航空航天中的
典型高频问题仿真工程实例

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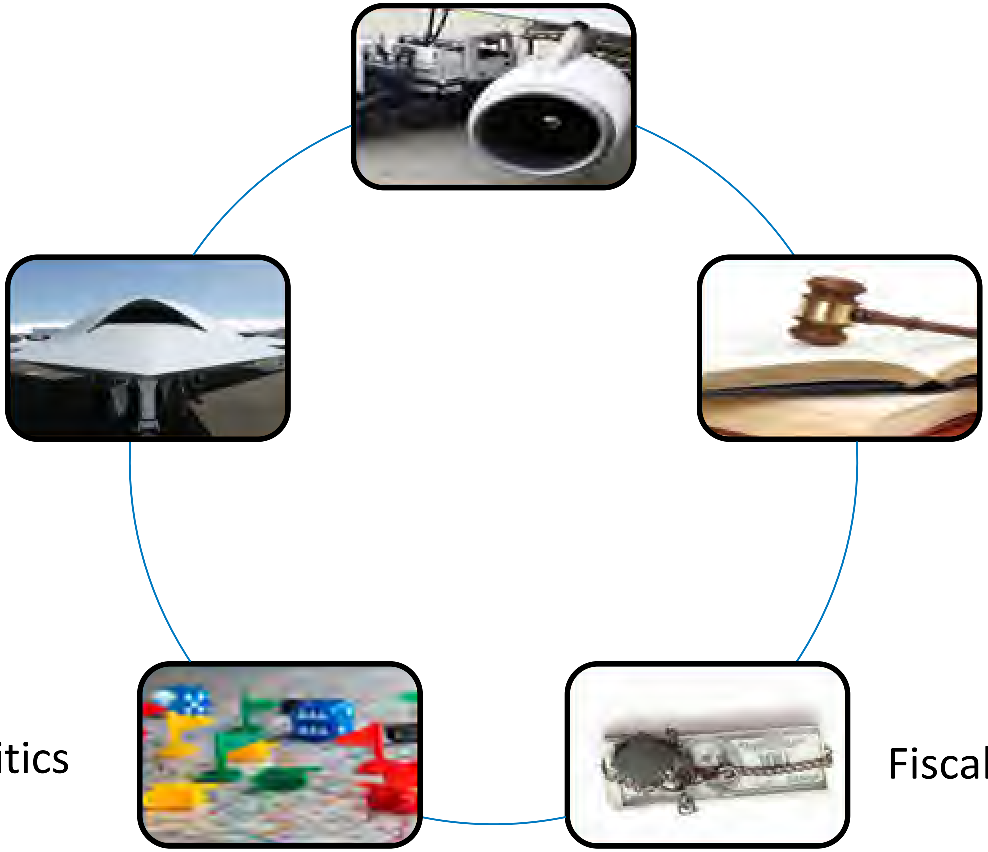
内容概要

- **航空航天中的高频问题及其ANSYS解决方法**

- **典型高频问题仿真工程实例**
  - 带罩测向天线阵列仿真案例
  - 阿帕奇直升机天线布局设计
  - 星载天线的热效应仿真
  - 雷击及防护设计

Global Trends are Shaping the Aerospace and Defense Industry



Rising Fuel Cost

Warfare Revolution

Evolving Regulation

Geopolitics

Fiscal Constraint

The Industry Continues Its Adoption of Simulation to Meet Its KBIs

ANSYS strategy is aligned with industry requirements

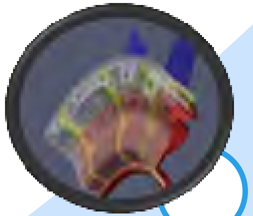
Advanced Simulation
Orbital ATK saves $10m with each full scale test they replace with CFD

Advanced Technologies

Coupled Simulation
SpaceX saves hundreds of thousands of payload equivalent dollars

Virtual Prototyping

Cloud, HPC & ACT
Rolls Royce run simulations 5 times faster

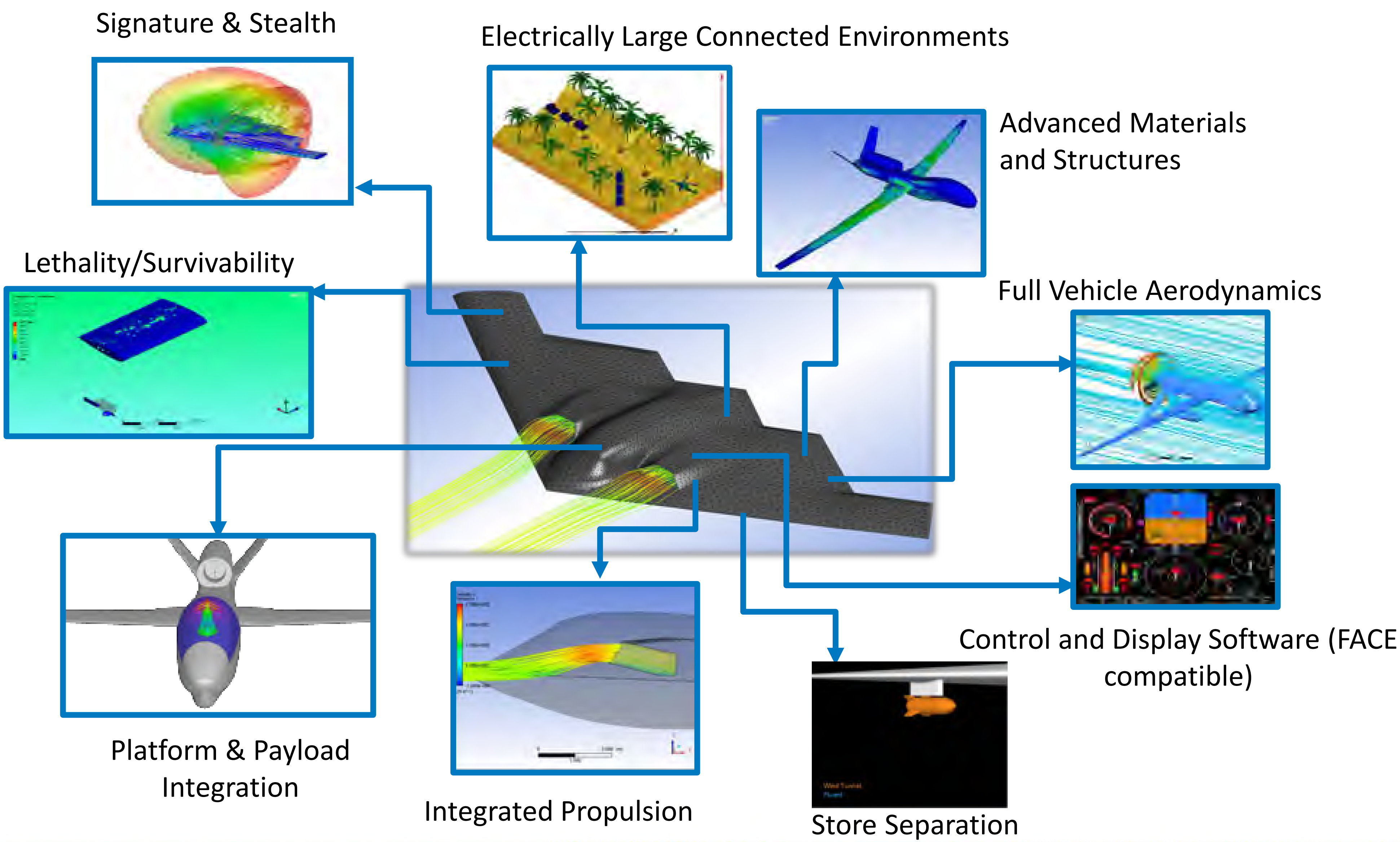


Process Compression

Digital Twin Concept
e.g. The Airbus Digital Mock-Up, The US DoD Digital Thread Initiative, The Model Based Enterprise

Dynamic CAE Collaboration

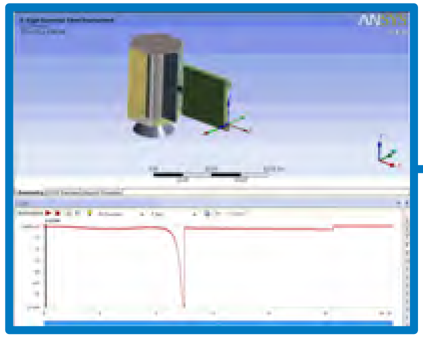
Solutions for Defense

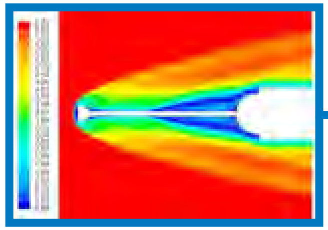


Solutions for Space

Payload Robustness

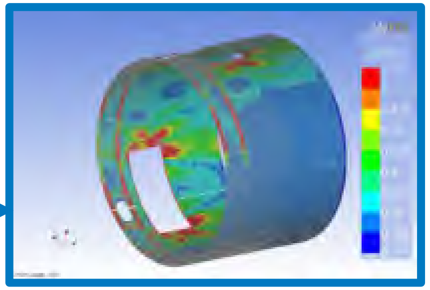
Satellite Design

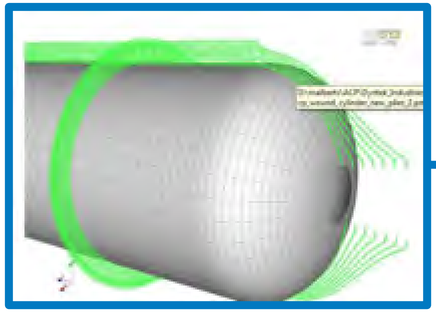




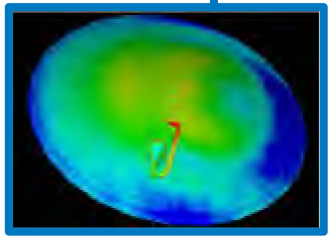
Hypersonics

Structural and Thermal Management

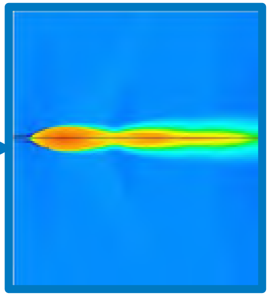




Propellant Management Device Tanks



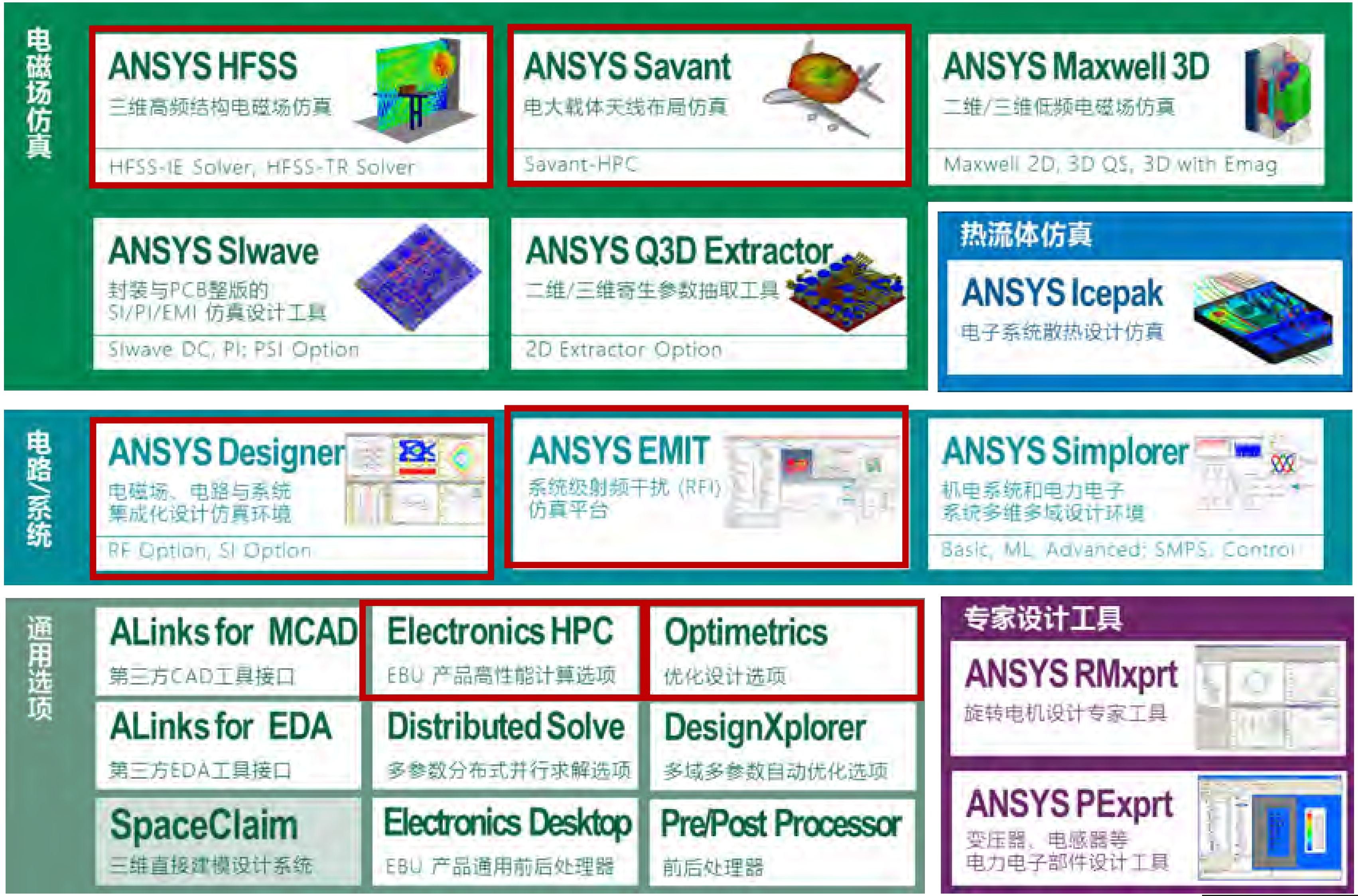
Space and Ground Station Communications



Propulsion Systems

EBU 产品体系

- **航空航天中的典型高频问题**
  - 雷达及系统
  - 天线与天线罩
  - 高速电路
  - 天线布局
  - 射频干扰
  - 雷击/HIRF
  - RCS



