Microwave Coupling into a Generic Object. FDTD Simulations and Comparison with Measurements.

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Introduction (I)

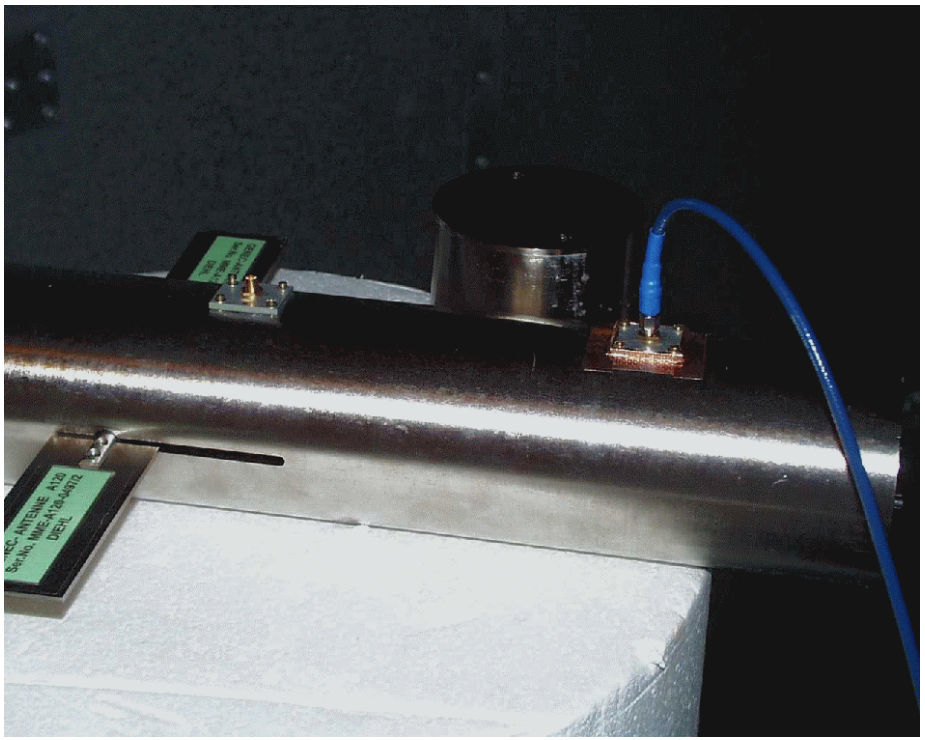
- Ongoing dispute over the correlation between measurement and simulation
- Discrepancies often seen for complex structures
- Traditional explanation is: “Simulations are wrong and of no use!”
- Our objective: Show that good agreement is indeed achievable by carefully controlling measurements and using high spatial resolution in simulations

Introduction (II)

- Swedish-German project to study HPM (High Power Microwave) protection
- Extensive measurements and simulations have been made on a generic missile, GENEC
- Measurements are reported in detail in a companion paper by the same authors

The GENEC Object

- 0.8 m long, hollow metal cylinder filled with representative metallic and lossy dielectric structures
- Penetration via thin slots (5 x 80 mm)

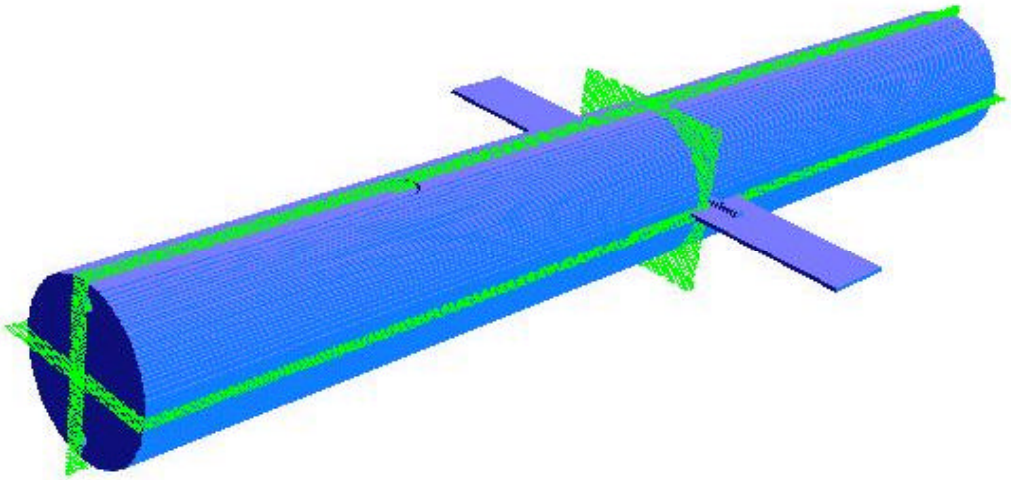


- Field is probed at two internal points, using 20 mm stripped conductor (pin) probes

