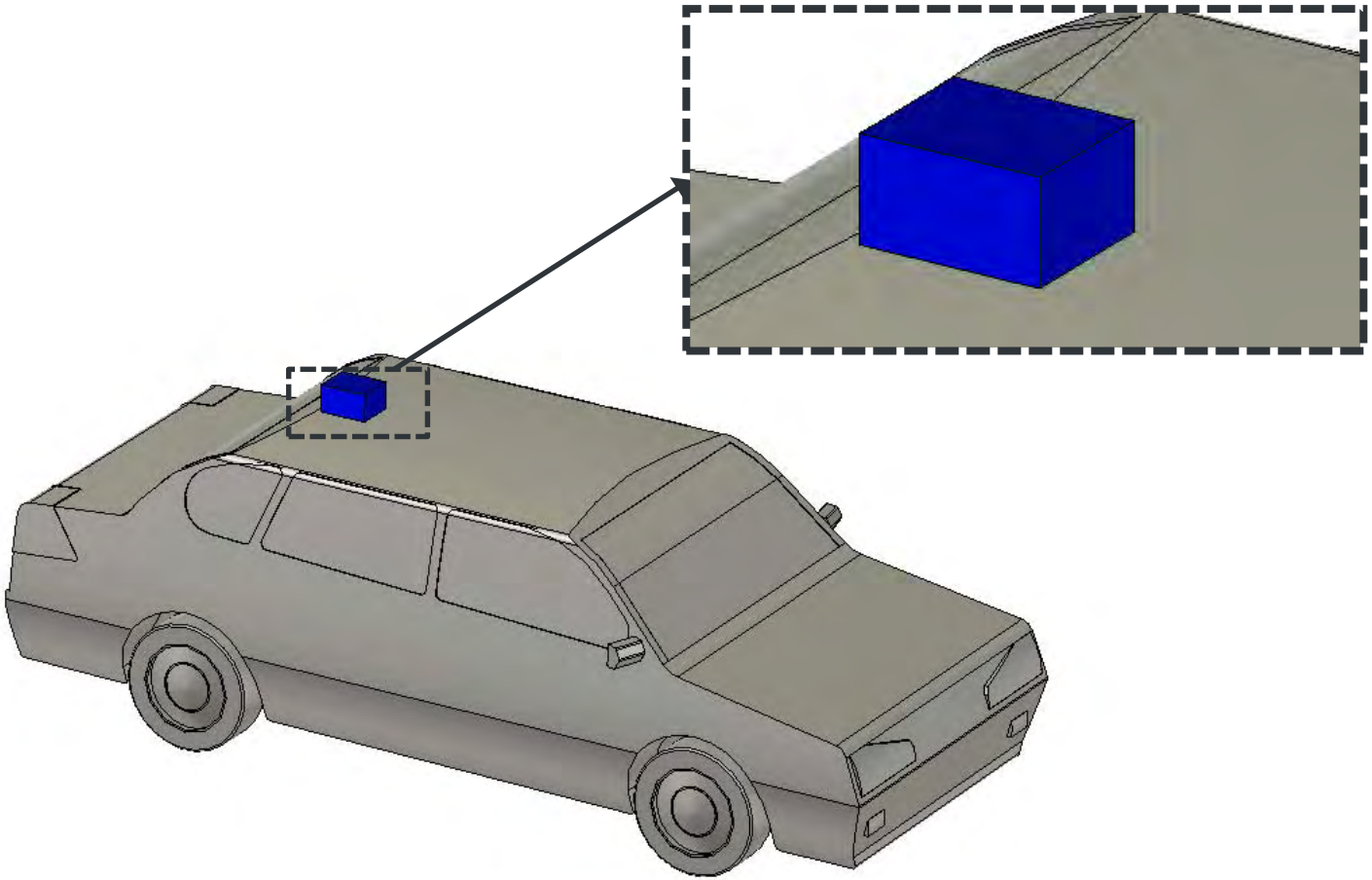
Amplitude (dB)



Equivalent Currents as measured source in CST

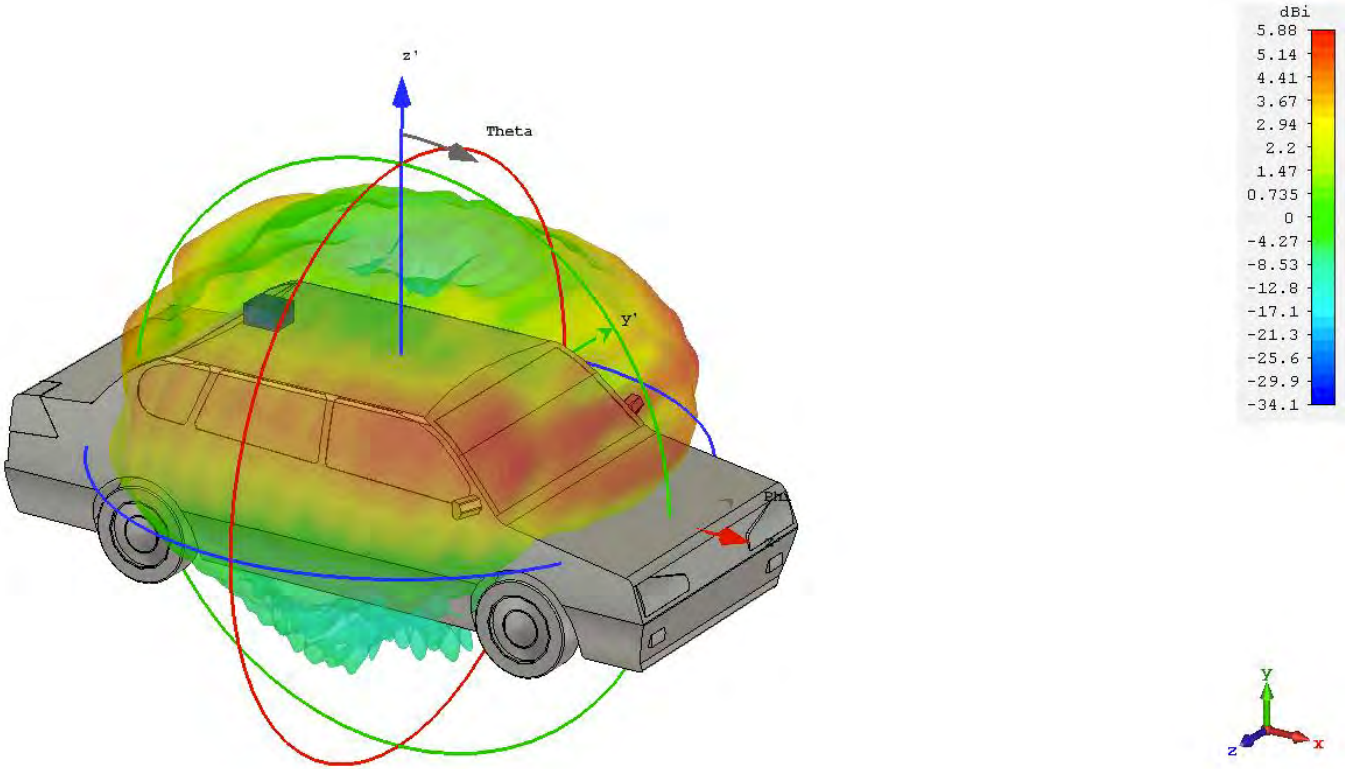
Use of the Huygens box (measured data) in CST