带罩测向天线阵列仿真

Direction finding antenna array with radome

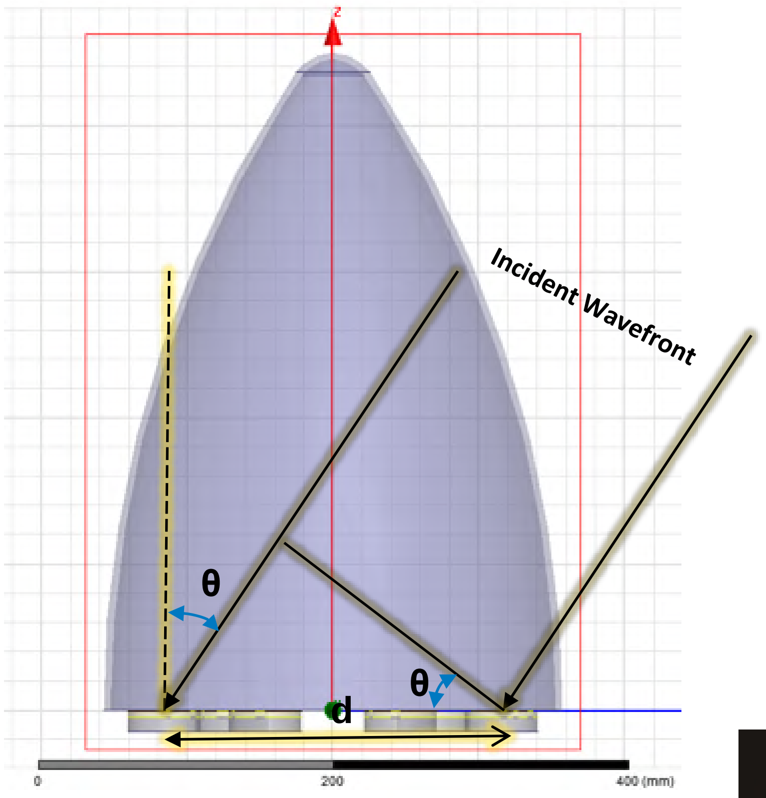
- DF array consists of spiral antennas configured in receiving mode, used in estimating the Angle of Arrival (AoA) of an incident wave.
- Phase difference between Rx antennas used to find AoA.
- Effect of radome in phase distortion is very important and needs to be determined.
- Solution: HFSS, HPC pack

$$\Delta\varphi = \frac{2\pi * d}{\lambda}\sin\theta$$

$\Delta\varphi$: Phase difference between elements

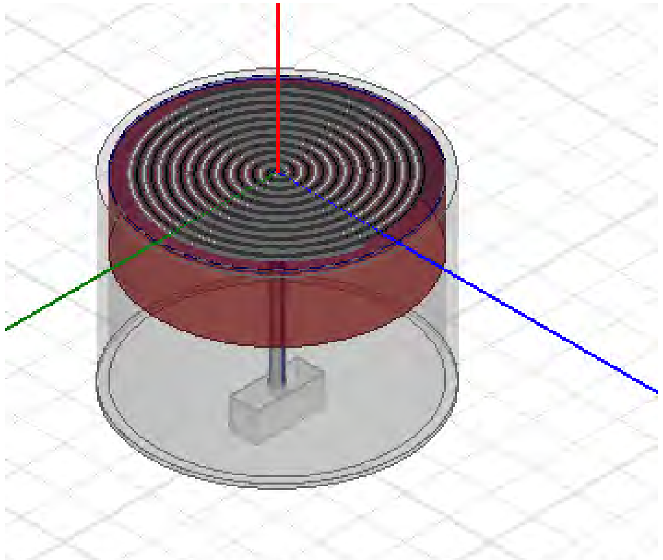
θ : Angle of arrival

Capture $\Delta\varphi$ with HFSS

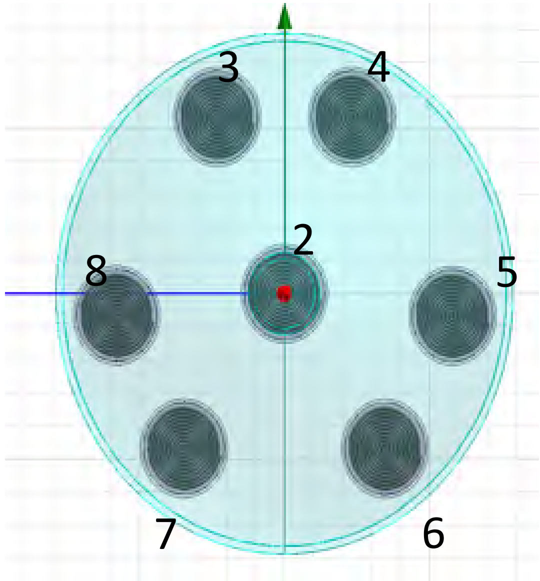


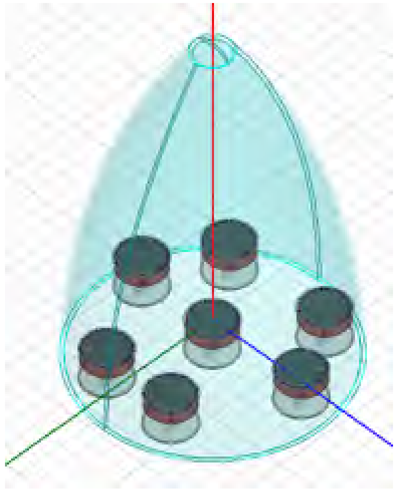
Simulation methodology

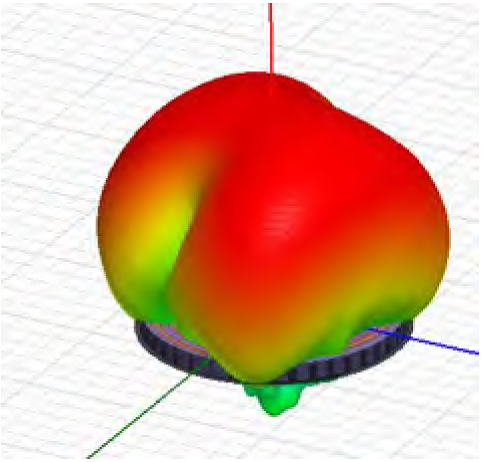
- Cavity-backed spiral antenna used – wide bandwidth with no back-lobe.
- Radome: 450mm height, 315mm dia
- Plane wave excitation, -30 to +30deg sweep
- Full FEM solution preferred, faster than using FEBI.



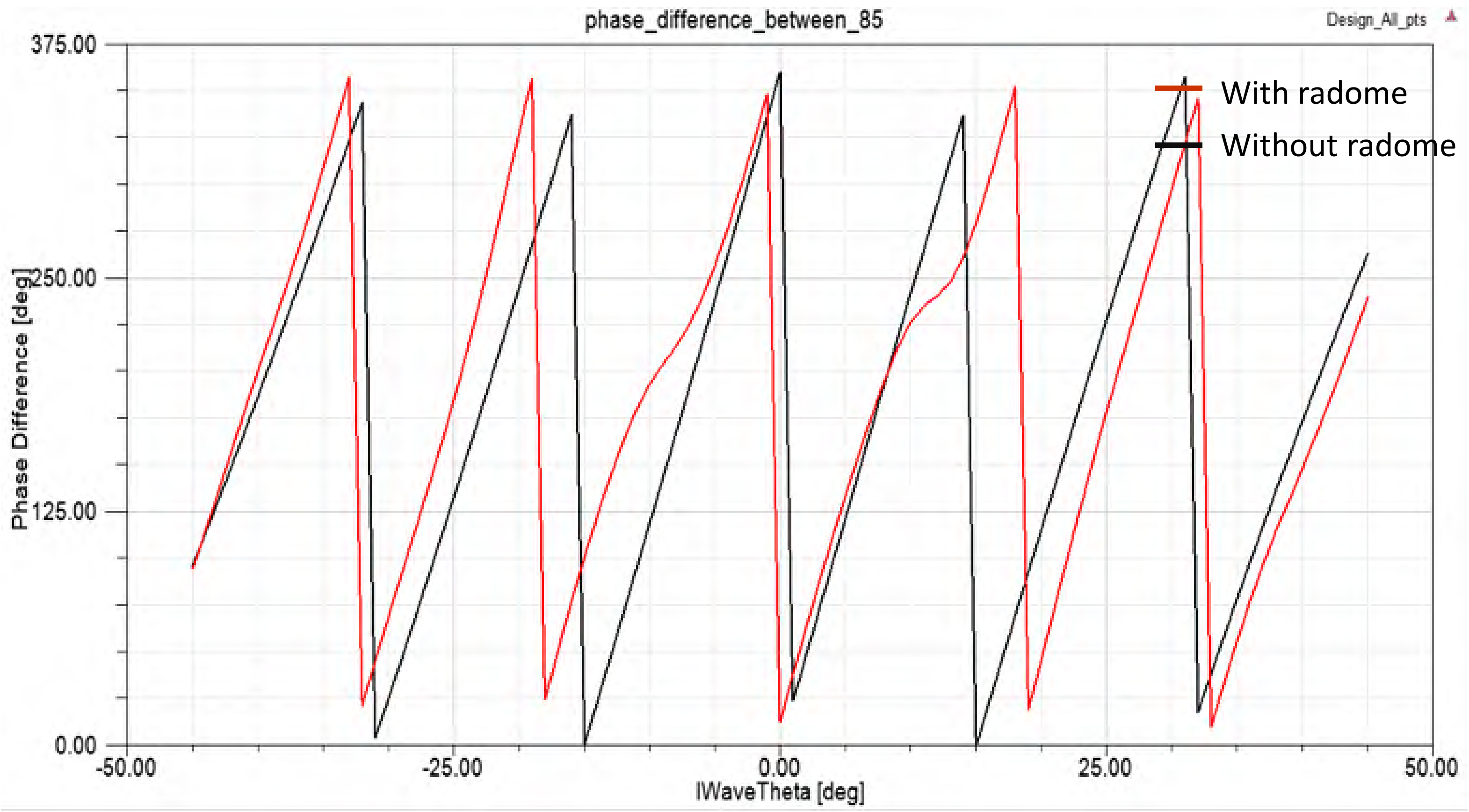
Antenna Element – Cavity-backed Spiral Antenna