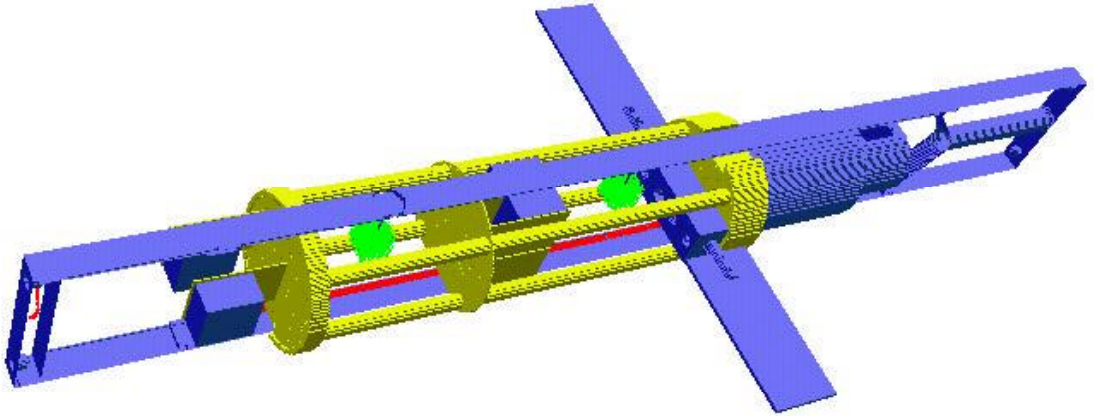
Simulation Parameters

- Finite Difference Time Domain (FDTD) simulations with 1 mm spatial resolution
- 900 x 400 x 300 unit cells
- Illumination with Gaussian plane wave pulse
- Frequency range: 0 - 18 GHz
- Lossy dielectric parts with e_r = 5.0 + j0.2 and e_r = 5.0 + j0.05
- 4 layer PML absorbing boundary condition