- The computed Huygens box (measured data) is positioned in the simulation final scenario.



Use of the Huygens box (measured data) in CST

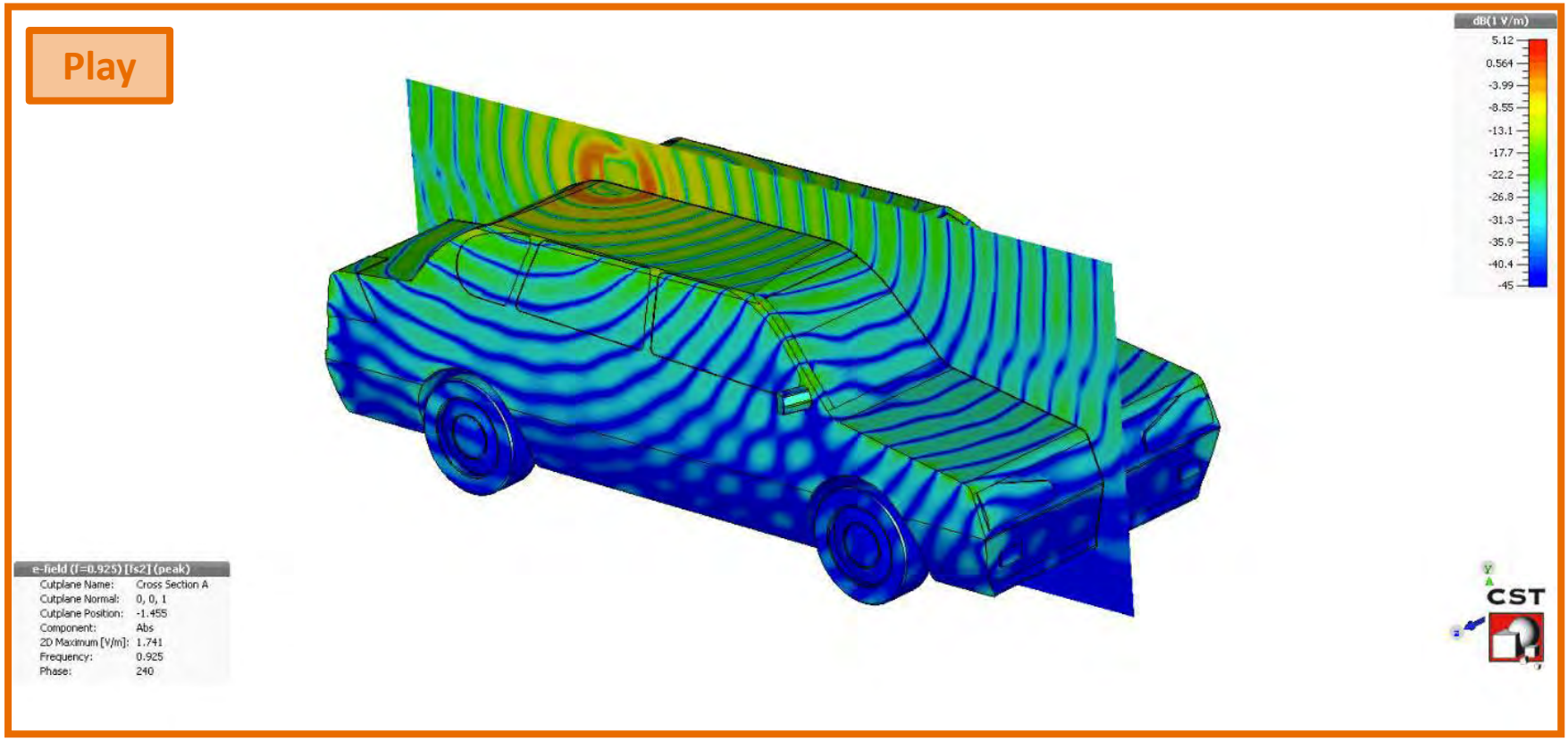
- Simulation of the radiation pattern at 925MHz with the Time Domain Solver



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=0.925) [fs2]
Component	Abs
Output	Directivity
Frequency	0.925
Dir.	5.879 dBi