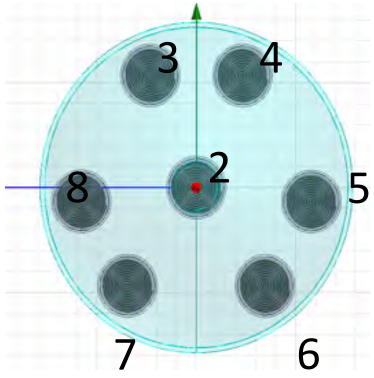






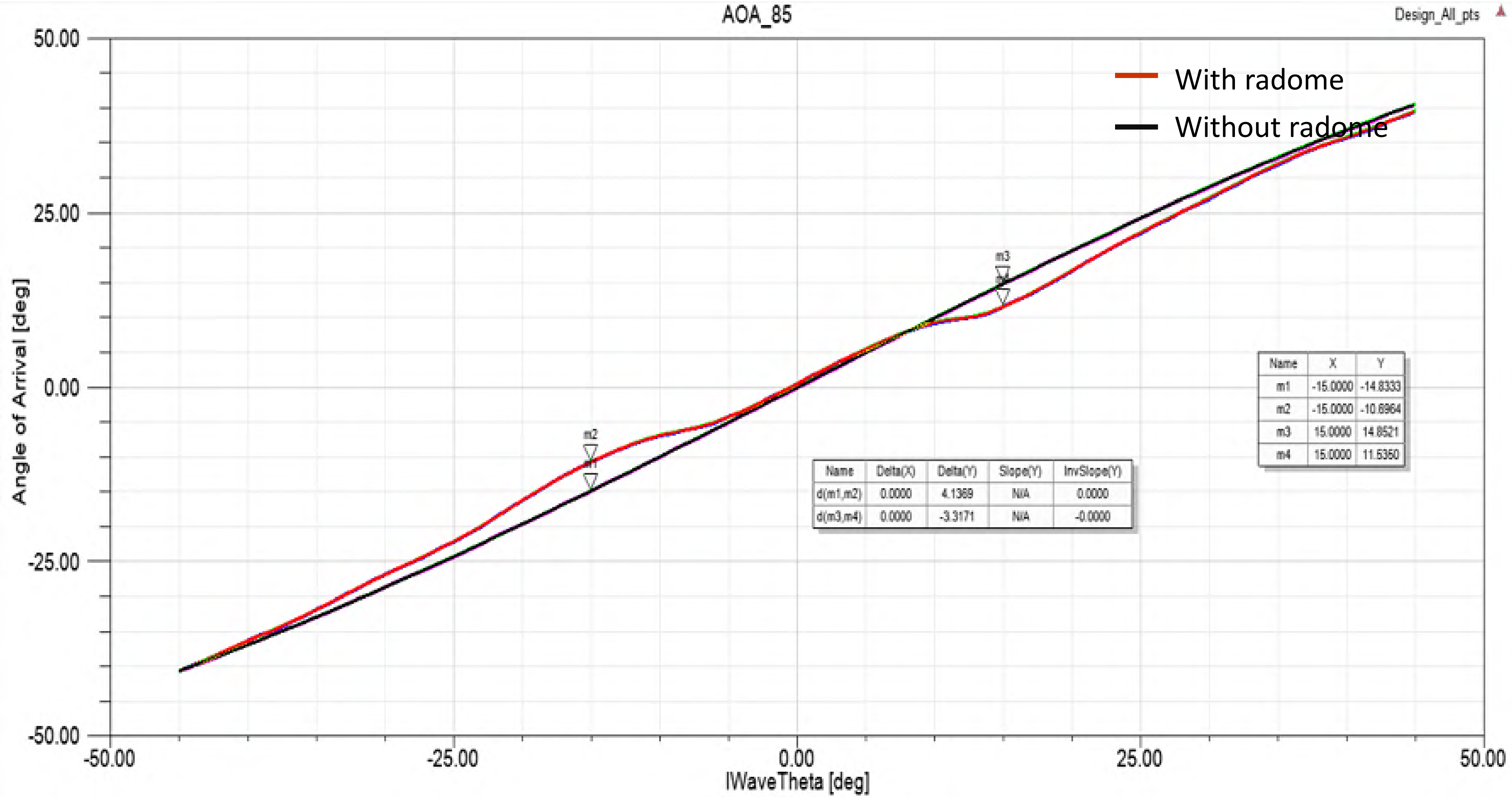
Results – effect of radome

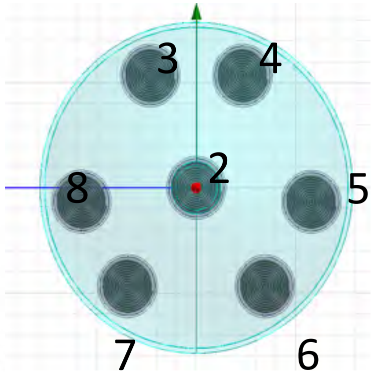




Phase difference between 8,5

Results – effect of radome





Angle of Arrival from 8,5

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Conclusion:

Learnings / points to note:

- No ports used at antenna, use polylines to find voltages and phase info
- Accurate phase information needs accurate field solution, used convergence based on phase difference values
- Full FEM faster than FEBI here
- Adaptive mesh created using only few points for incident angles. For full angle sweep, adaptive mesh takes very long time

HFSS competitive advantages:

- xxT takes very long time to simulate spiral antennas + radome, HFSS much faster
- HFSS gives accurate answer using phase angle based convergence

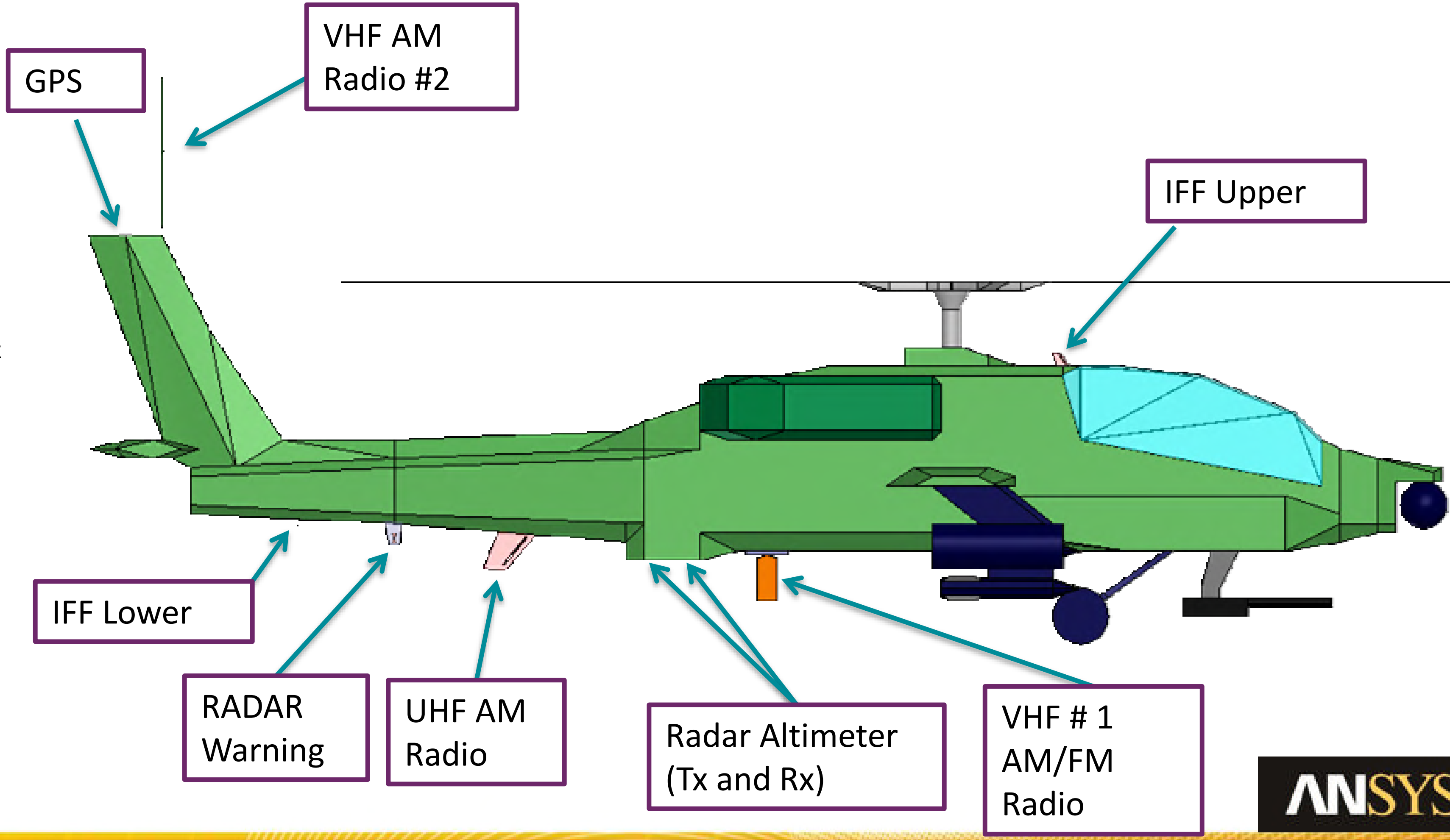
阿帕奇直升机天线布局设计

Attack Helicopter Antenna Co-site Example

- Representative platform to demonstrate HFSS-IE application to co-site antenna simulations
- Generic Attack Helicopter
- Length ~ 18 meter
- Rotor Diameter ~ 15 meter
- Several co-located antennas
- Ideally modeled using HFSS

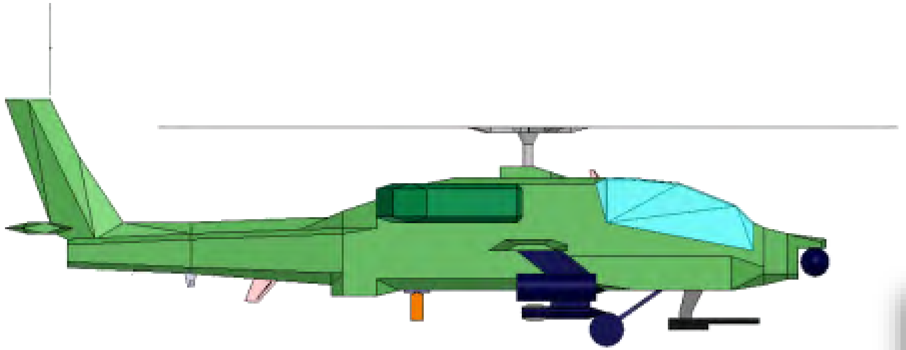
Generic Attack Helicopter: Example Antenna List

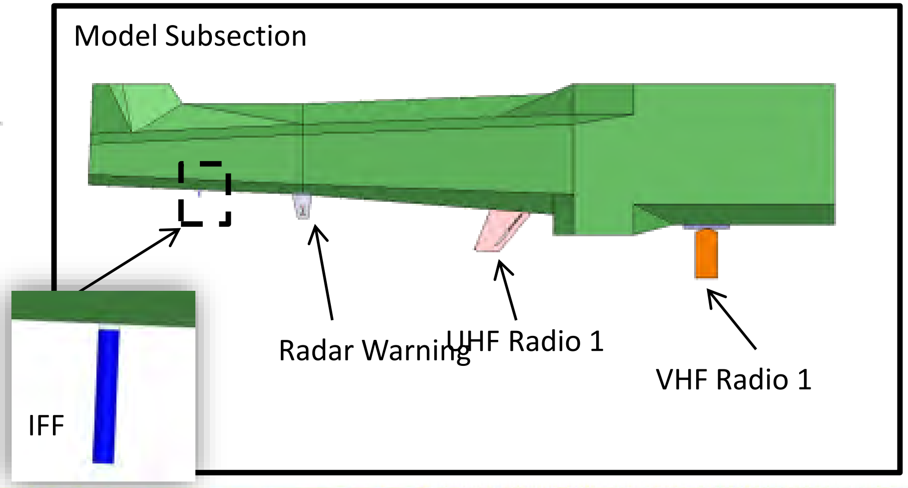
- **Typical military aircraft will operate with similar antenna elements in a co-site environment**
- **VHF AM/FM Radio #1**
  - ✓ 116MHz-151.975MHz
- **UHF AM Radio**
  - ✓ 339MHz-350MHz
- **VHF FM Radio #2**
  - ✓ 88 MHz (SINCGARS)
- **Radar Altimeter**
  - ✓ 2 Antennas (Rx, Tx) 4200MHz-4400MHz
- **Identify Friend or Foe (IFF) System**
  - ✓ 2 Antennas - 1030 MHz – 1090 MHz
- **GPS**
  - ✓ 1575 MHz
- **Countermeasures Antennas**
  - ✓ Radar Warning



Antenna Placement

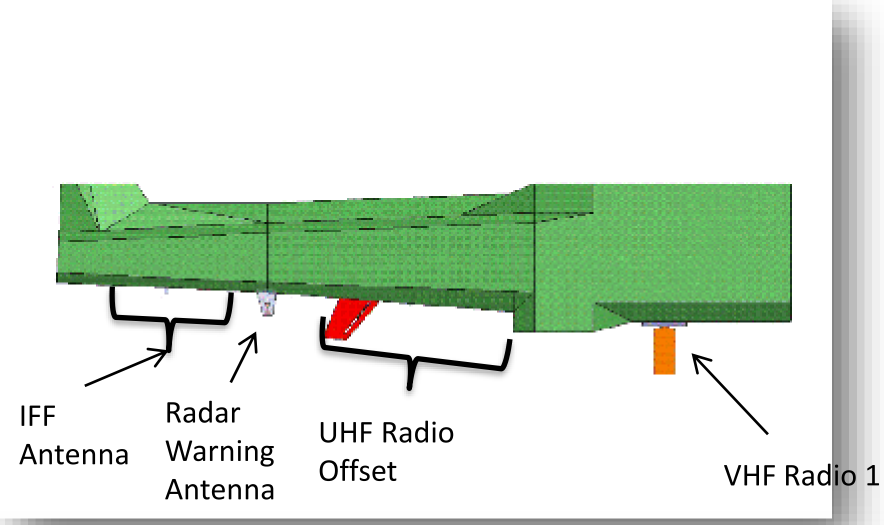
- Co-site interference mitigation
- Antenna placement to reduce coupling between antenna's
- Majority of antennas are on underside of aircraft
- Highest coupling most likely to occur between these closely spaced antennas
- Entire platform simulation not always needed to determine optimal placement of most antenna's
- Simulation of smaller subsection will yield accurate coupling predictions and quicker simulations