FDTD Model of GENEC

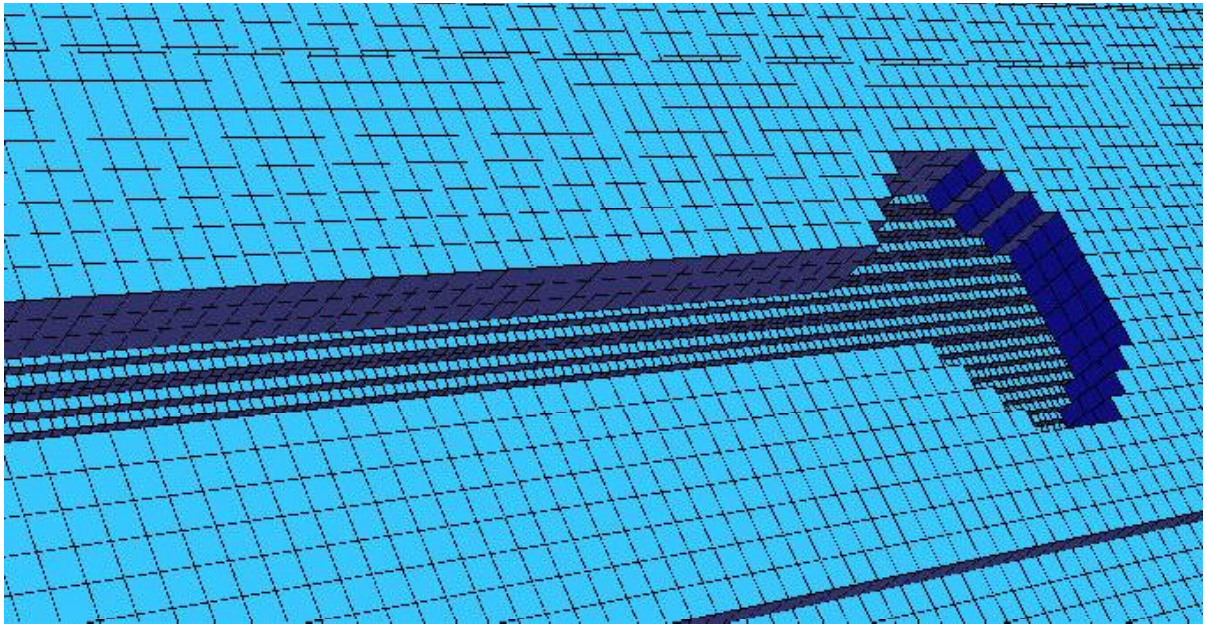


External view with three fictitious probe planes in green



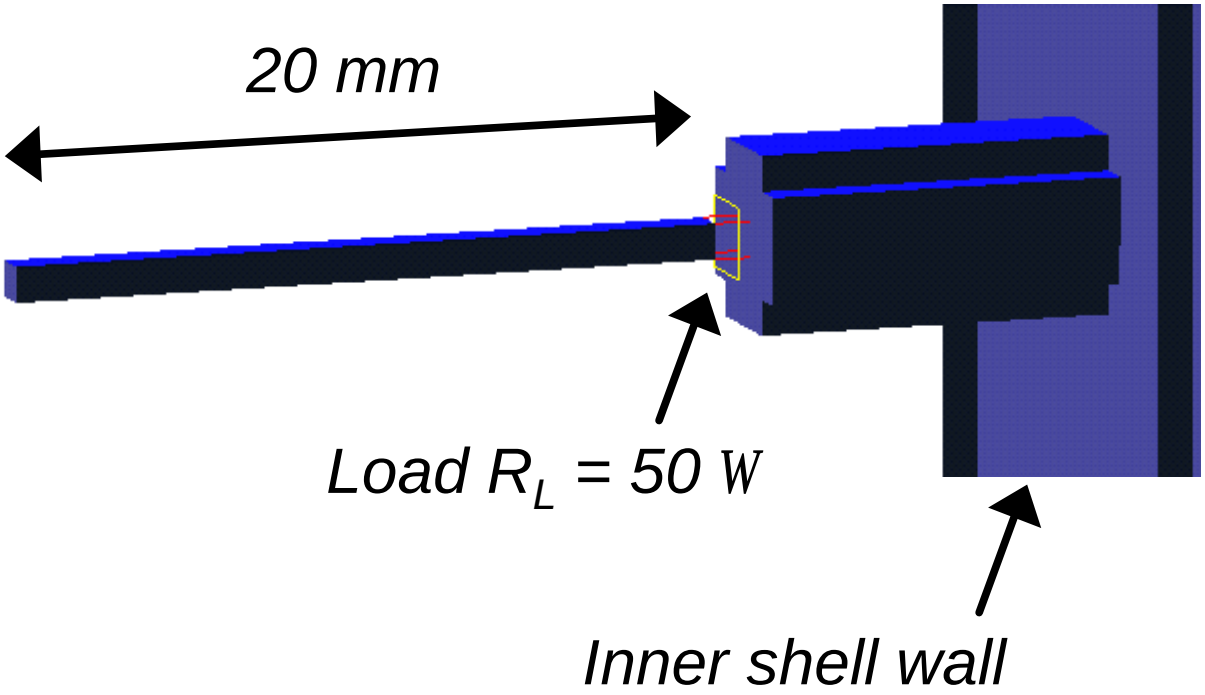
Internal structure

Slots



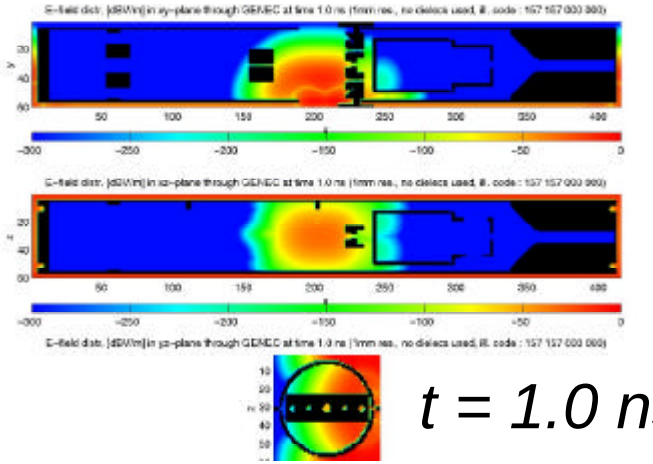
Close-up of one of the two slots at the wing suspension holes

