2024 IEEE Electrical Design of Advanced Packaging and Systems (EDAPS)

December 17-19, 2024, Bengaluru, INDIA

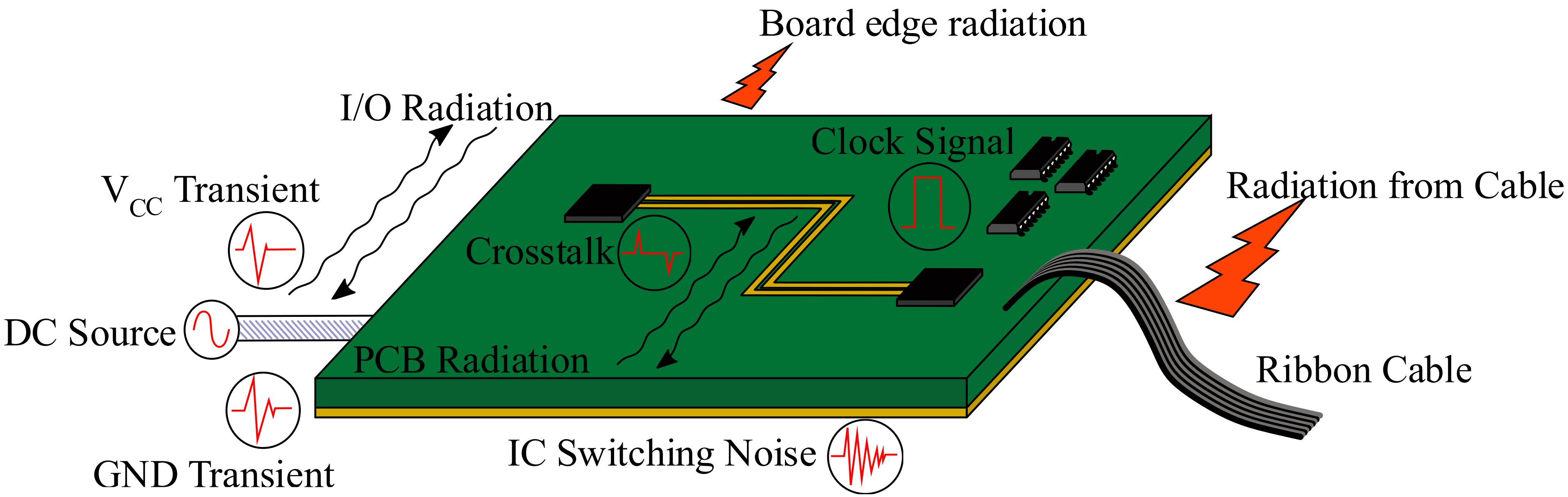



A Fast Algorithm for the Near-Field Radiation Assessment of Interconnects

Martijn Huynen, Kamil Yavuz Kapusuz, Victor Verstraete, Alessandro Felaco, Dries Vande Ginste