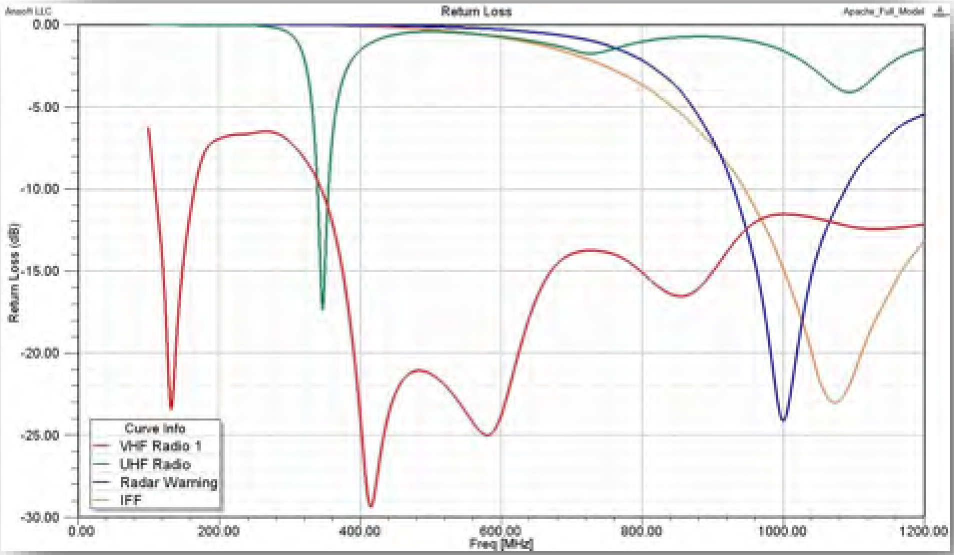




Antenna Placement

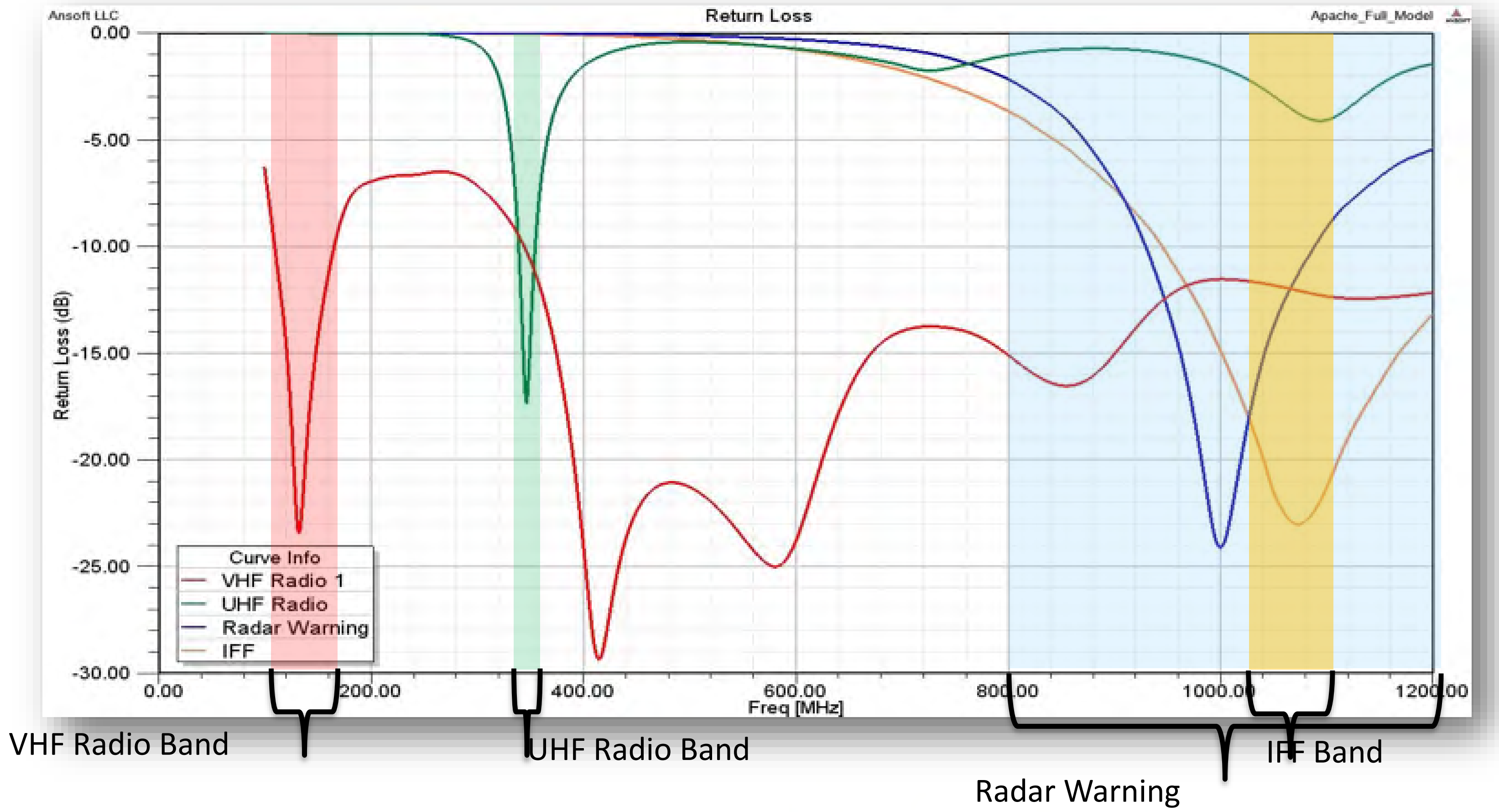
- HFSS-IE Simulation of sub-section of model shows
- Return loss is not very dependent on location along axis of airframe
- Coupling is very dependent on placement of antenna's
- Ideal locations is to spread out as far as possible between elements
- Not always possible due to mechanical limitations
- Co-site analysis is important to determine acceptable locations





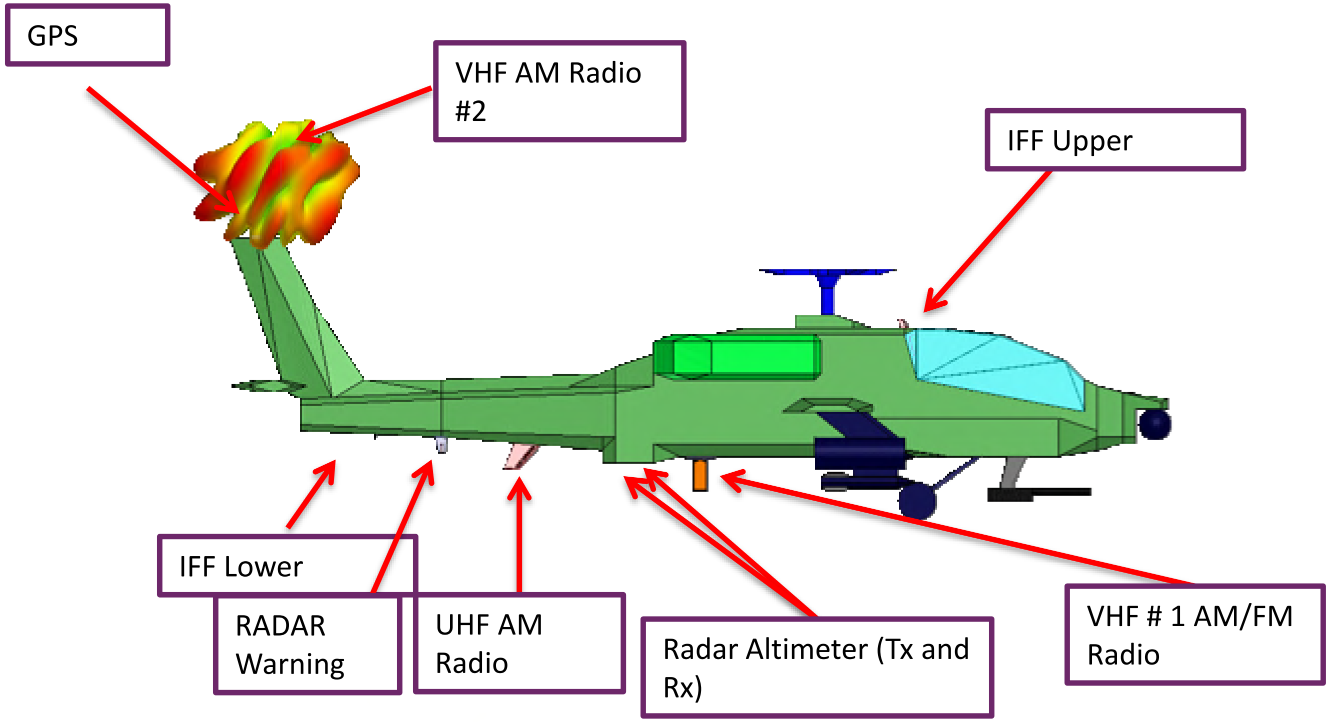
Return Loss: Operating Bands

- **Out of band performance of several antenna's could lead to higher coupling**
  - ✓ Example: At UHF Band, the VHF antenna shows a good impedance match



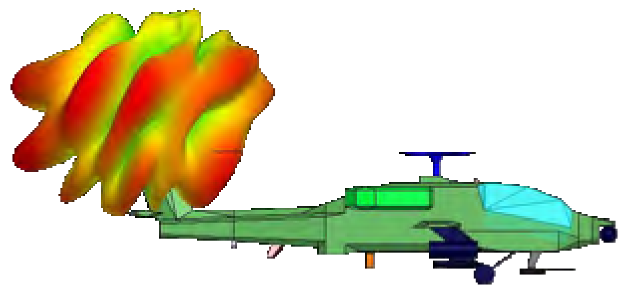
Co-site Platform Verification

- Simulation of entire platform with 9 antenna's
- 9x9 coupling matrix calculated at each frequency of interest
- Far-field pattern generated for each antenna

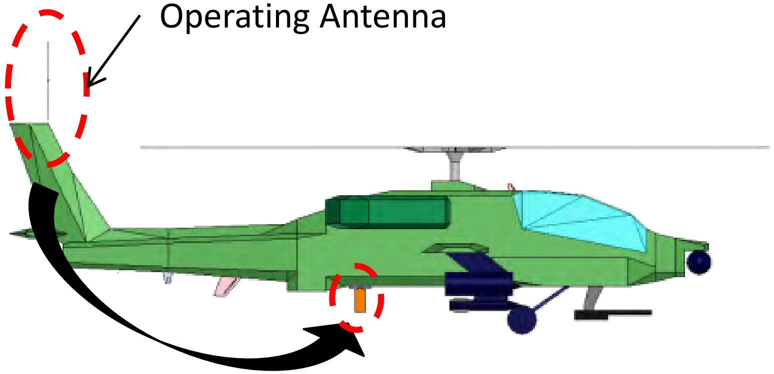


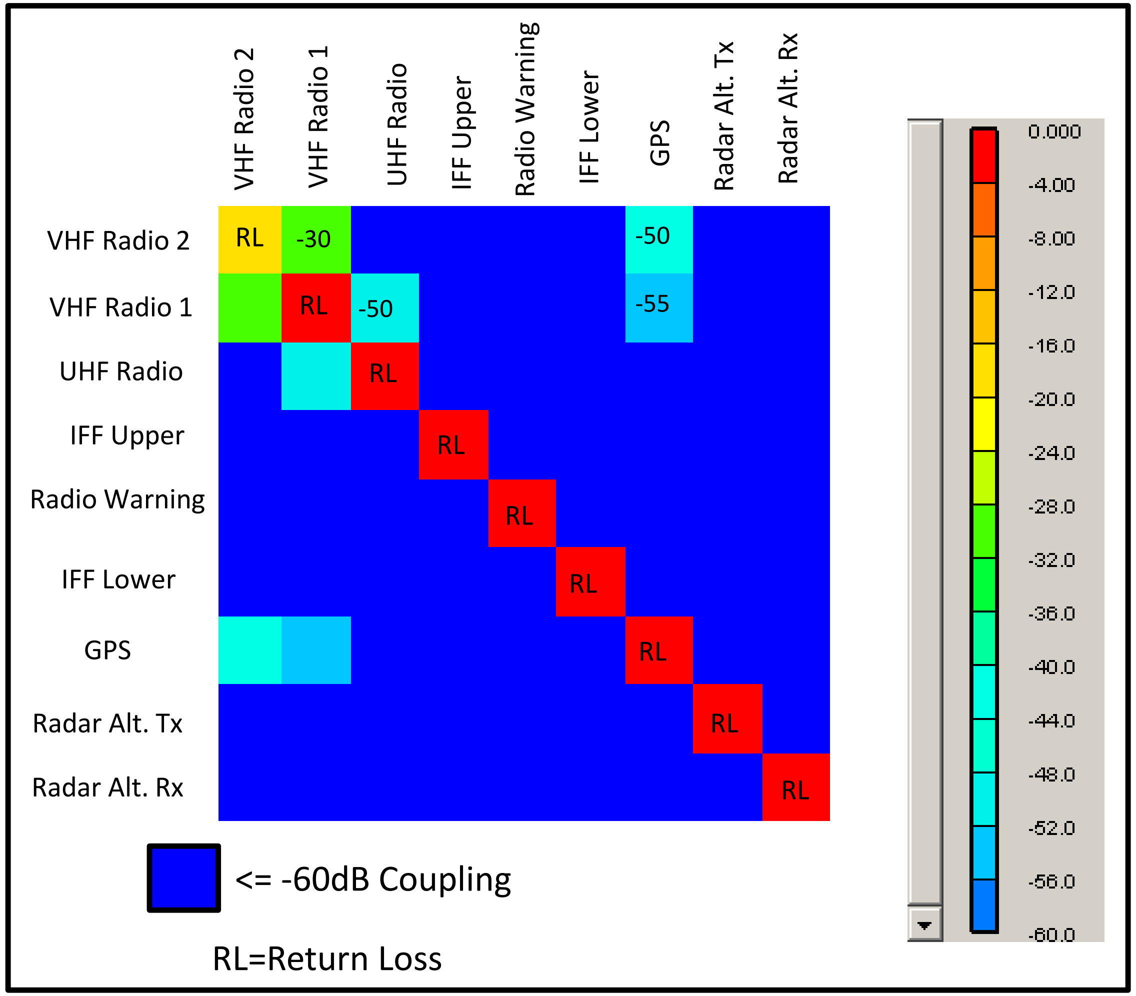
Coupling Matrix: 88MHz

VHF Radio 2 Operating Frequency



- **Coupling value on the order of -30dB can be seen for the two VHF radio despite placement**