Probes

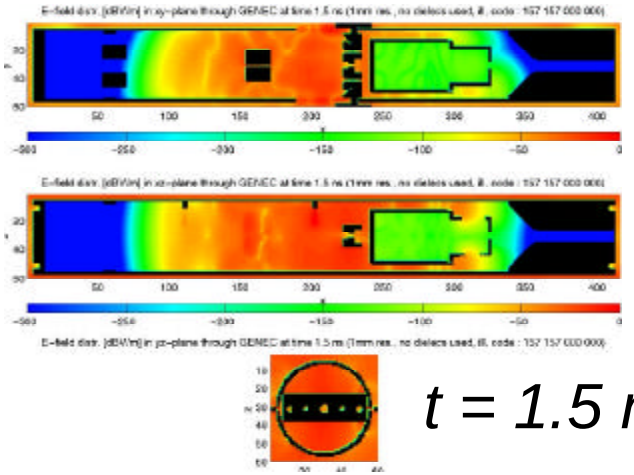


Close-up of one of the two probes

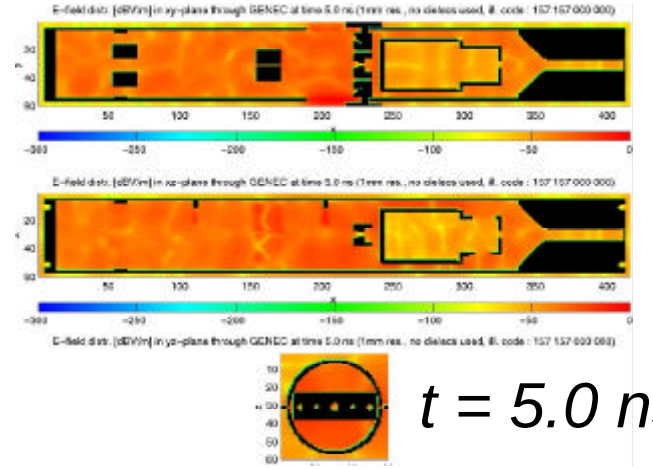
Field Patterns in Time Domain



t = 1.0 ns



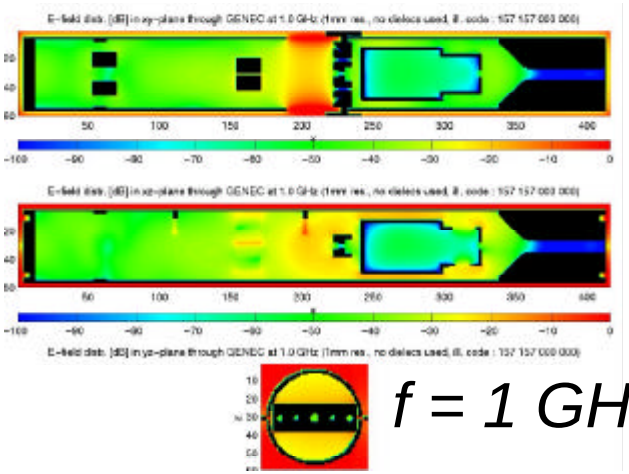
t = 1.5 ns



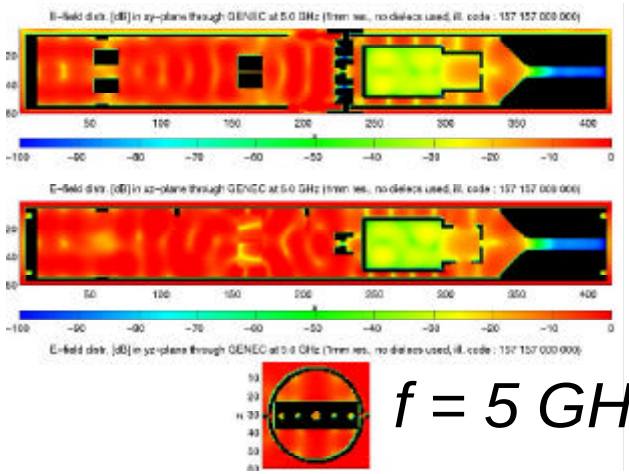
t = 5.0 ns

Electric field amplitude at three different times