IDLab/Quest, Ghent University/imec

PCB radiation

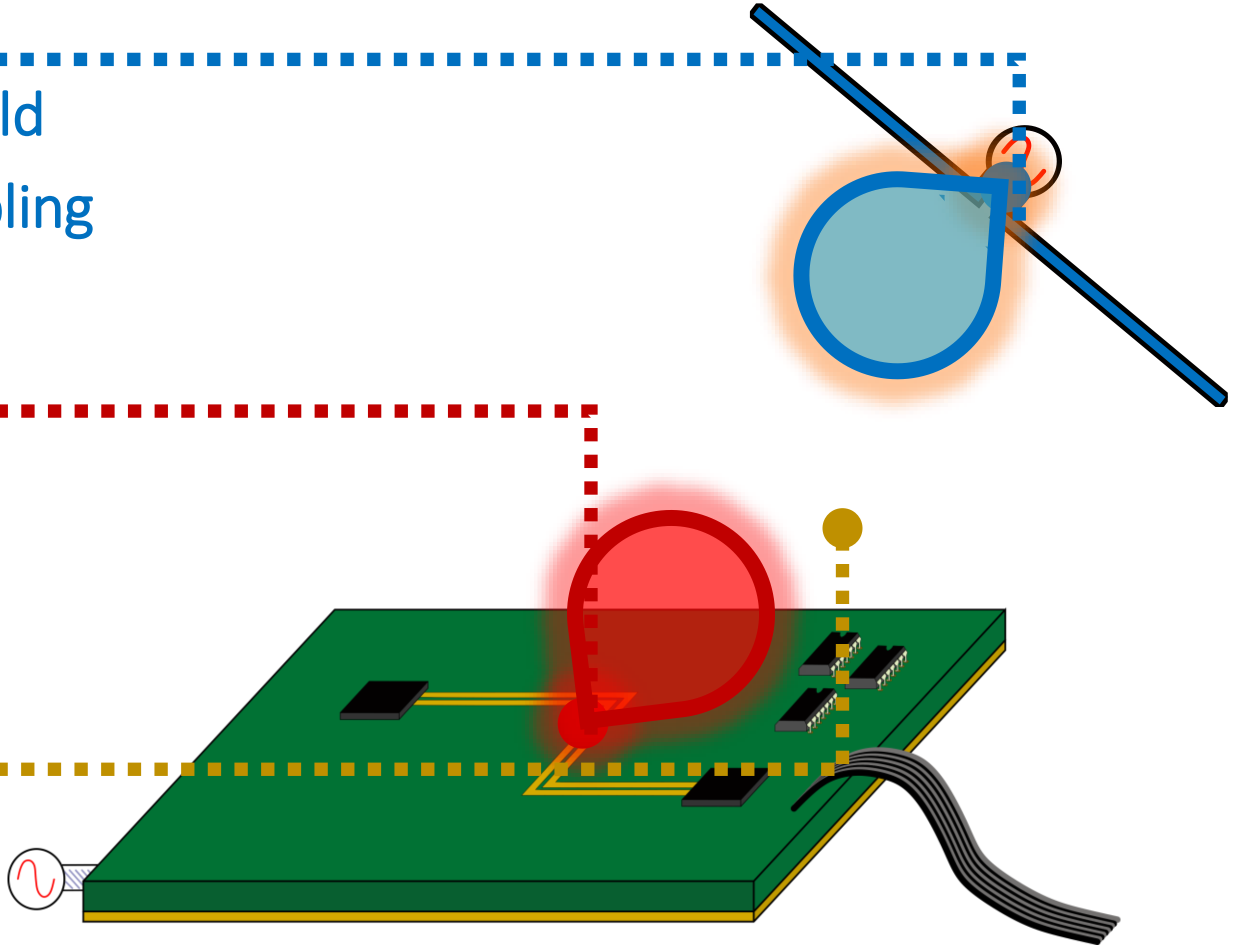


Problem: Unwanted radiation of microwave boards and interposers

Need for **accurate** & **efficient** model to analyze EMC performance

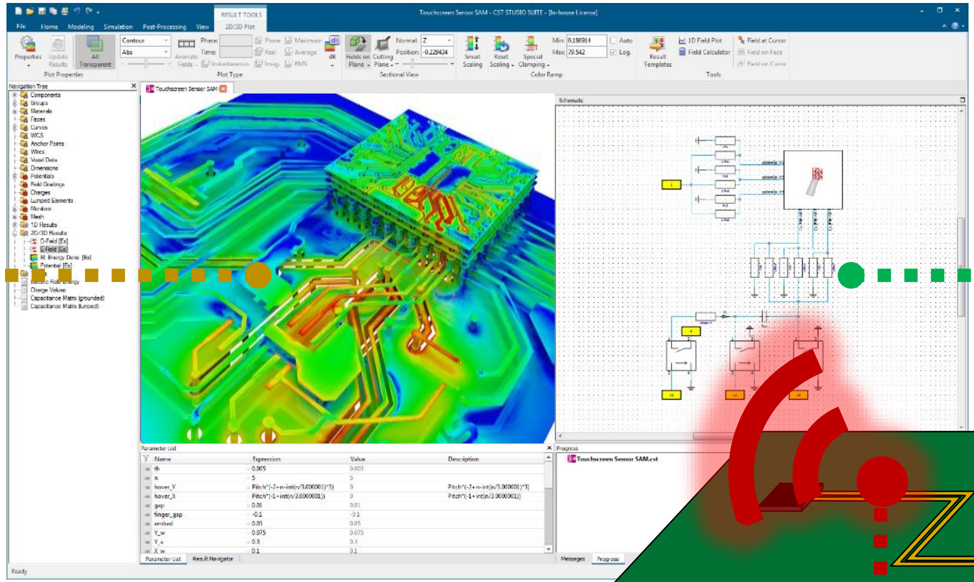
Analytical approach (Friis formula)

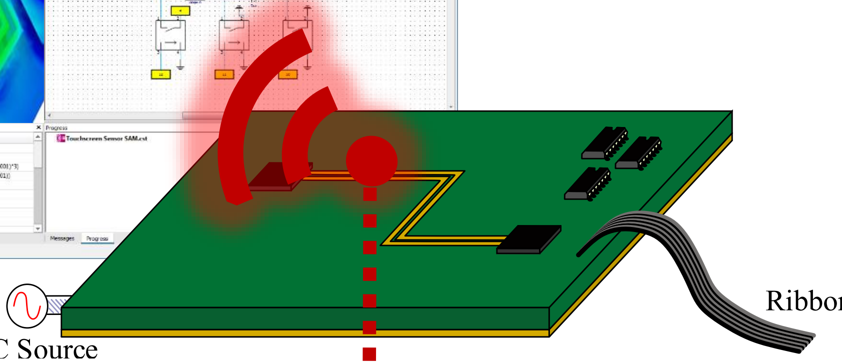
- **Emission (antenna)**
  - ✓ Located in PCB/interposer's far-field
  - ✗ More interested in near-field coupling
- **PCB or interposer**
  - ✓ Assumes far-field operation
- **Inaccurate range**
  - ✗ Ignores platform effects
  - ✓ Very quick to determine