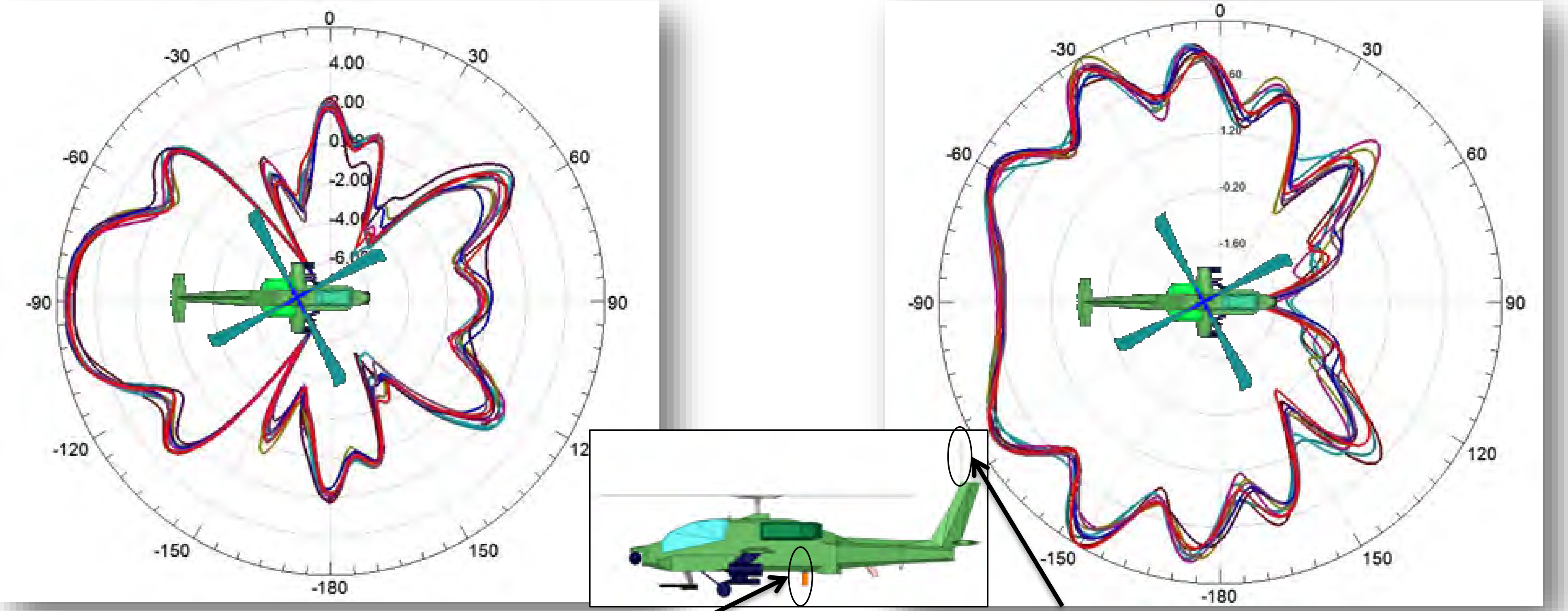




Effects of Rotor Position

- **Effect of Rotor Position**
- **Installed antenna performance**
  - ✓ Antenna impedance and coupling
  - ✓ Pattern shape
  - ✓ Rotor blade modulation
    - Quasi-stationary approach
    - Amplitude and phase distortion
- **Rotor effects observations**
- **All antenna's have only small changes in impedance and coupling with rotor positions**
- **Far field patterns are influenced by rotor position**

Total Gain Vs. Rotor Position



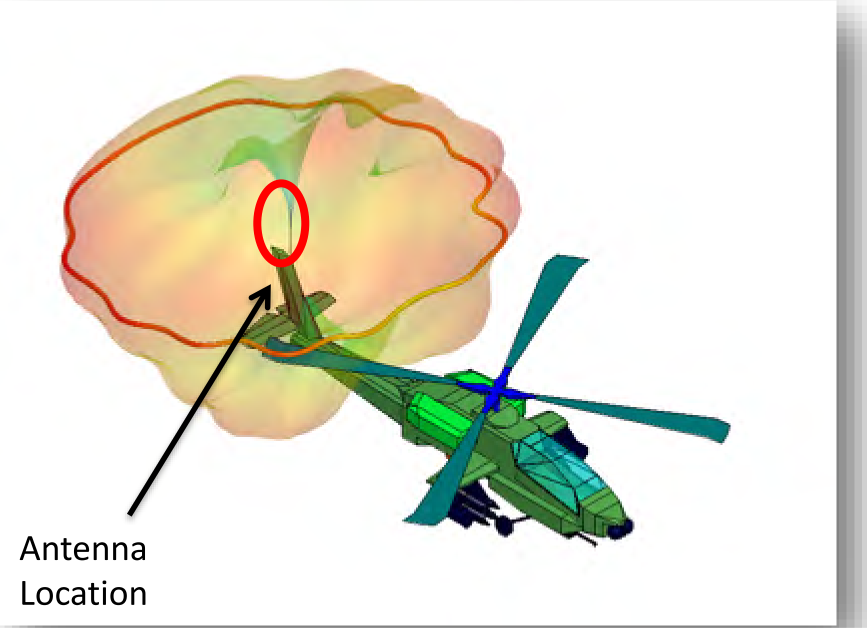
130 MHz VHF Radio 1

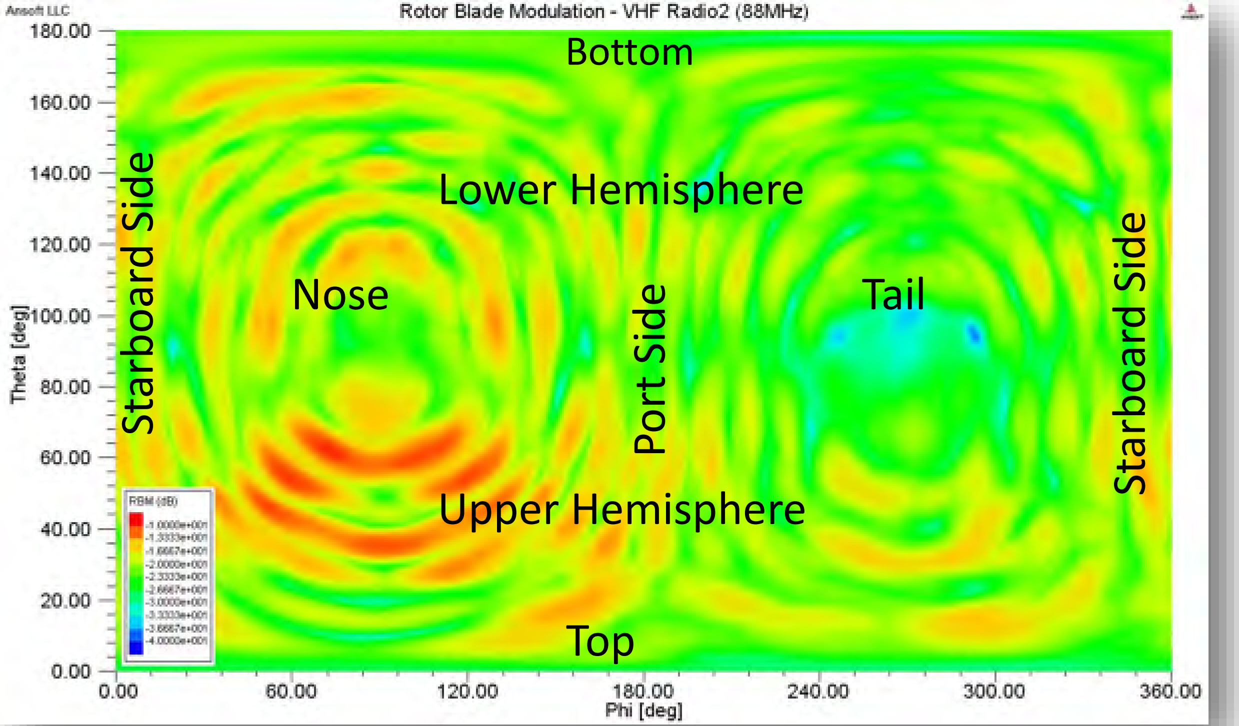
88 MHz VHF Radio 2

- Modulation effects can be seen for VHF radios
- Far field total gain values can differ by several dB for different rotor blade positions

Rotor Blade Modulation: VHF Radio 2 - 88 MHz

- VHF whip antenna mounted on tail of aircraft operating at 88 MHz
- As expected rotor blade modulation is highest in the upper hemisphere towards the nose of the helicopter and least towards the tail





$$RBM = 20\log_{10}(E_{max} - E_{min})$$

Maximum and minimum E Field determined over all rotor positions

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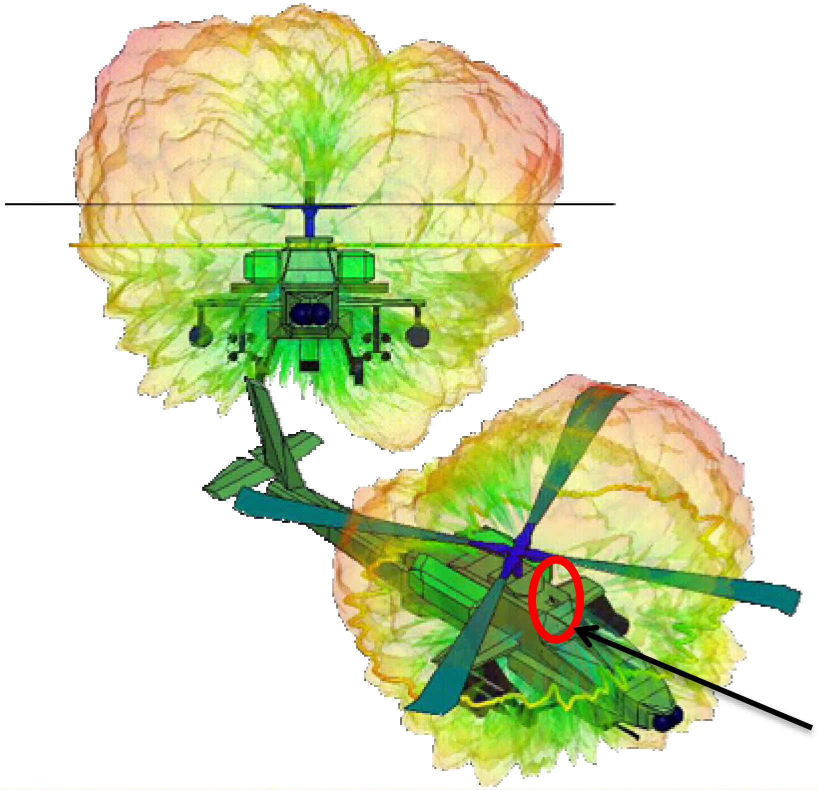
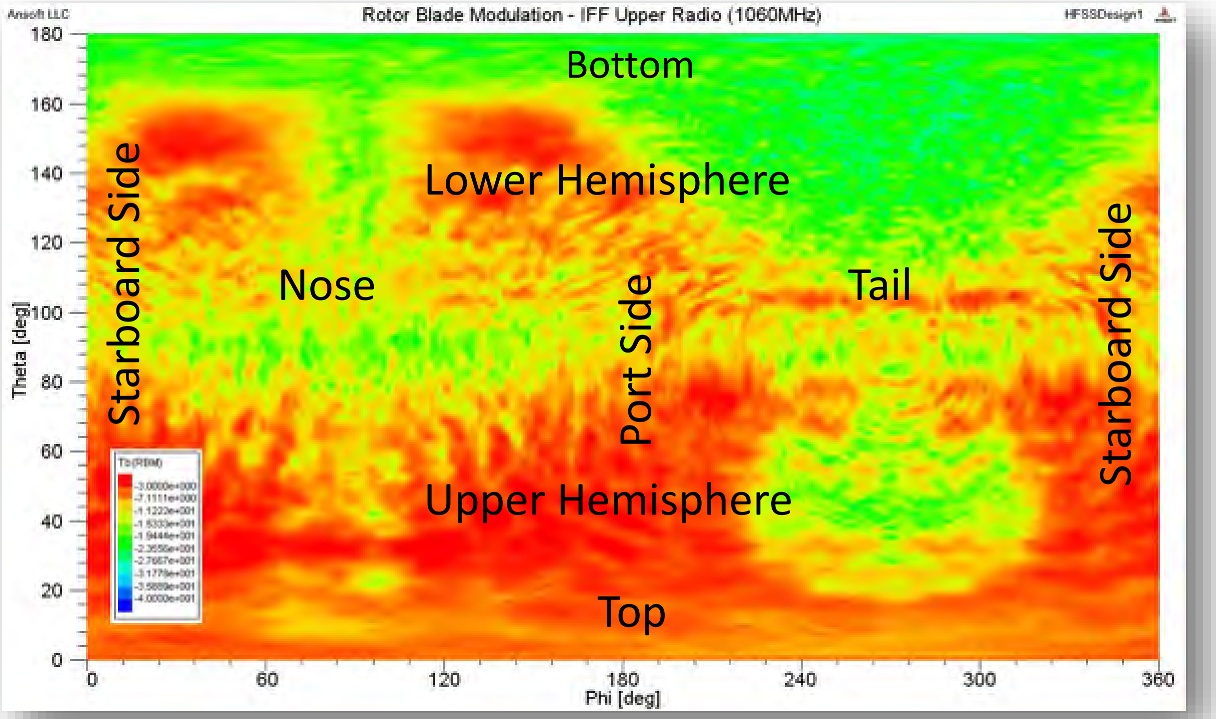
Rotor Blade Modulation: IFF Upper Radio - 1060 MHz

- Highest RBM of all antenna in upper hemisphere due to close proximity to rotor blades