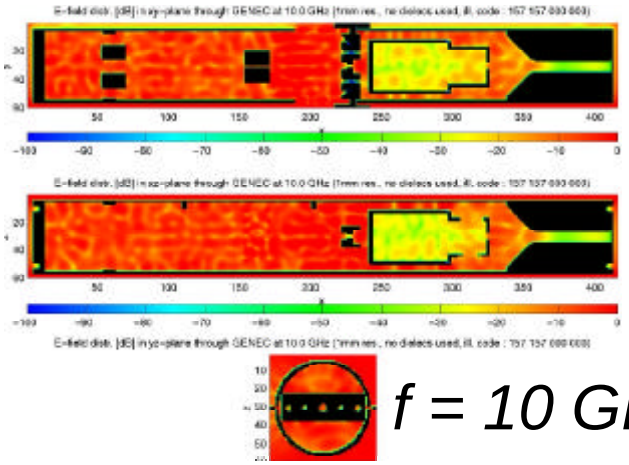
Field Patterns in Frequency Domain



f = 1 GHz



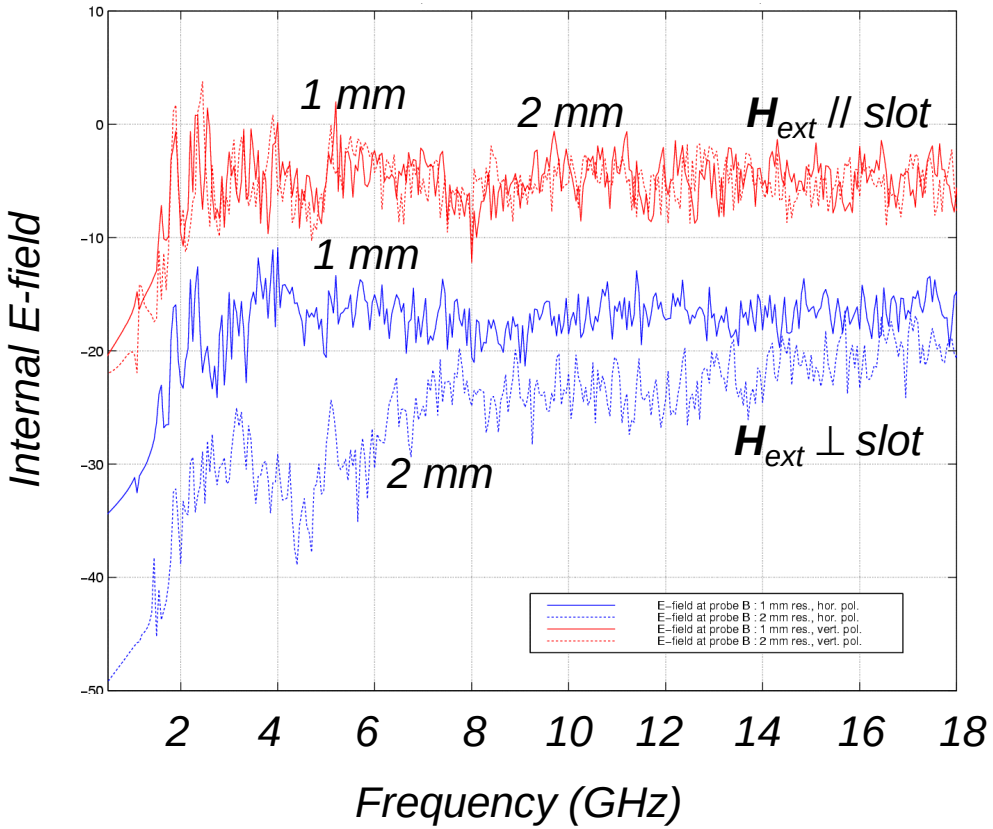
f = 5 GHz

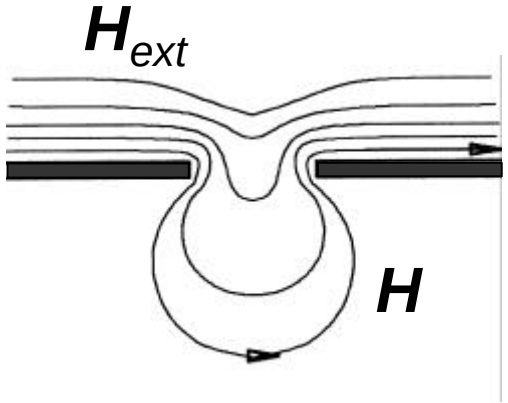


f = 10 GHz

Electric field amplitude at three different frequencies

Impact of Spatial Resolution (1 mm vs. 2 mm)