Full-wave software

✓ Rigorously analyzed

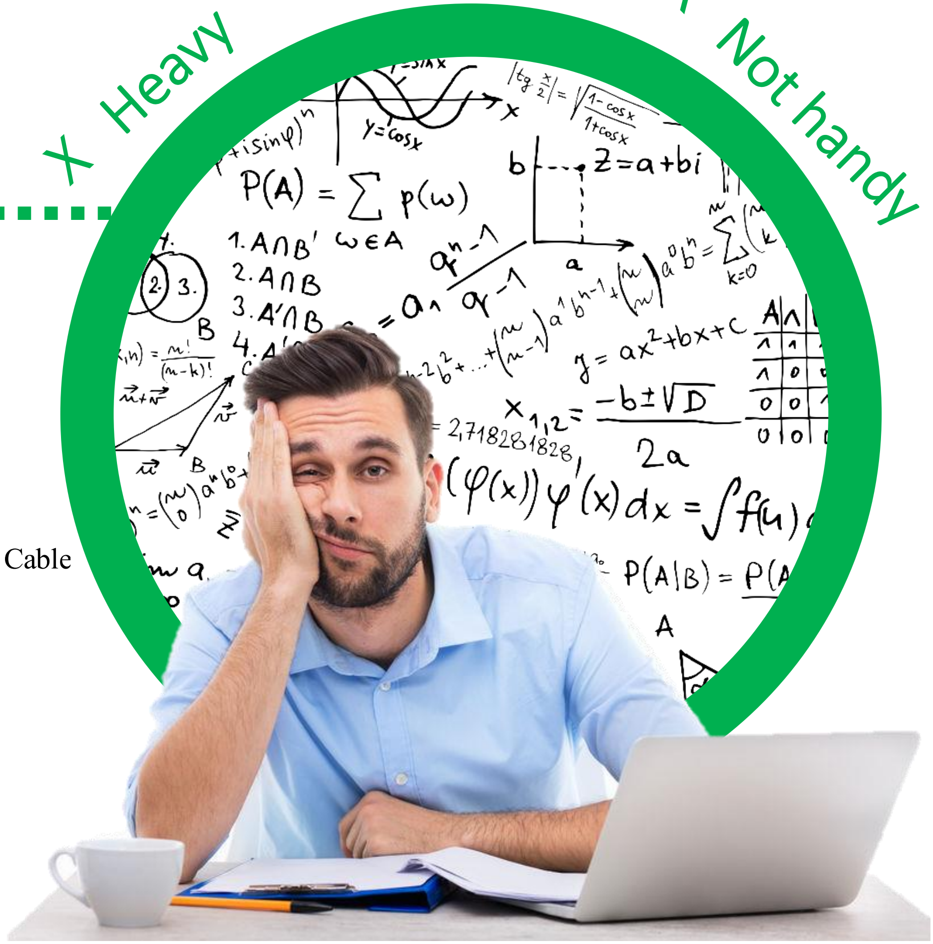


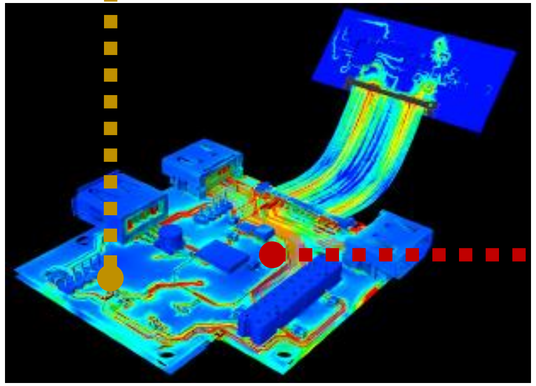


X Heavy

X Slow

X Not handy

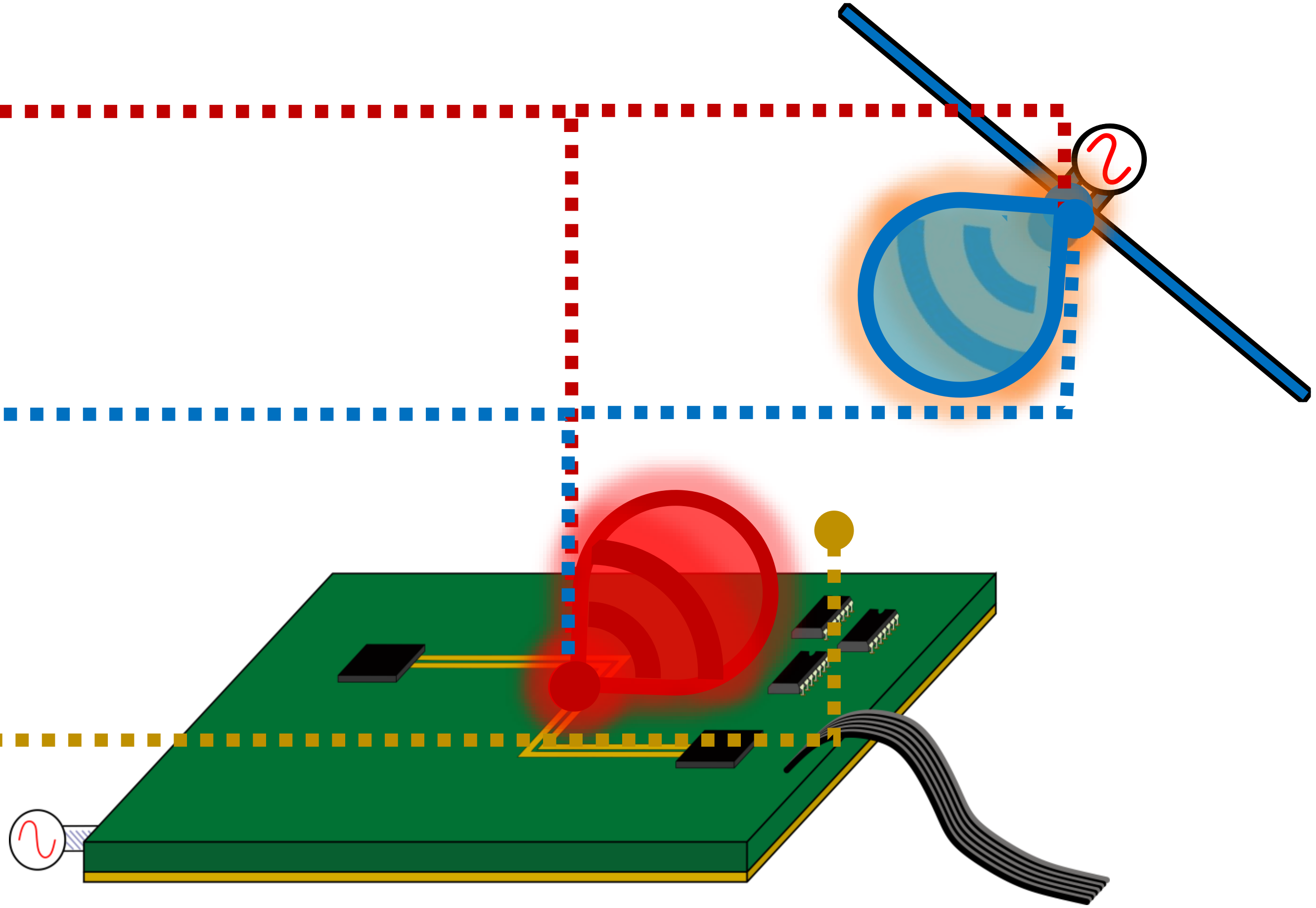




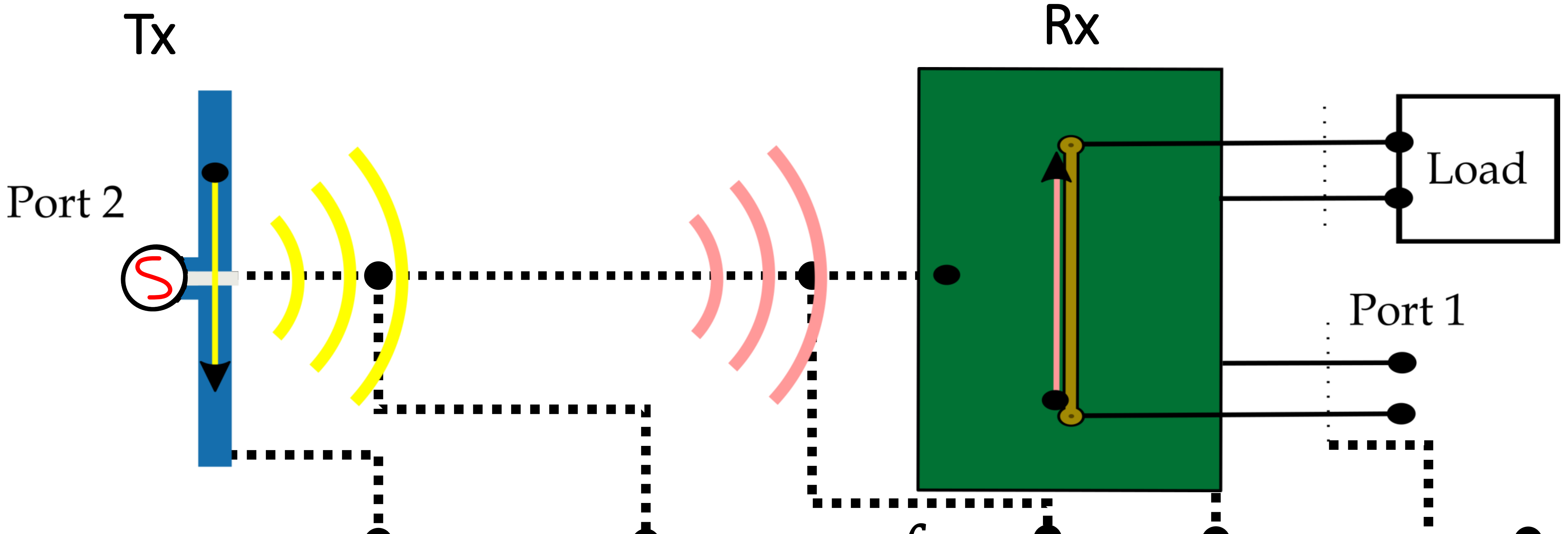
✓ Realistic models

Spherical Harmonics Decomposition

- **Far-field as input**
  - ✓ Under deployment conditions
  - ✓ Accounts for platform effects
- **Far-to-near transformation**
  - ✓ Employs multipoles expansion
  - ✓ Produces precise near-fields
- **Accurate computation**
  - ✓ Evaluates near-fields interaction
  - ✓ Runs in just a few seconds