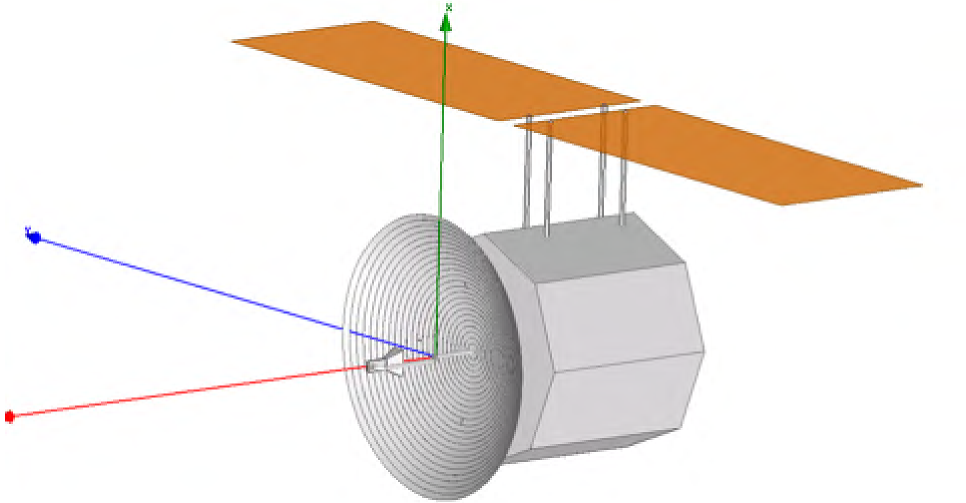
$$RBM = 20\log_{10}(E_{max} - E_{min})$$

Maximum and minimum E Field determined over all rotor positions

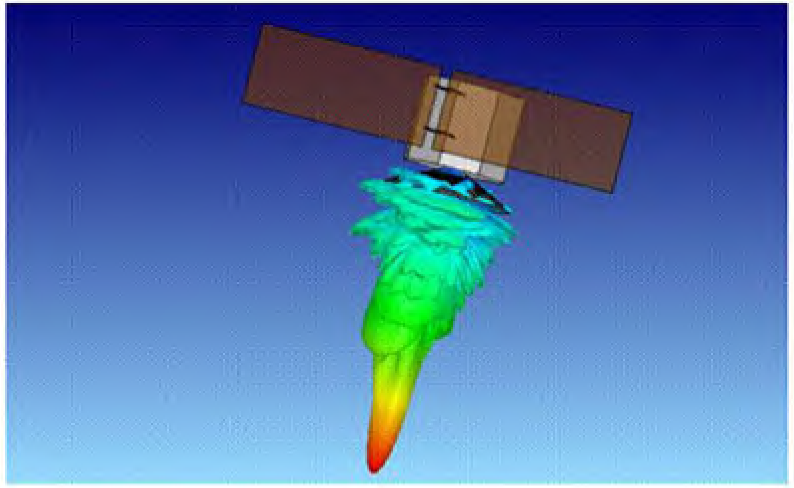
星载天线的热效应仿真

Thermal Effects on Electrical Performance

- **Need to be able to simulate thermal effects for high power systems**
- **Example:**
  - Dish Antenna on Satellite in Orbit
  - Space environment causes potential for thermal issues

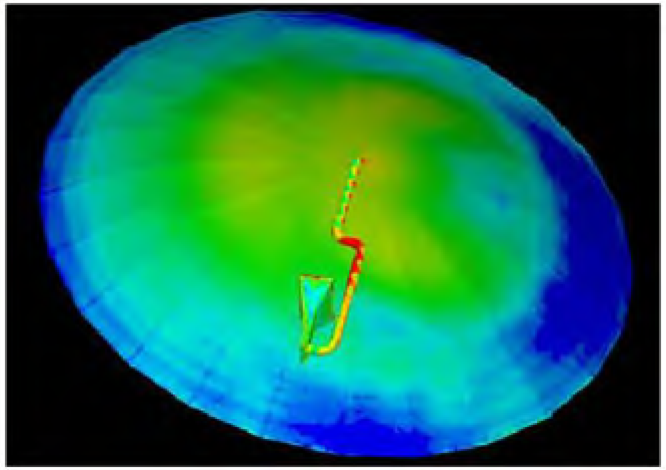


Solve for Antenna Gain

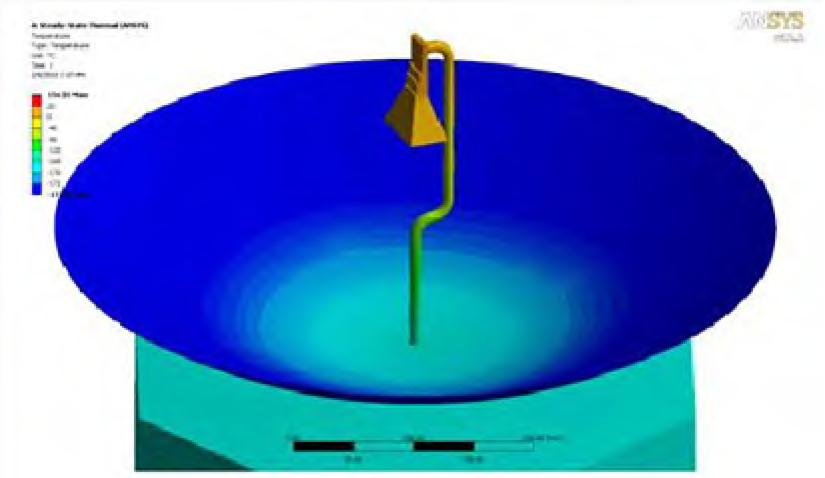


Thermal Effects on Electrical Performance

- Note the surface losses due to the use of real metals and the true power radiated by the feed!



Solve for Surface Losses

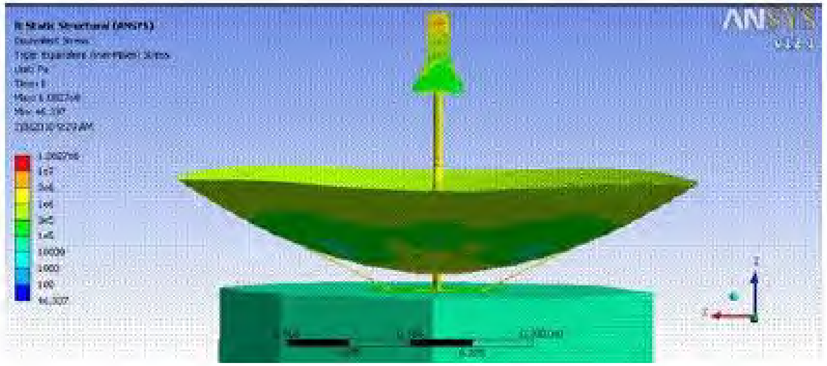


Link Solutions to Thermal Solver and determine the temperature distribution!

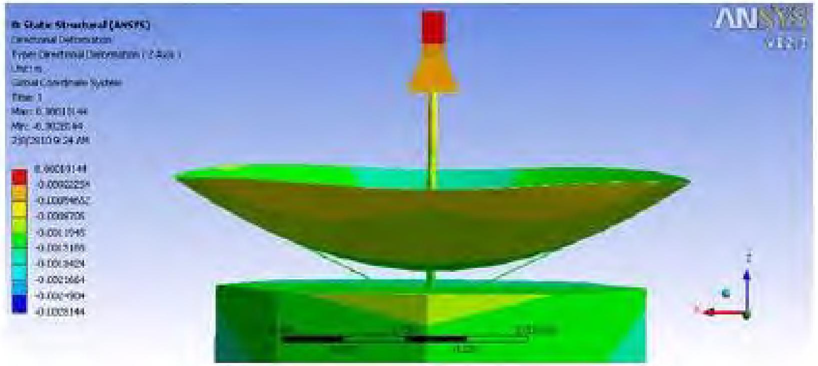
Thermal Effects on Electrical Performance

- **With the ANSYS multiphysics solutions, can now port the thermal solutions to the mechanical stress solvers!**
  - Determine the mechanical stresses and distributions
- All of this is very important for space based antennas as they are in thermally non ideal environments!
- Antenna deformation due to thermal stresses change antenna performance…

Thermally Induced Mechanical Stresses

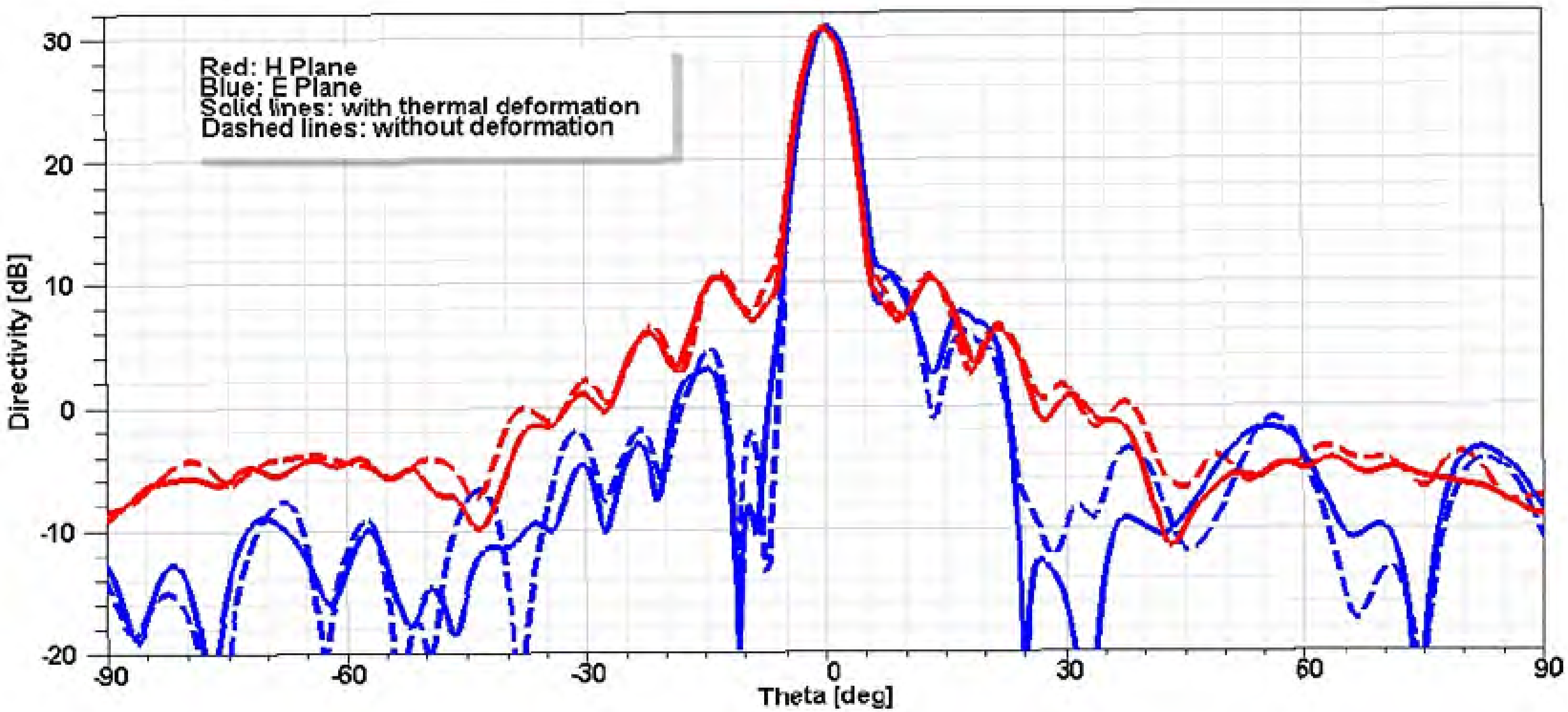


Thermally Induced Deformations



Thermal Effects on Electrical Performance

- **Looking below, it is seen that the deformation due to thermal loading is very important!!**
  - Skew and increase in side lobes introduced