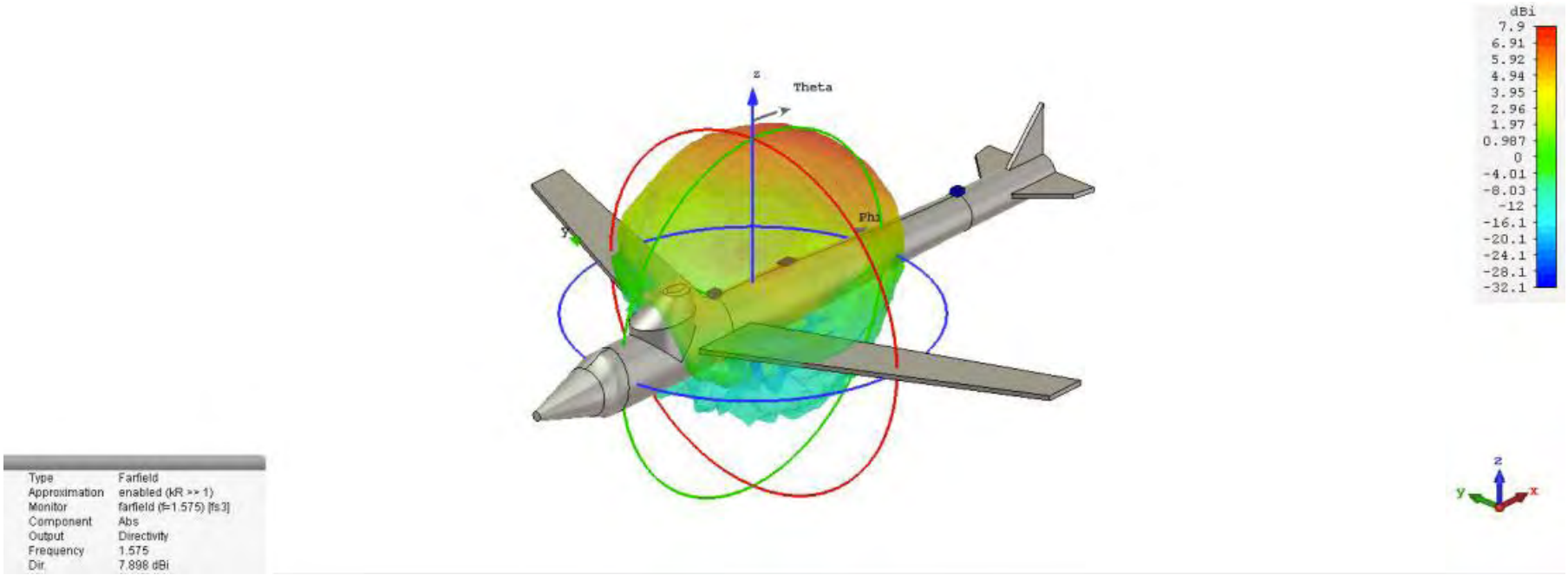
Use of the Huygens box (measured data) in CST

- Simulation of the radiation pattern at 925MHz with the Time Domain Solver

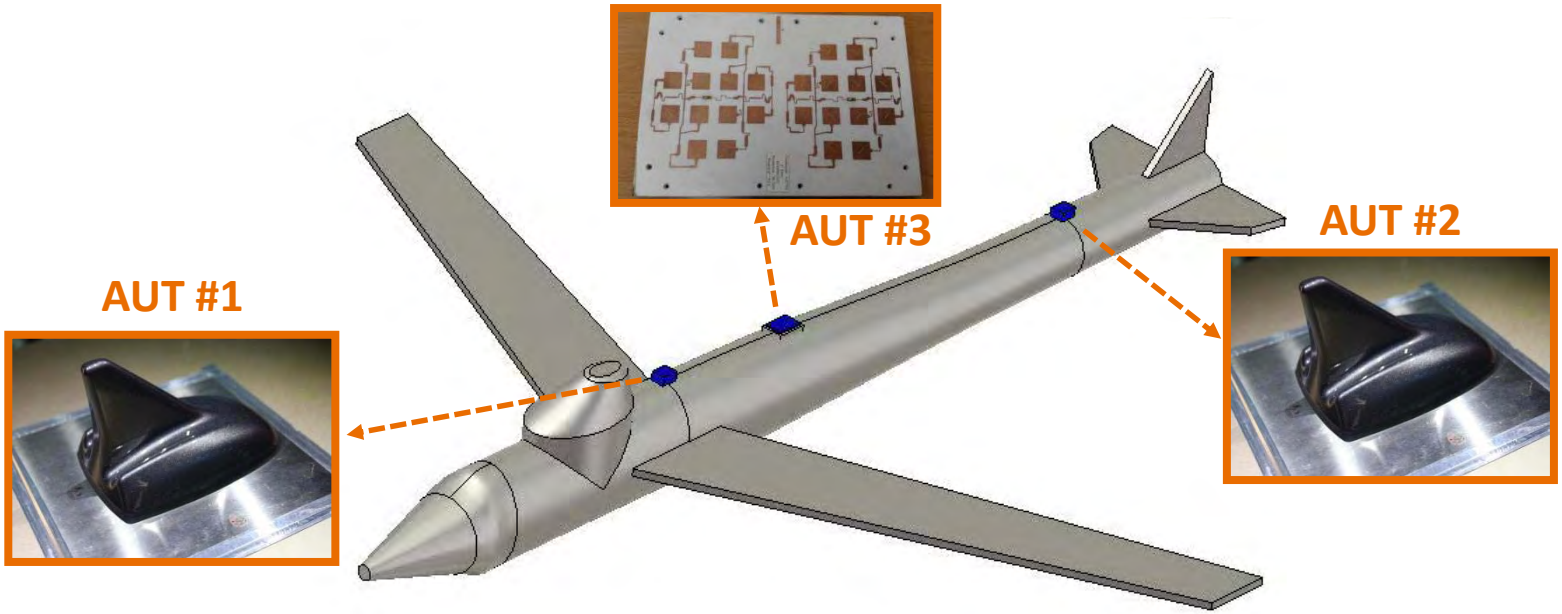


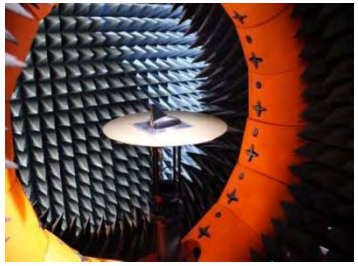
Antenna placement

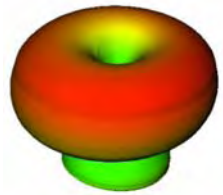
- Antenna placement and coupling between more antennas in an aircraft