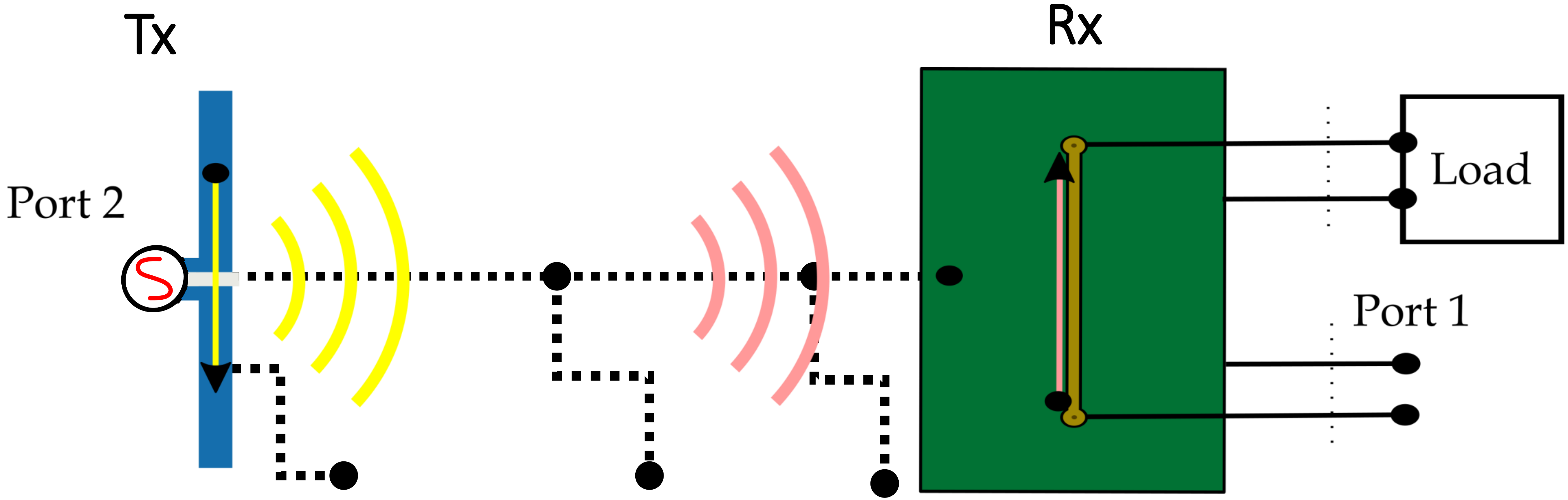


Electric Field Integral Equation

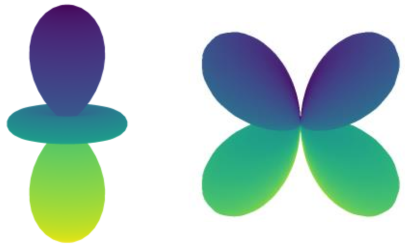


$$\int_{\mathrm{Tx}} \boxed{\mathcal{G}(\mathbf{r}-\mathbf{r}')} \cdot \boxed{\mathbf{j}_{\mathrm{Tx}}(\mathbf{r}')}\,\mathrm{d}\mathbf{r}' \propto \boxed{\mathbf{E}_{\mathrm{Tx}}(\mathbf{r})} \rightarrow \int_{\mathrm{Rx}} \boxed{\mathbf{E}_{\mathrm{Tx}}(\mathbf{r})} \cdot \boxed{\mathbf{j}_{\mathrm{Rx}}(\mathbf{r})}\,\mathrm{d}\mathbf{r} \propto \boxed{v_{\mathrm{Rx}}}$$

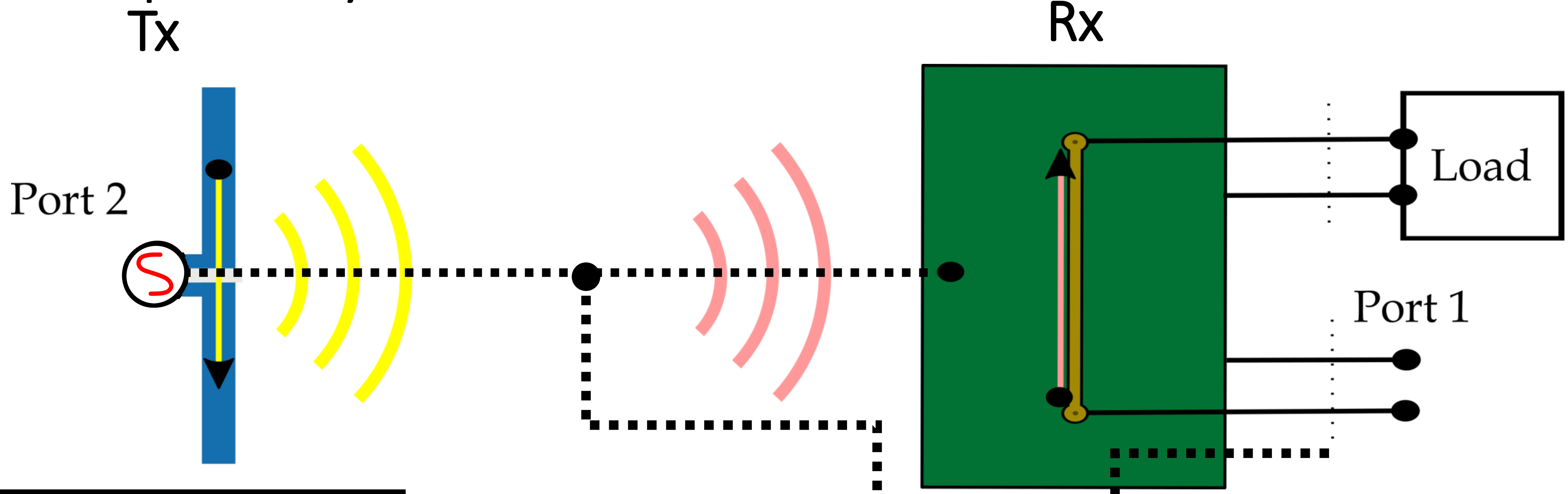
Spherical harmonics decomposition



$$\mathbf{F}_{\mathrm{Tx}} \approx \sum Y_l^m \qquad \mathcal{G}(\mathbf{r}-\mathbf{r}') \approx \sum Y_l^m \qquad \mathbf{F}_{\mathrm{R}x} \approx \sum Y_l^m \propto$$