雷击效应及防护设计

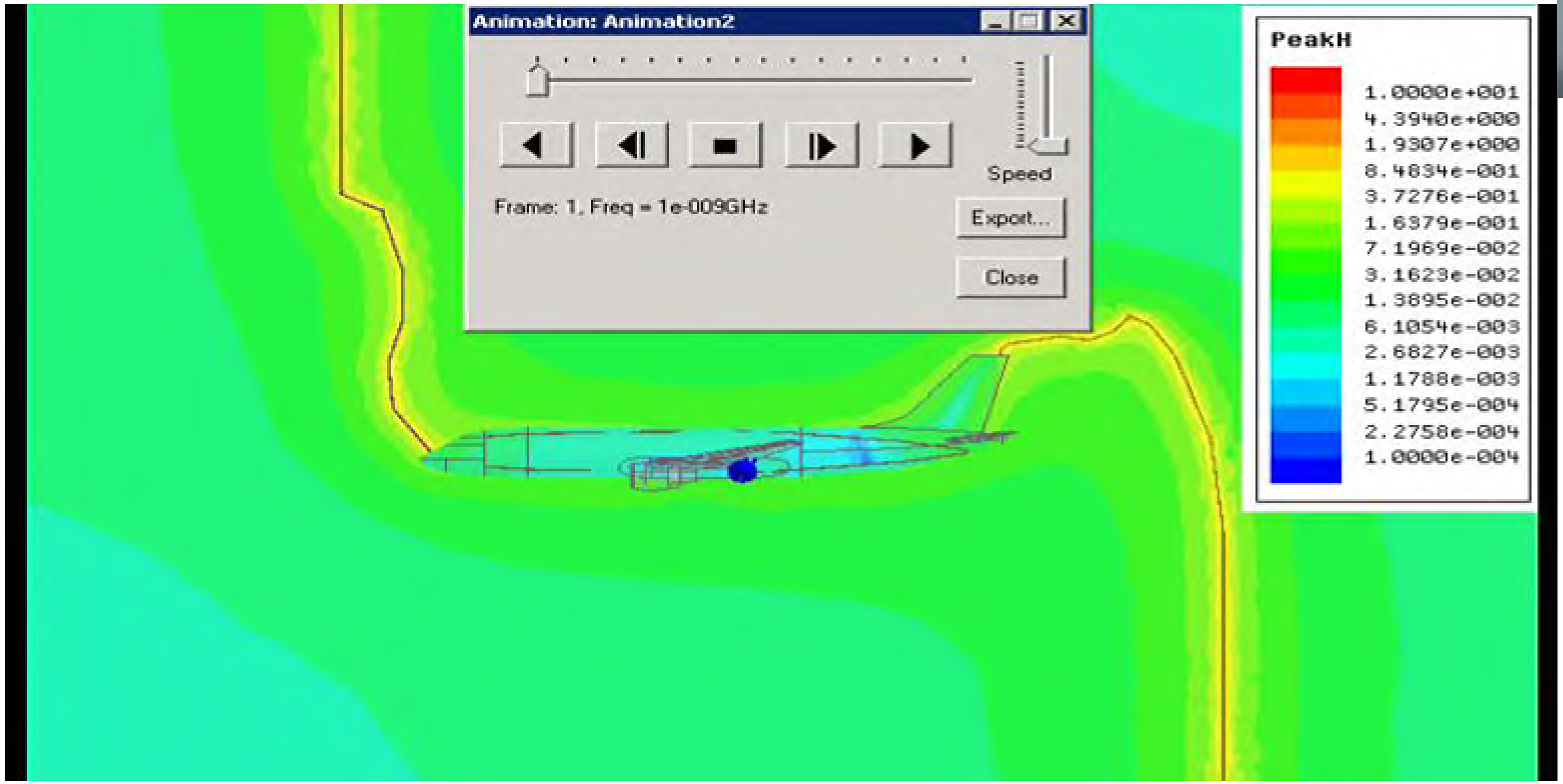
雷电现象

- 云层之间，云层与地，静电放电现象

- 类似于一个巨量电流脉冲.