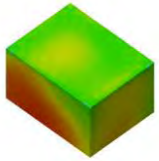


Antenna placement on an aircraft



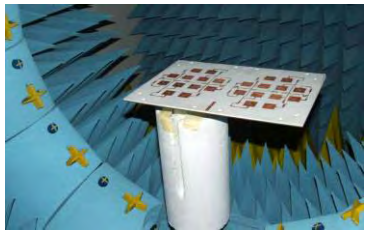


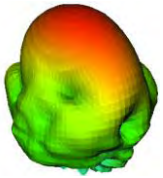


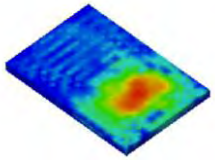


NF radiation pattern @925MHz

NF source



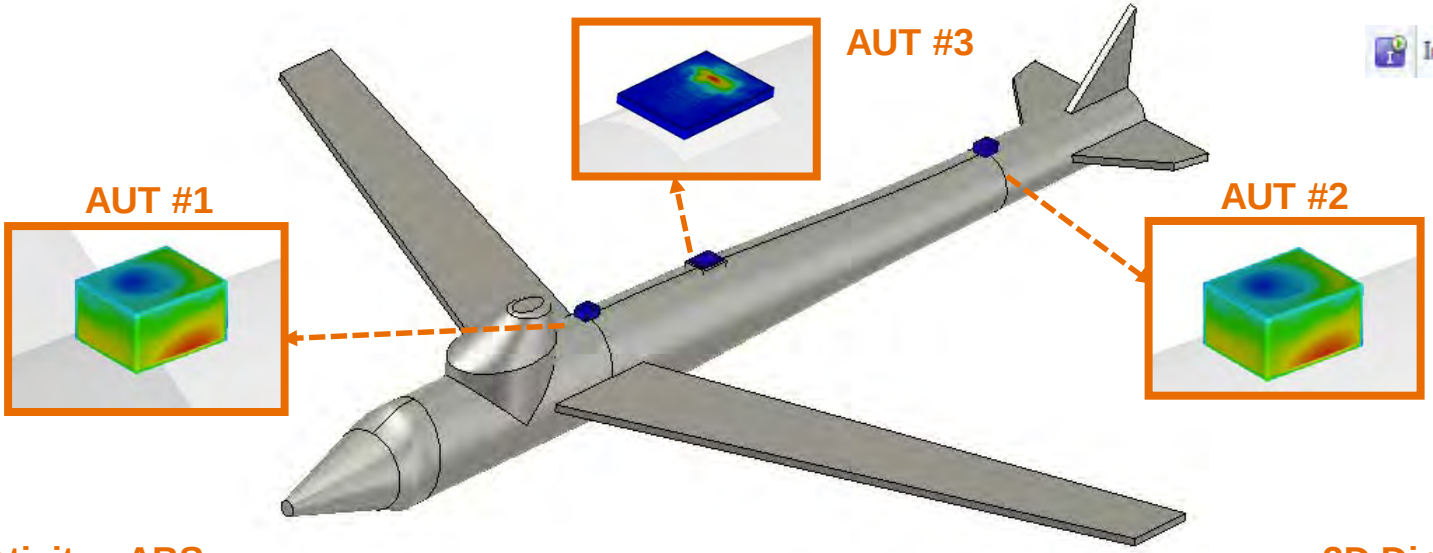




NF radiation pattern @1575MHz

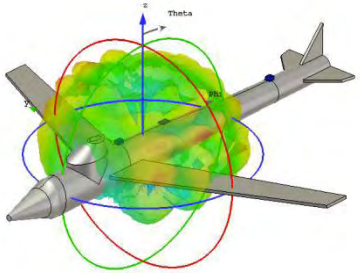
NF source

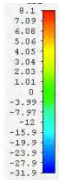
Antenna placement on an aircraft



Integral Equation Solver

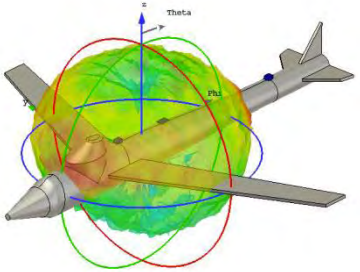
3D Directivity - ABS @925MHz AUT #1

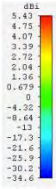




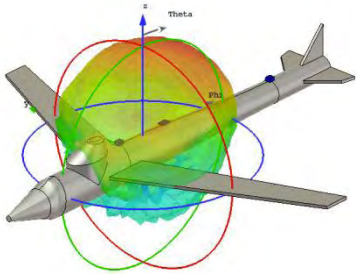
Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=0.925) [fs1]
Component	Abs
Output	Directivity
Frequency	0.925
Dir.	8.181 dBi