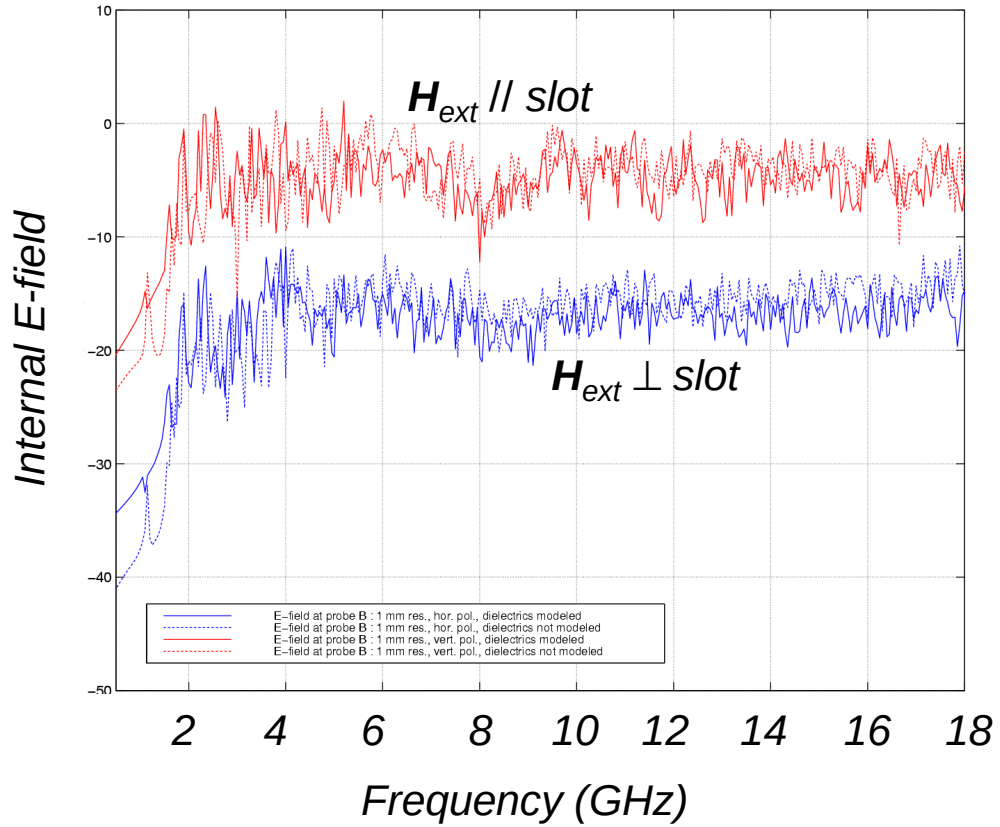




***H*$_{ext}$ // slot (red): Many cells available to resolve H-line bending**

***H*$_{ext}$ ⊥ slot (blue): Few cells available to resolve H-line bending**

Effect of Internal Lossy Dielectric Structure



Internal losses have little effect on field level (solid: dielectrics included, dashed: no dielectrics)

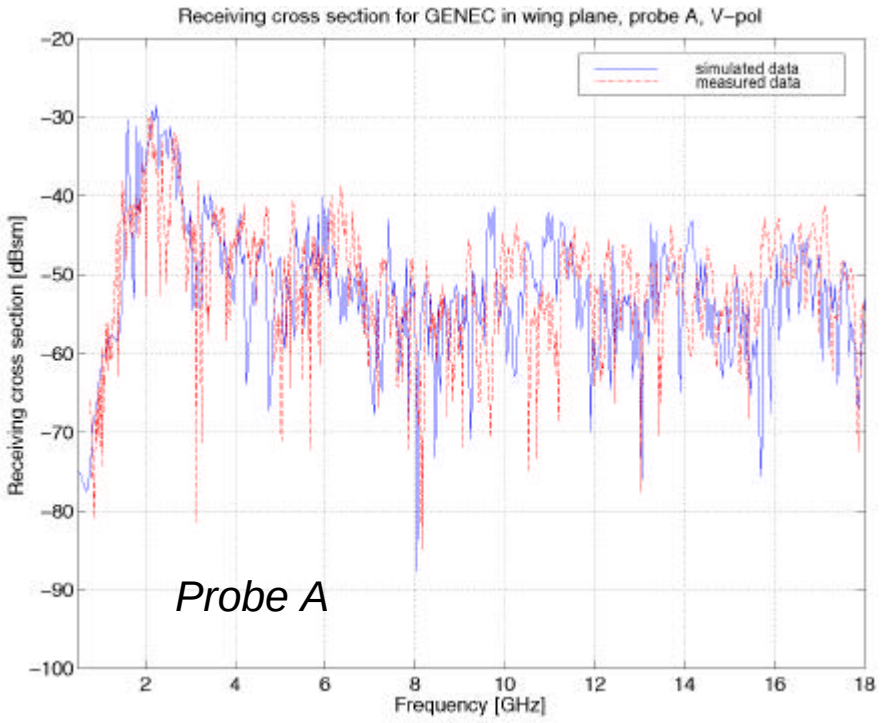
Losses through slots dominate for frequencies above slot cut-off (i.e. for f > 1.9 GHz)