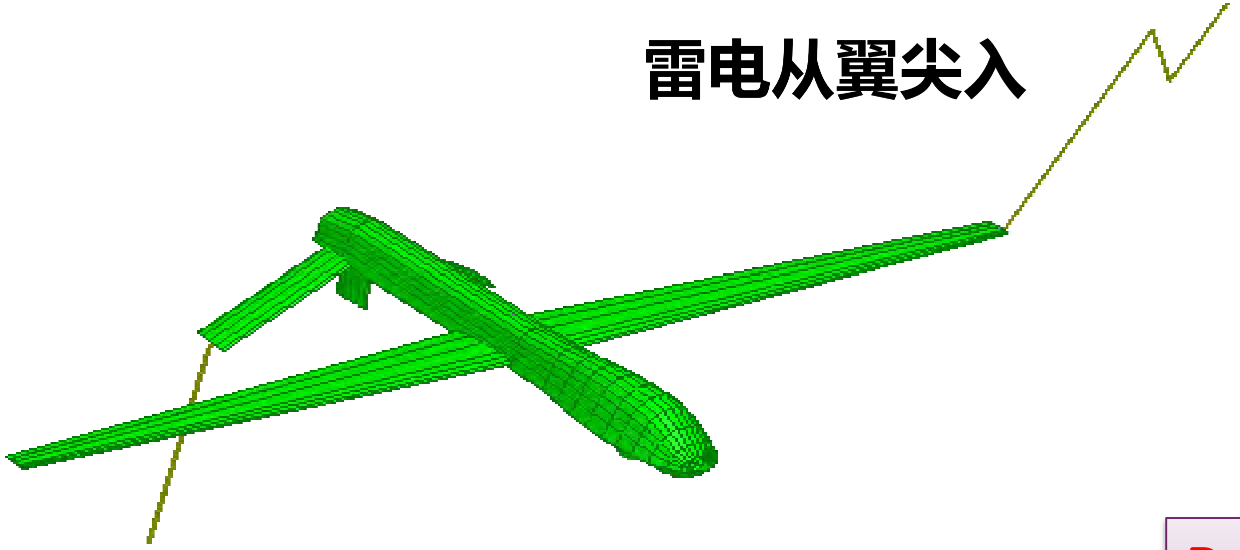
飞机 – 雷击直接效应

HFSS: Aircraft direct strike

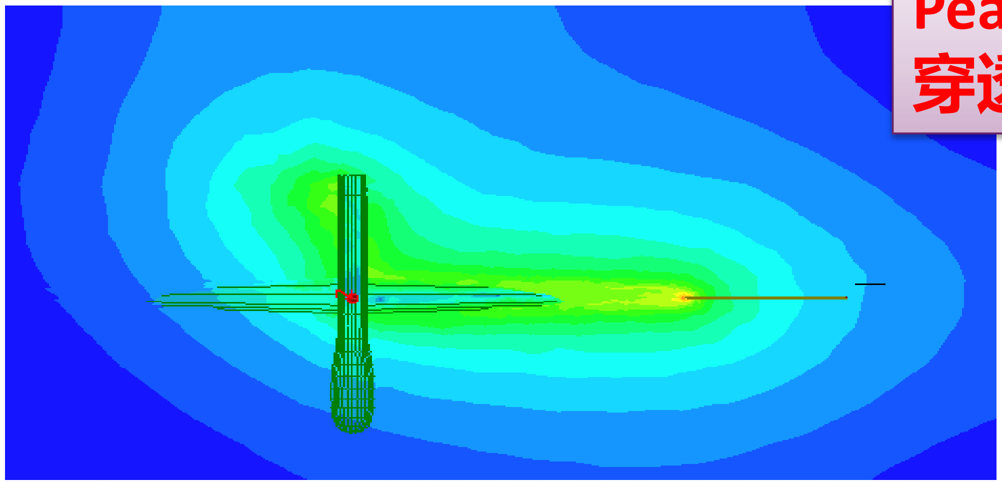


碳纤维外壳的捕食者无人机

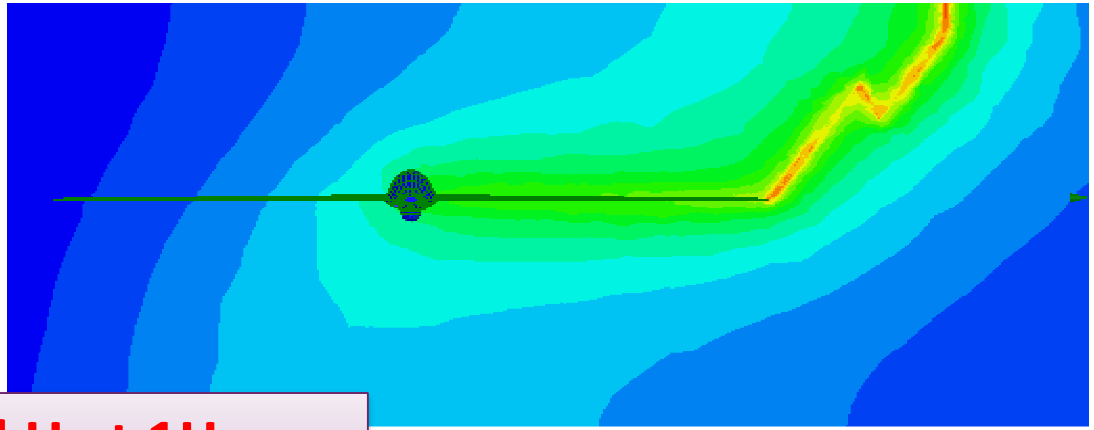
雷电从翼尖入

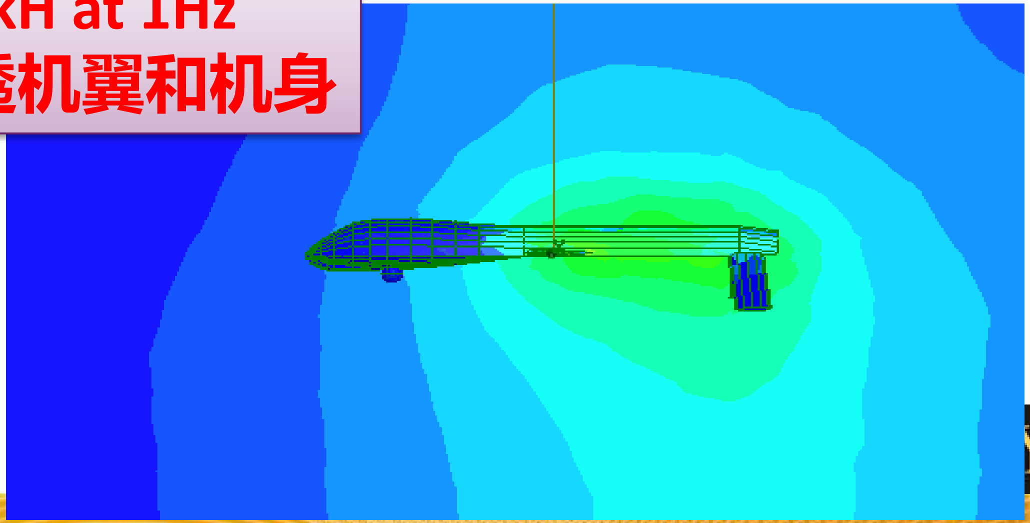


尾翼出

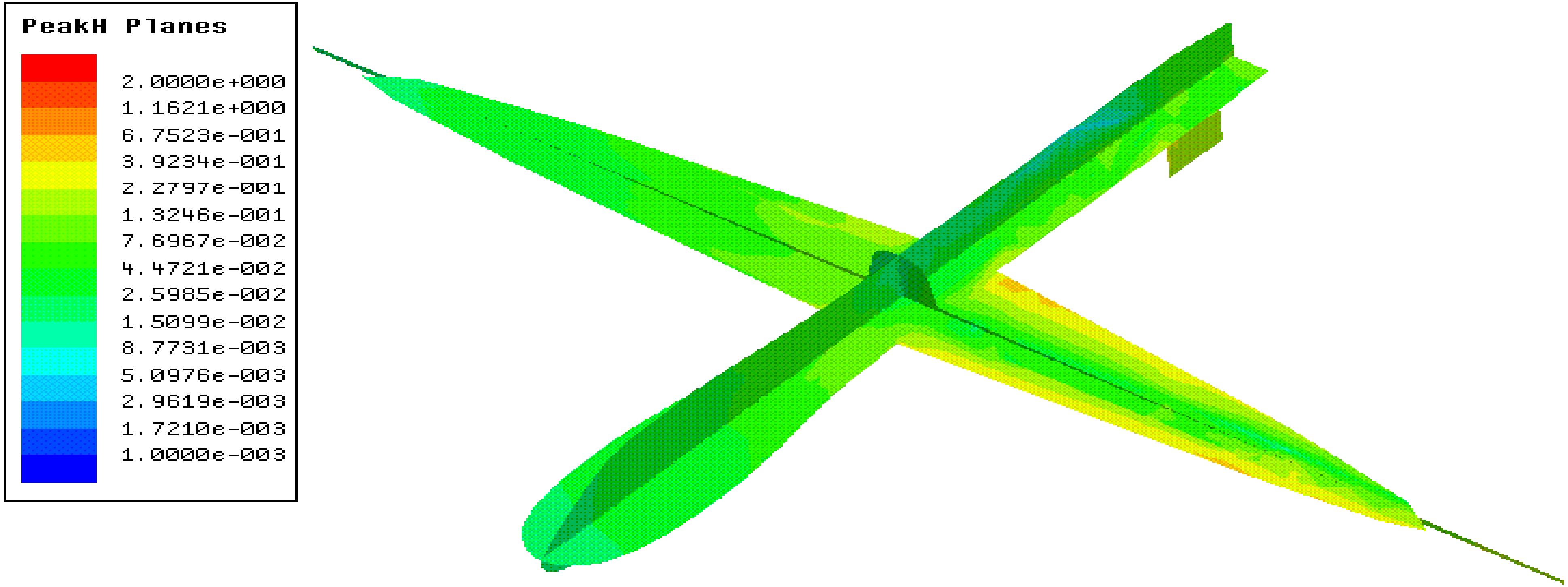


PeakH at 1Hz
穿透机翼和机身





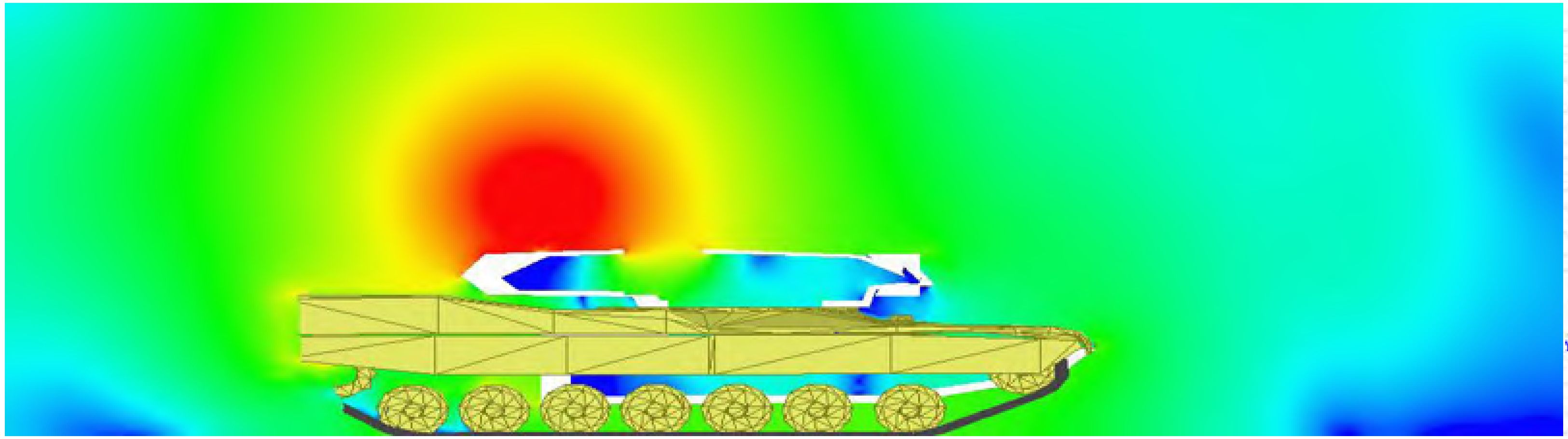
内部切面的H场分布

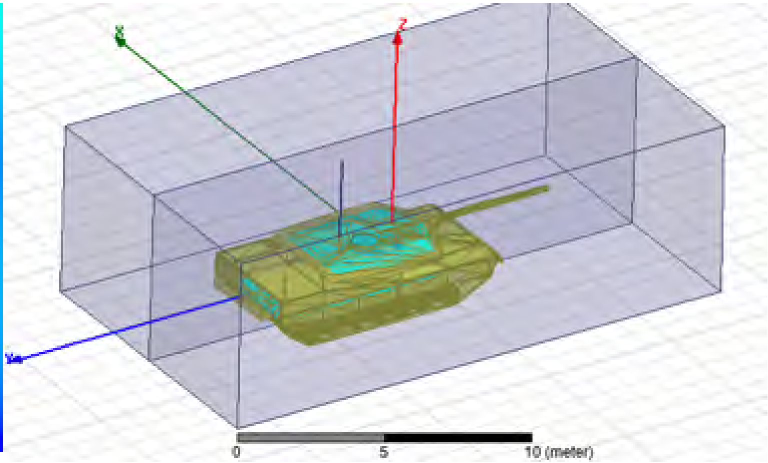


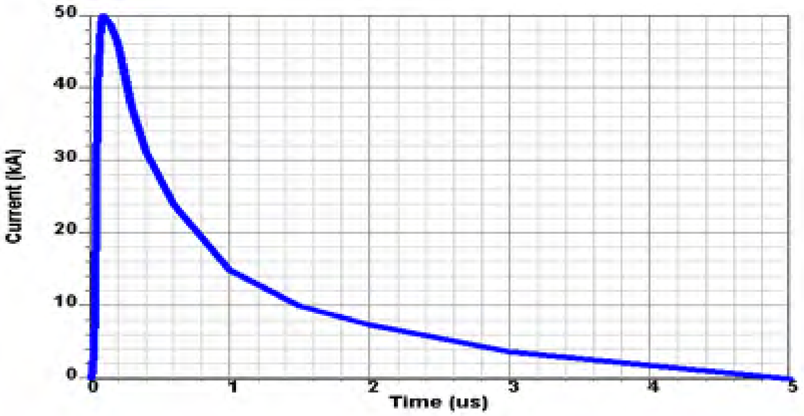
H-Field vs Frequency

低频率时穿透，高频率时磁屏蔽.

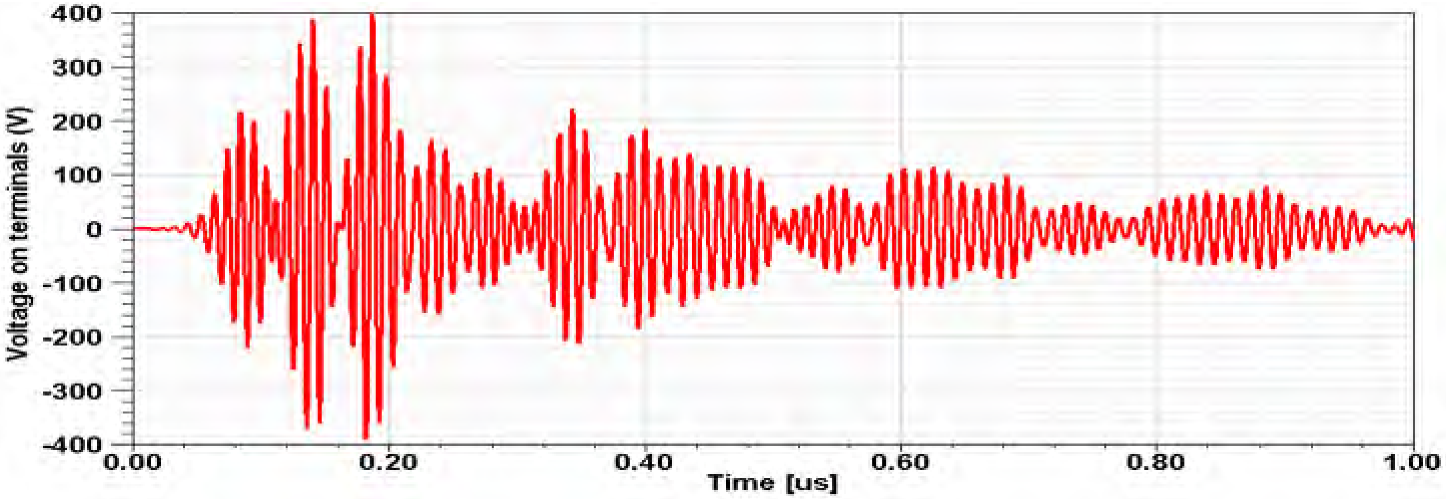
雷击脉冲在天线端口上的感应电压波形





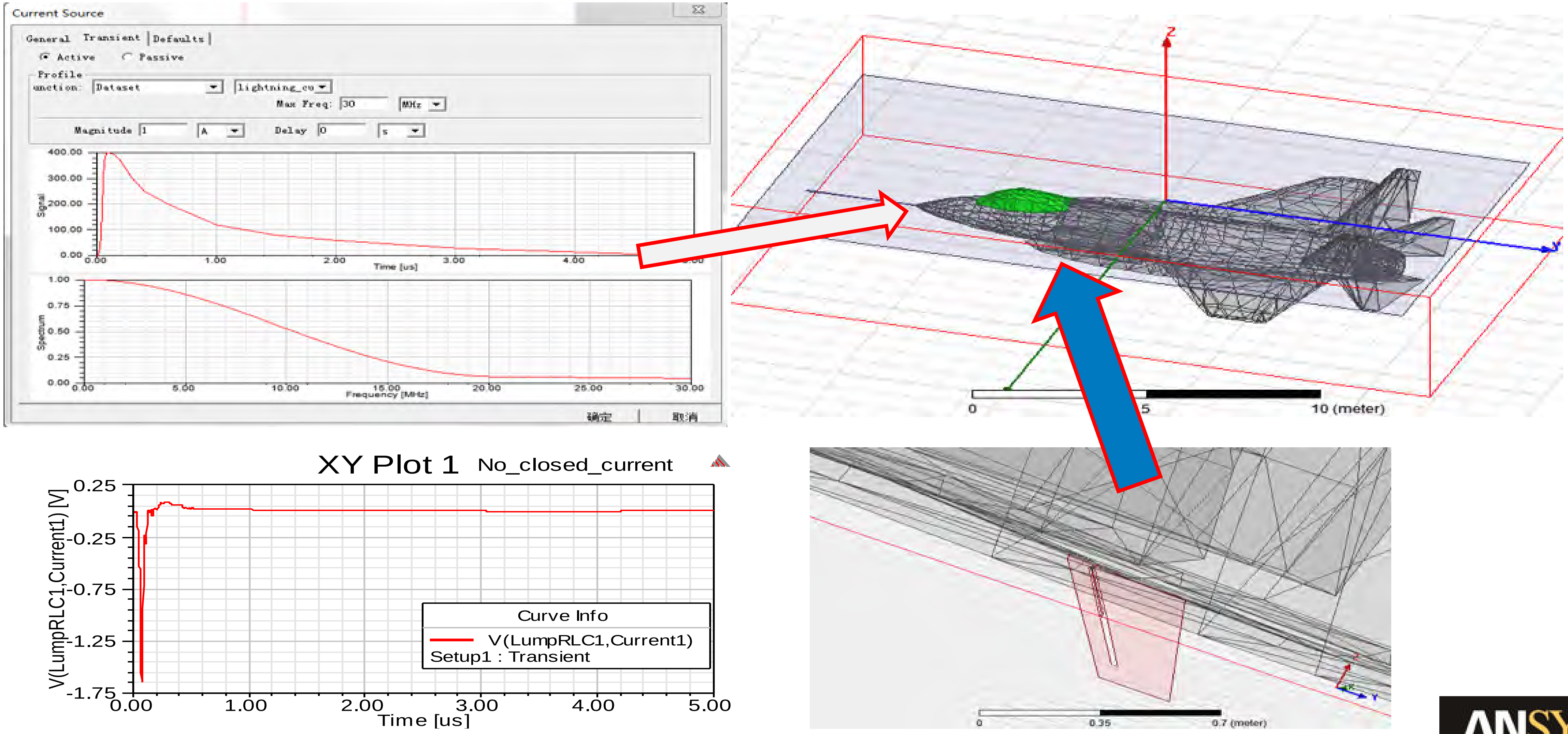


雷击电流波形



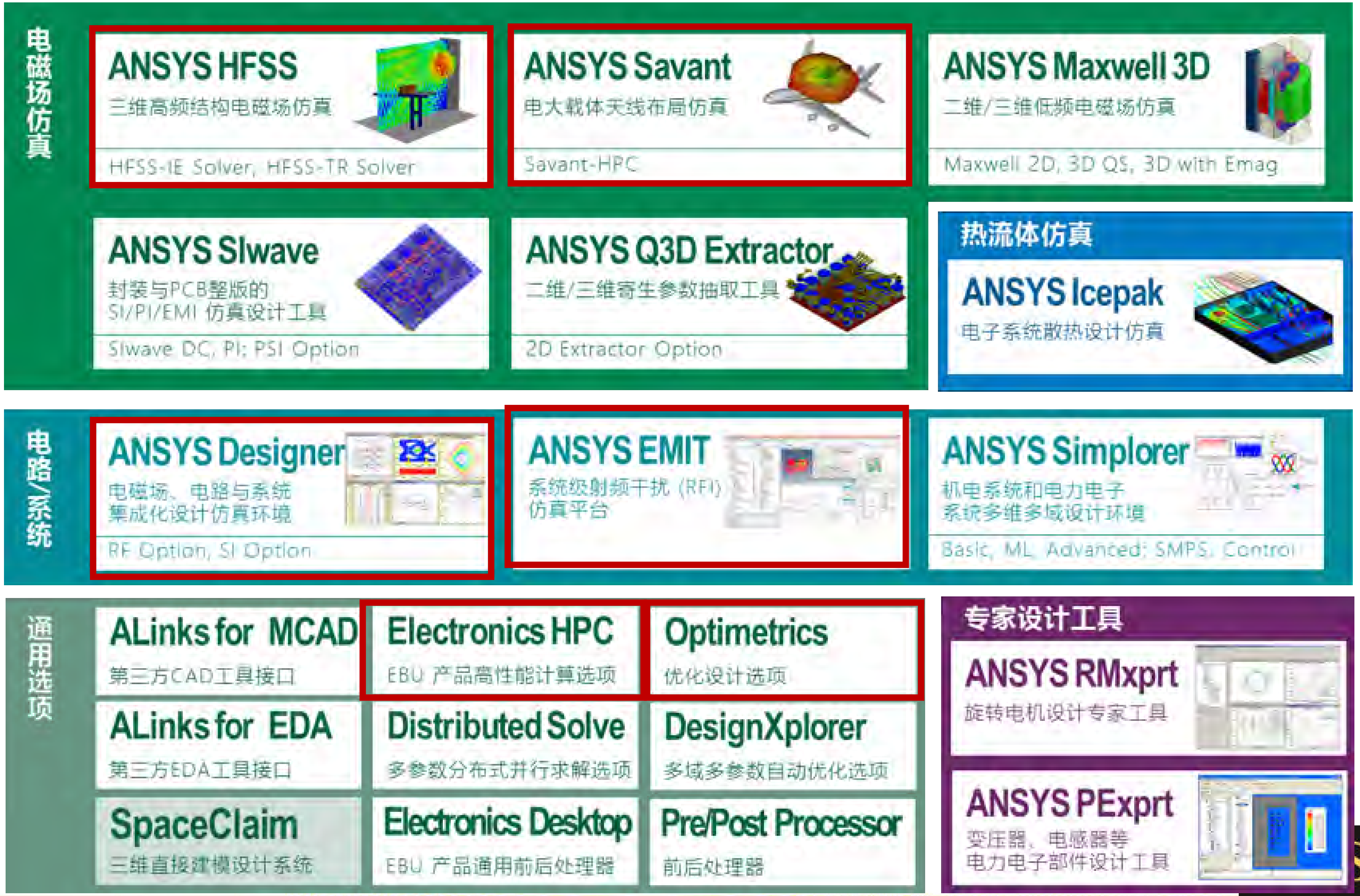
天线端口的感应电压波形

F35雷击间接效应分析



航空航天中的典型高频应用

- 雷达及系统
- 天线与天线罩
- 高速电路
- 天线布局
- 射频干扰
- 雷击/HIRF
- RCS



感谢聆听

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