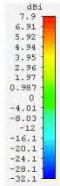
3D Directivity - ABS @925MHz AUT #2





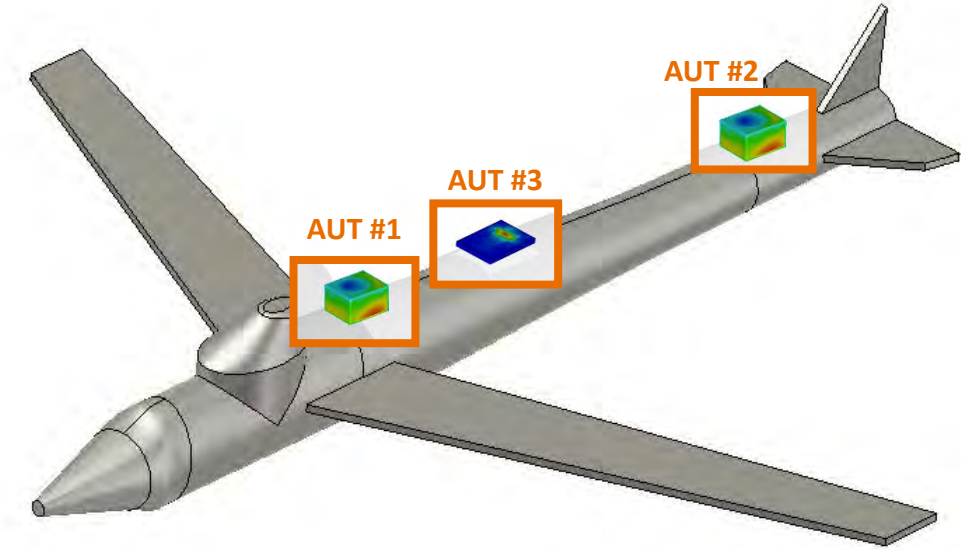
3D Directivity - ABS @1575MHz AUT #3

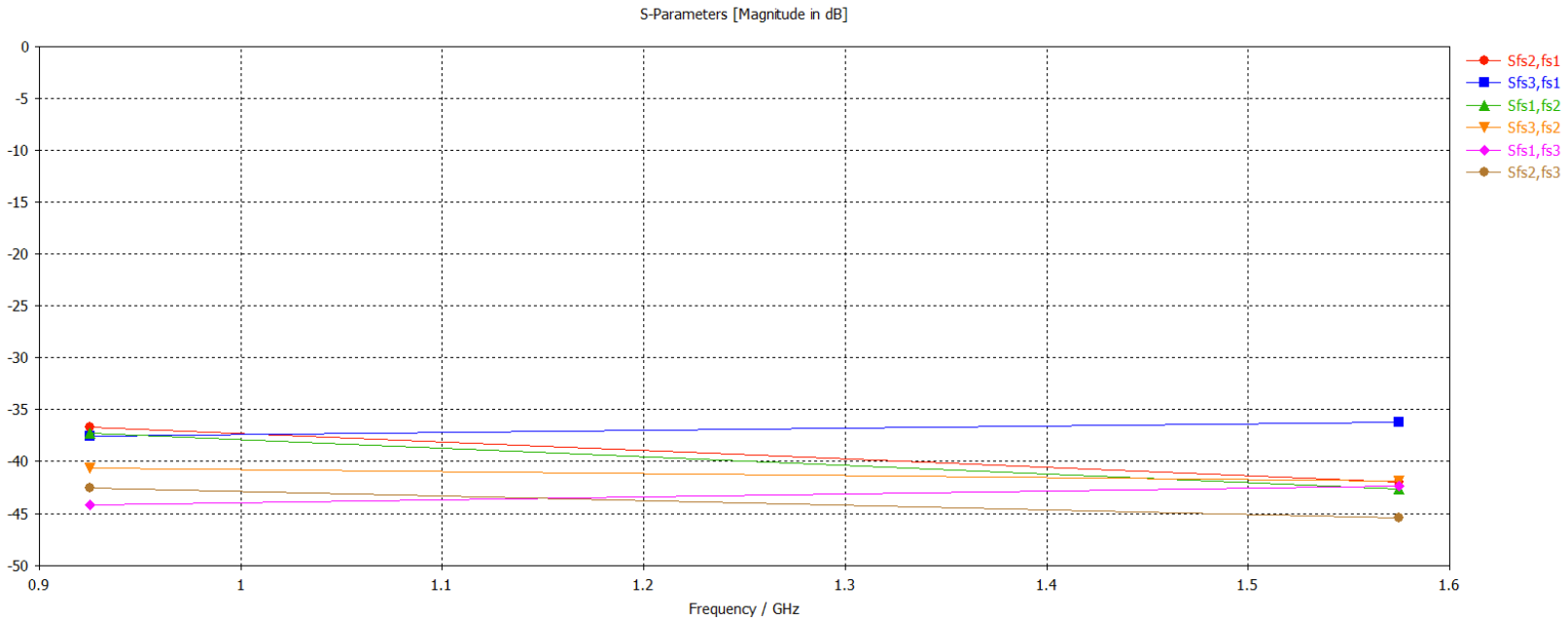




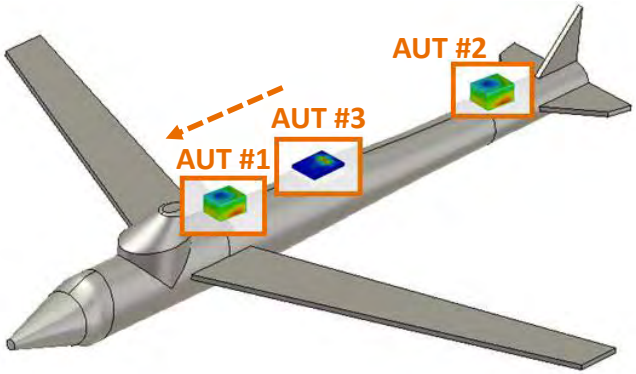
Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=1.575) [fs3]
Component	Abs
Output	Directivity
Frequency	1.575
Dir.	7.898 dBi

Antenna placement and coupling on an aircraft

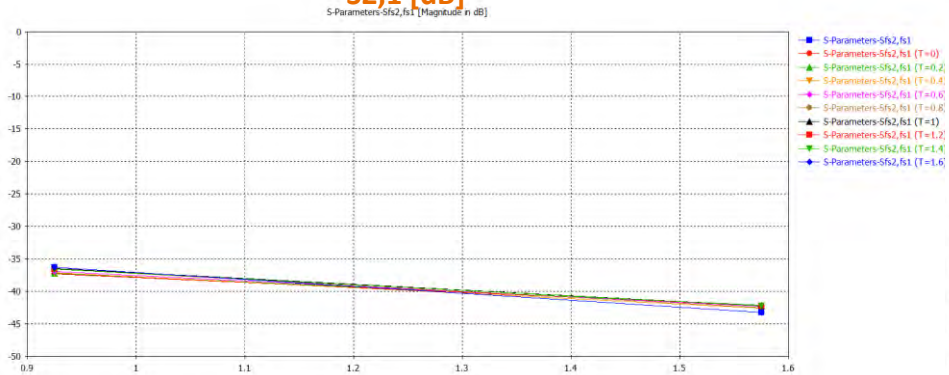




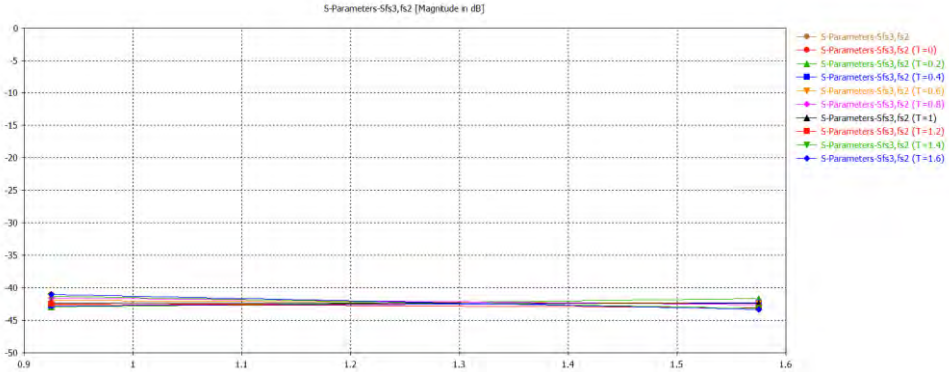
Antenna placement and coupling on an aircraft