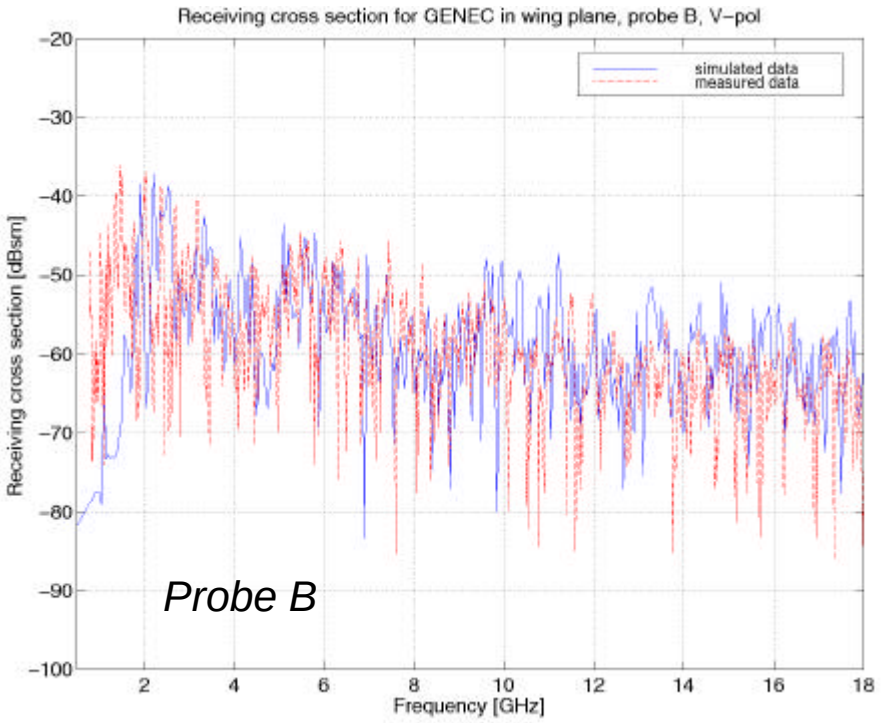
Simulation vs. measurement

- Simulations compared with detailed measurements in anechoic chamber
- Power density S_{inc} in incident plane wave
- Relevant parameter for comparison is the receiving cross-section s_P, defined in terms of the power delivered by the probe

$$s_{P,meas} = \frac{P_{rec,probe}}{S_{inc}} \qquad s_{P,sim} = \frac{R_L I_L^2}{S_{inc}}$$