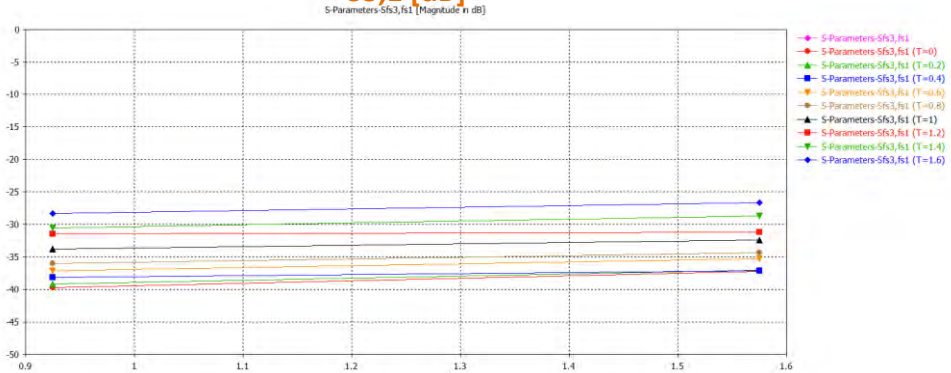
S2,1 [dB]



S3,2 [dB]



S3,1 [dB]

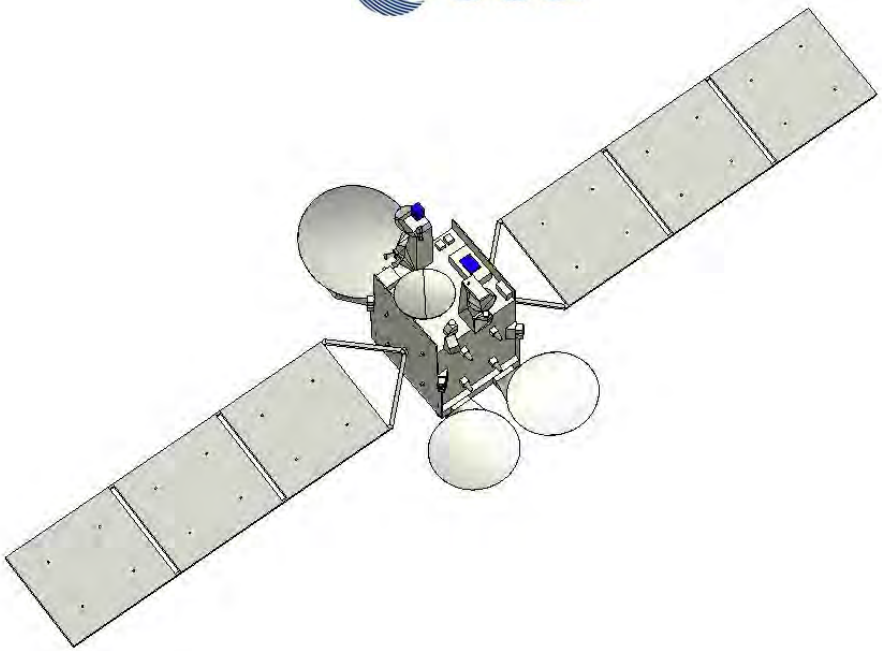


T = translation along the long side of the aircraft [m]

Application examples

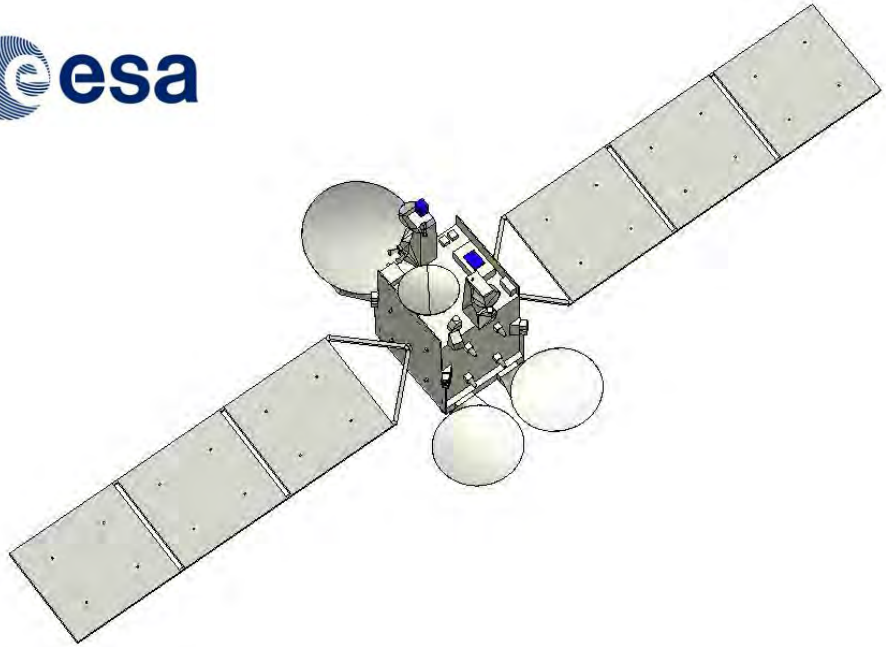
Antenna placement

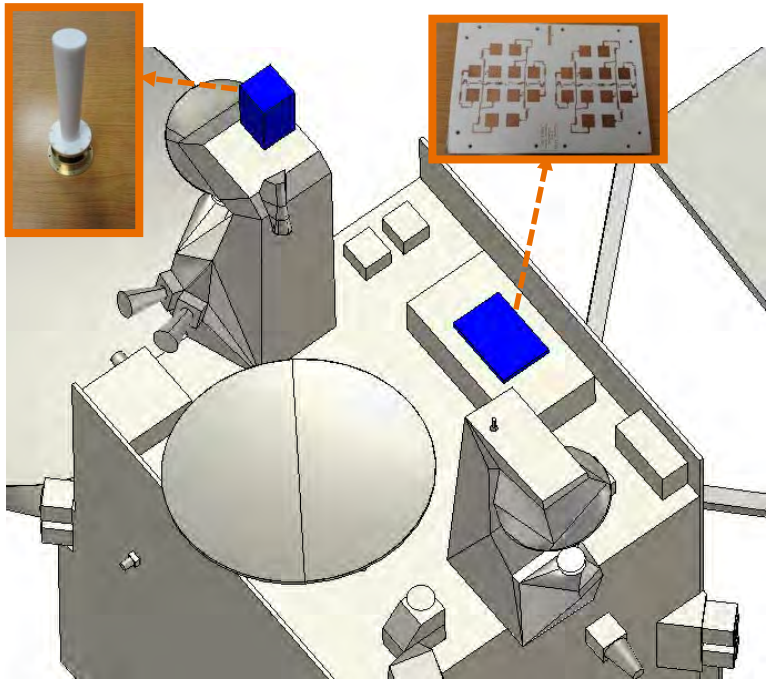
- Antenna placement and analysis in the Emerald satellite

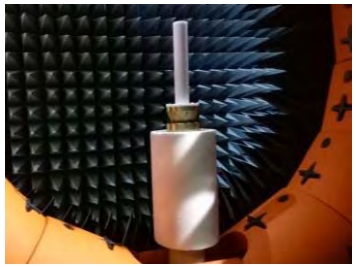


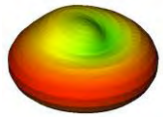
F. Mioc, M. Saporetti, M. Sabbadini, M. Del Muto, "Application of the Structure Data Dictionary to Satellite Antenna Modelling", EuCAP, Davos, Switzerland, April 2016.

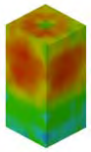
Antenna placement on the Emerald satellite





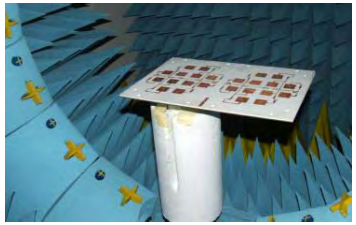


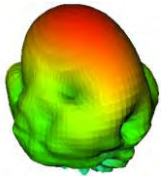


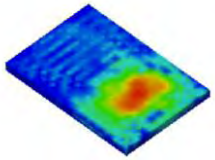


NF radiation pattern @2200MHz

NF source



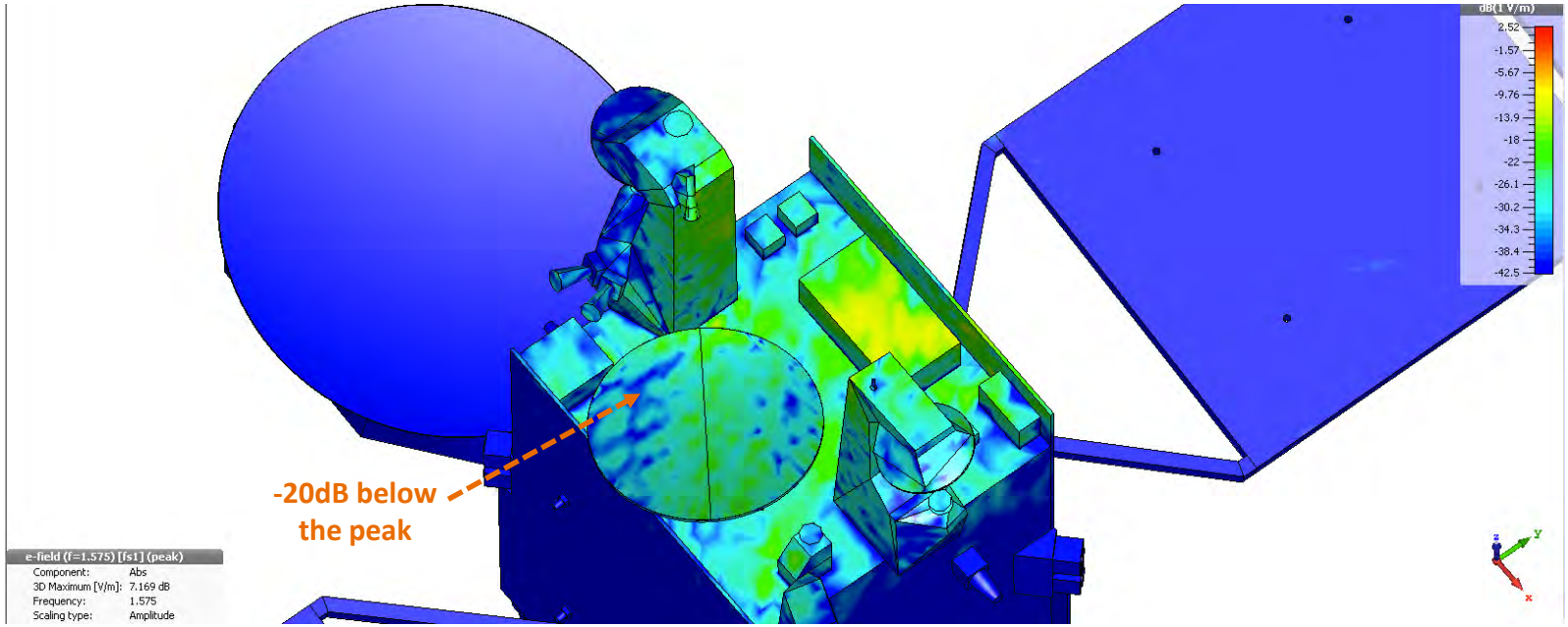




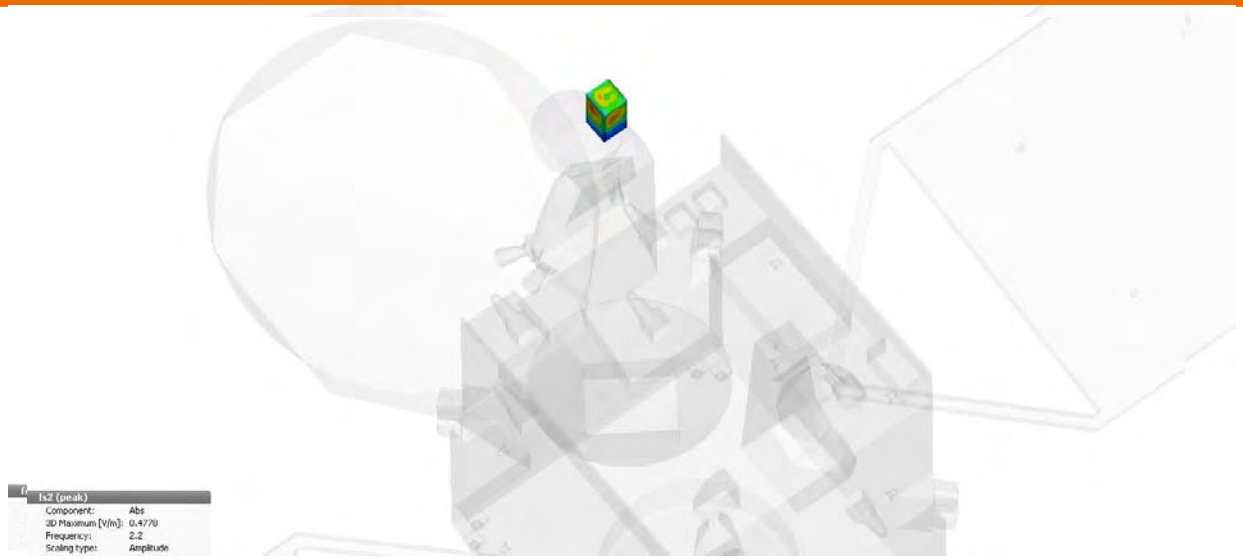
NF radiation pattern @1575MHz

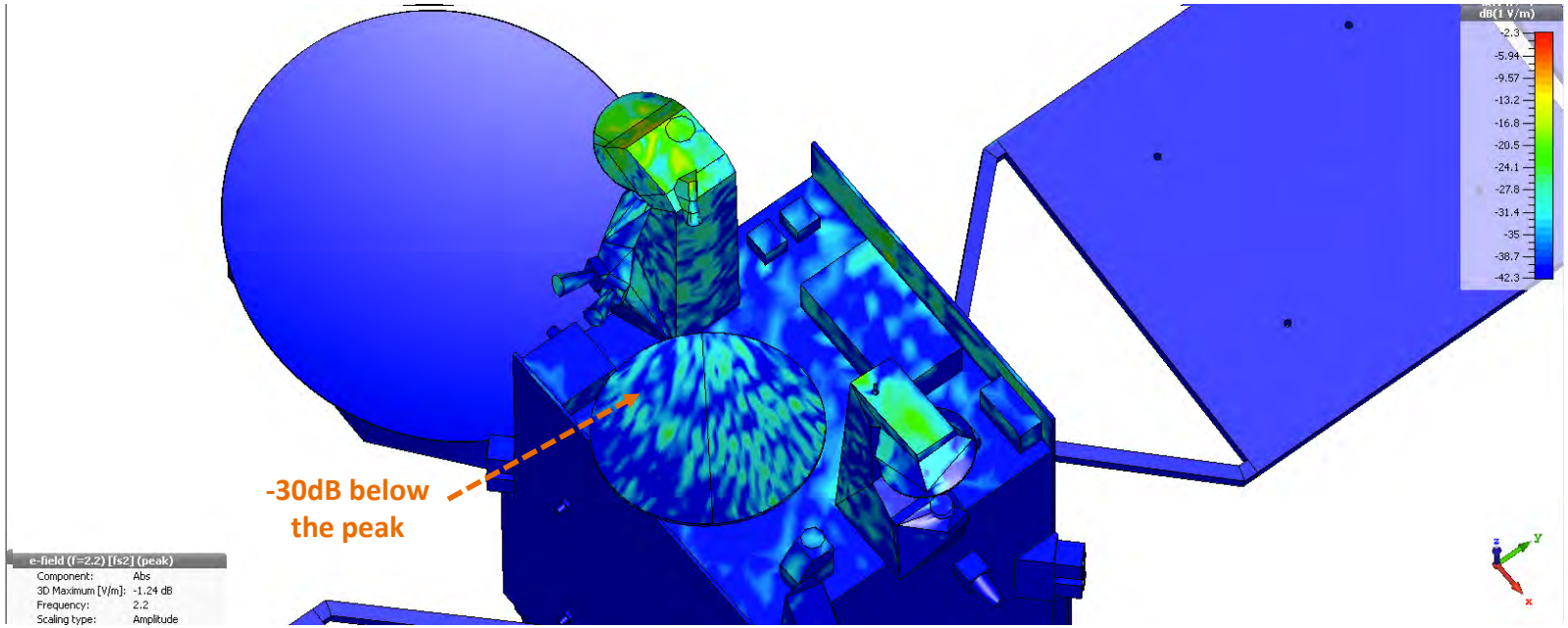
NF source

Antenna placement on the Emerald satellite



Antenna placement on the Emerald satellite