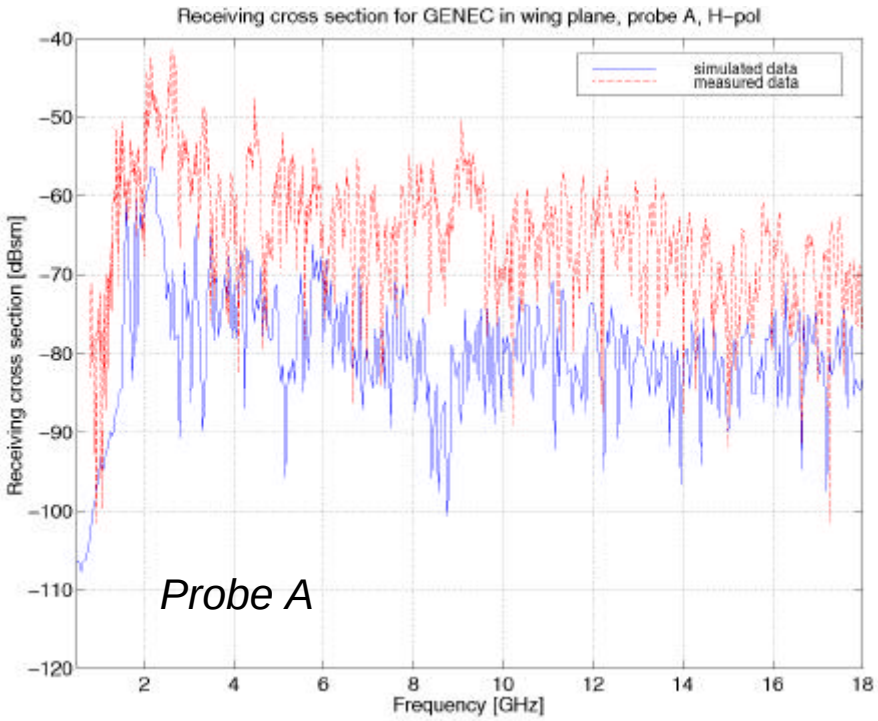
Simulation vs. measurement (H_{ext} // slot)

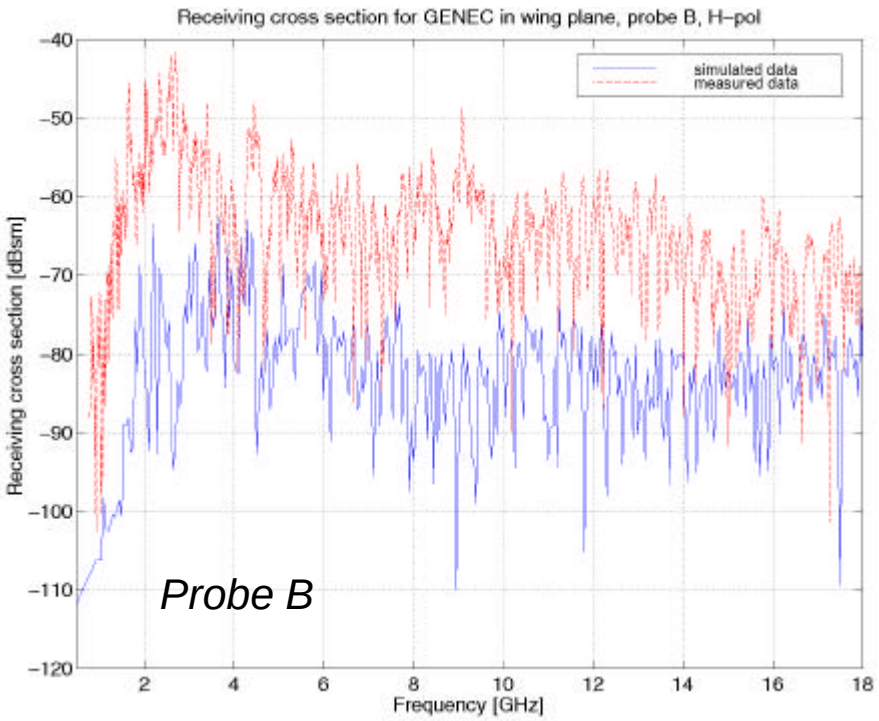




Excellent agreement between simulated (blue) and measured (red) data

Simulation vs. measurement ($H_{ext} \perp$ slot)





Deviations probably due to: (i) too few cells across the slot or (ii) other penetration channels in GENEC

Conclusions (I)

- The worst, and most interesting, case ($\boldsymbol{H}_{ext}$ // slot) is accurately modeled
- Other cases with less leakage may require: (i) finer resolution, (ii) subcell model, or (iii) some hybrid method
- Lossy dielectric structure has little influence for frequencies above slot cut-off

Conclusions (II)

- Agreement between measurements and simulations is indeed achievable, provided:

  1. Measurement setup is carefully defined and controlled

  2. Simulations have sufficient spatial resolution and correct material description

Conclusions (III)

- Uncertainties are to some degree present in measurements as well as in simulations
- “Correct” values of field levels are, however, usually defined *a priori* as measurement data obtained according to some standard
- Question: What accuracy is actually needed?
- Often, both methods may be used for comparative studies of different design solutions