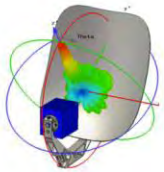




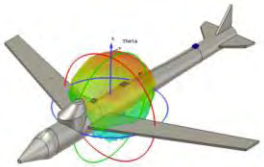
Summary and conclusion

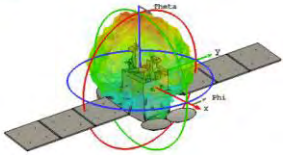
- INSIGHT processing is a revolutionary approach to link numerical simulations and antenna measurements.
- The method can be applied to various scenarios: complex environments, antenna placement scenarios and EMC applications.
- We are continuing to improve the source representation using INSIGHT processing and “the link” with CST.

- Antenna design

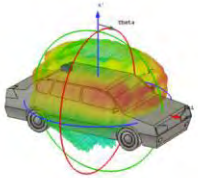


- Aerospace

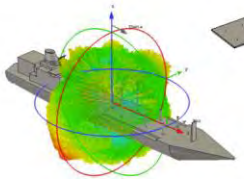




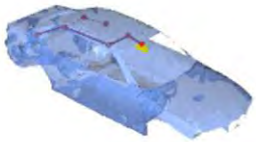
- Automotive



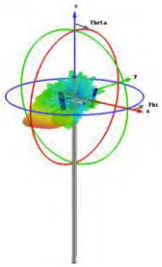
- Naval



- EMC



- Telecommunication



Thank you!
Questions?