Reciprocity theorem



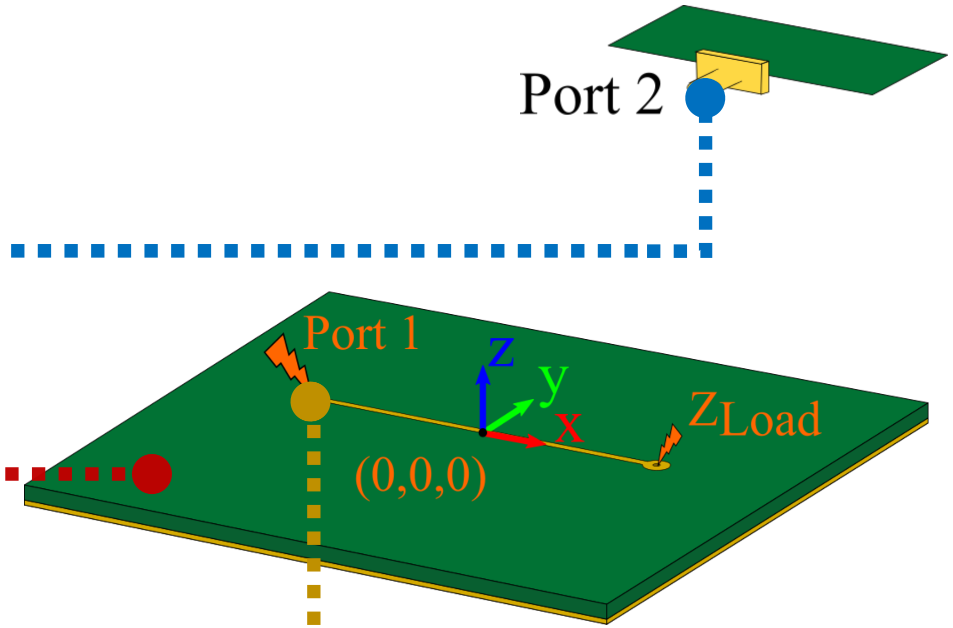
$c_l \propto \langle \mathbf{F}_{\mathrm{Tx}}, \mathbf{F}_{\mathrm{R}x} \rangle$
Computationally efficient
via spherical harmonics
Partially precomputed

$$\sum_l c_l(\mathbf{F}_{\mathrm{Tx}}, \mathbf{F}_{\mathrm{Rx}})\,\mathcal{H}_l^m(\mathbf{D}) \propto v_{\mathrm{Rx}}$$

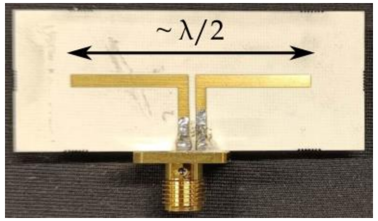
$\mathcal{H}_l^m(\mathbf{D}) = h_l(kD)Y_l^m(\widehat{\mathbf{D}})$
Multipole function
Harm. Dec. of Hankel
Accurate in near-field

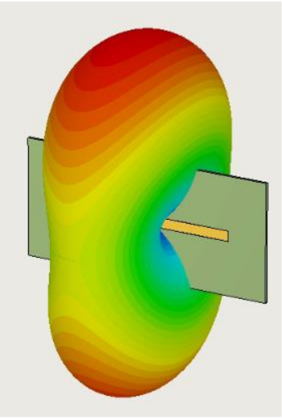
Simulation set-up

- **E- and H-Dipole Antenna**
  - ✓ Loaded by 50 Ω impedance
  - ✓ 1 V source
- **PCB and Interposers**
  - ✓ 5.5 GHz
  - ✓ Near-field within 6 λ
- **Simulations**
  - ✓ Voltage induced at Rx Port 1

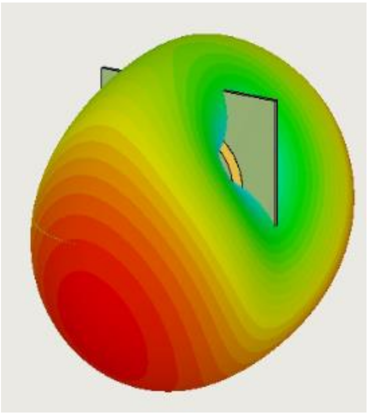


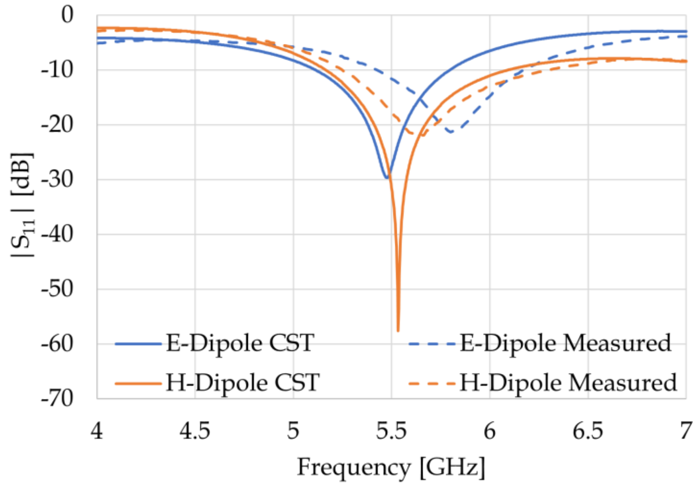
E-Dipole:





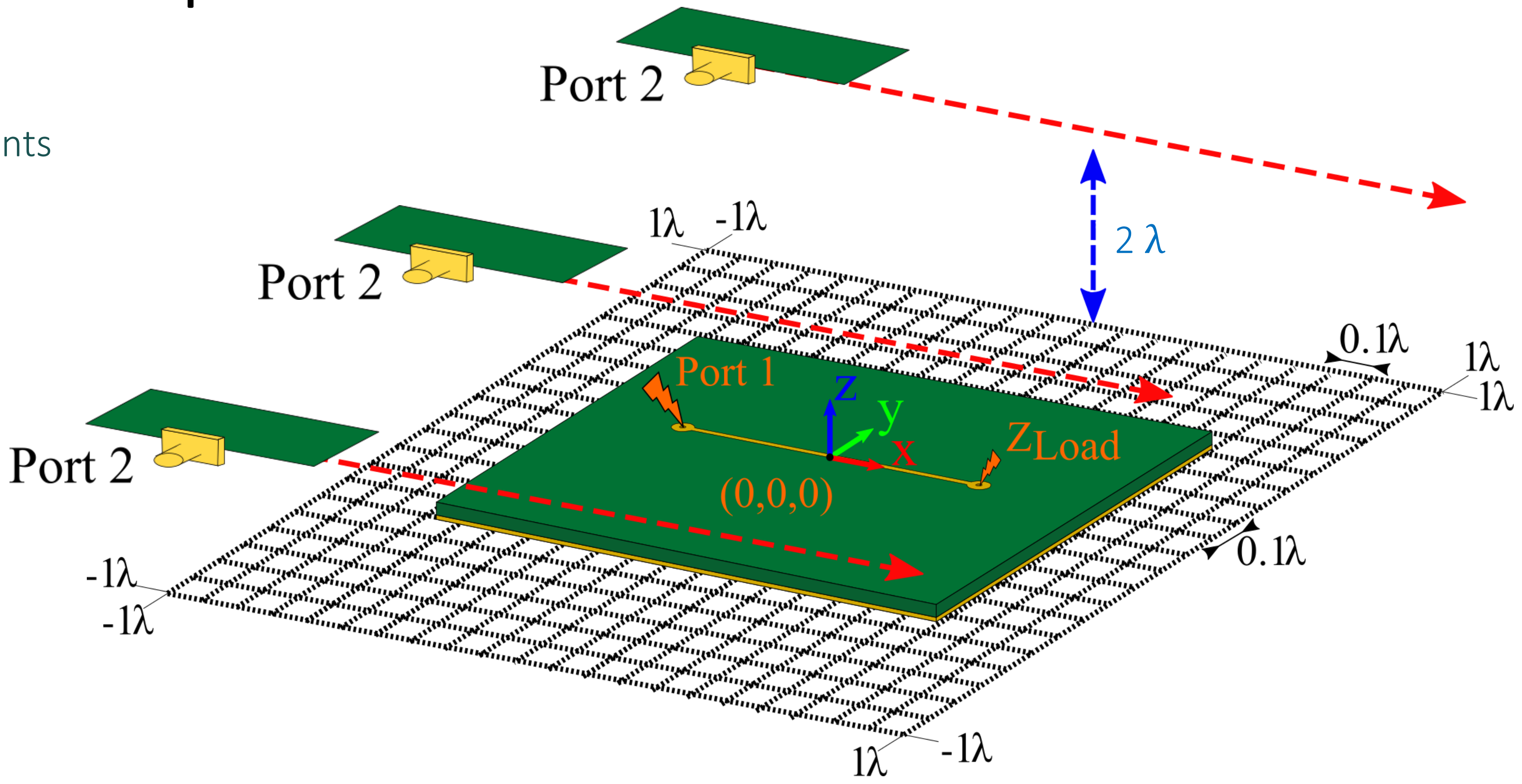
H-Dipole:



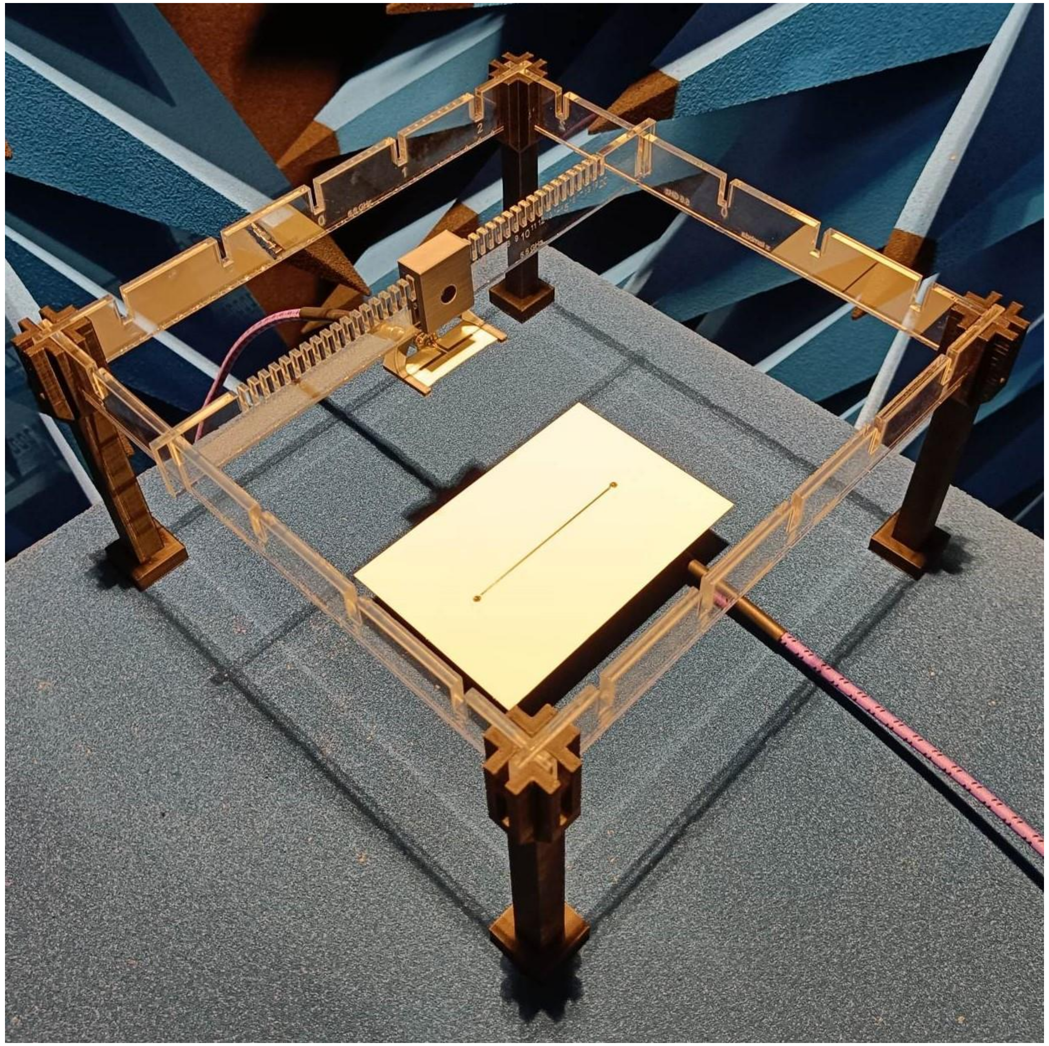


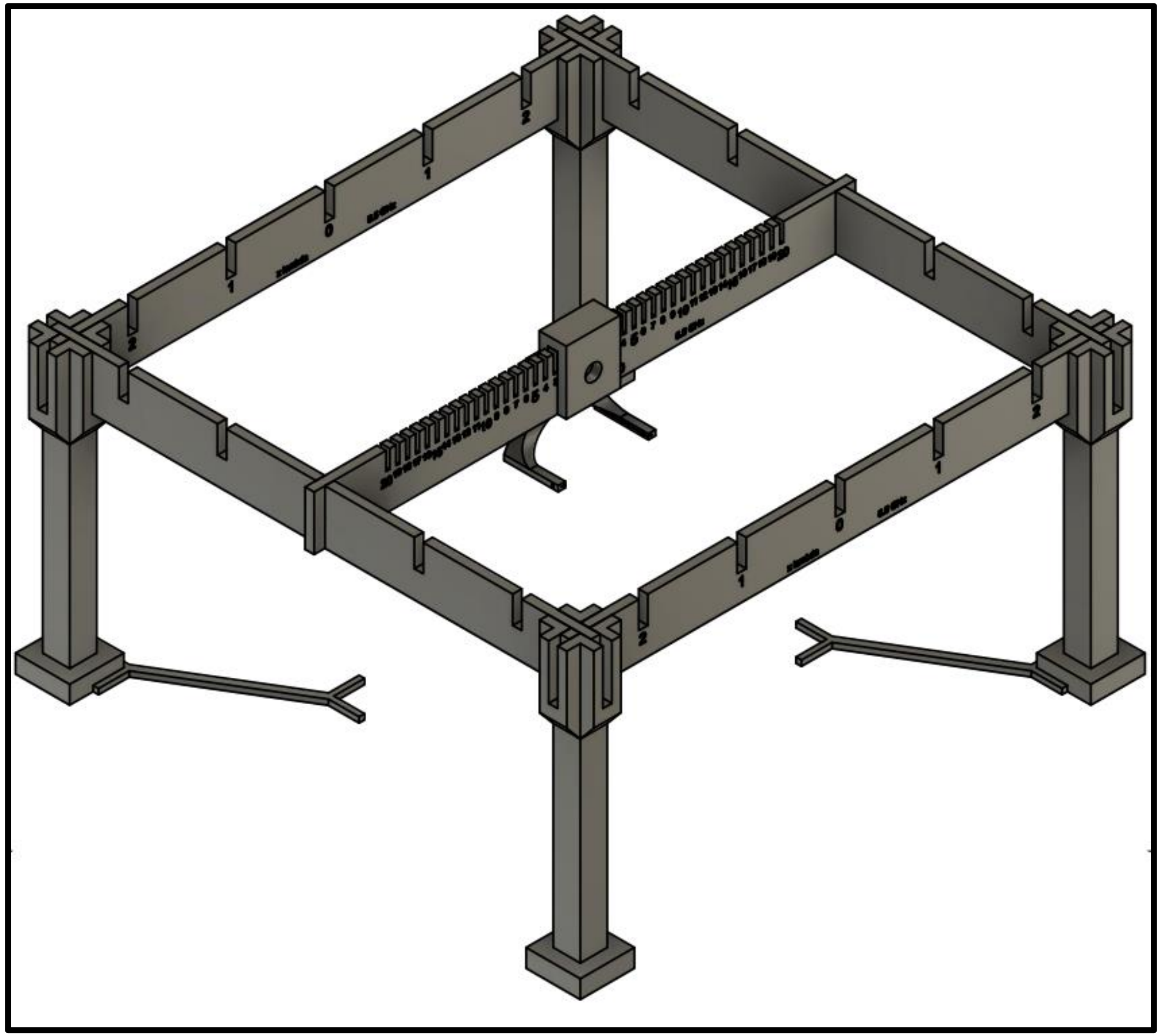
Simulation set-up

- **X- and Y-sweeps**
  - ✓ 21 points CST and measurements
  - ✓ 50 points novel method
- **3 lines each**
  - ✓ X: -1 λ to 1 λ
  - ✓ At Y = -1 λ, 0 and 1 λ
  - ✓ 2 λ distance
- **Simulations**
  - ✓ 5.5 GHz (λ = 54 mm)
  - ✓ Port Z_{Load} (mis)matched



Measurement set-up



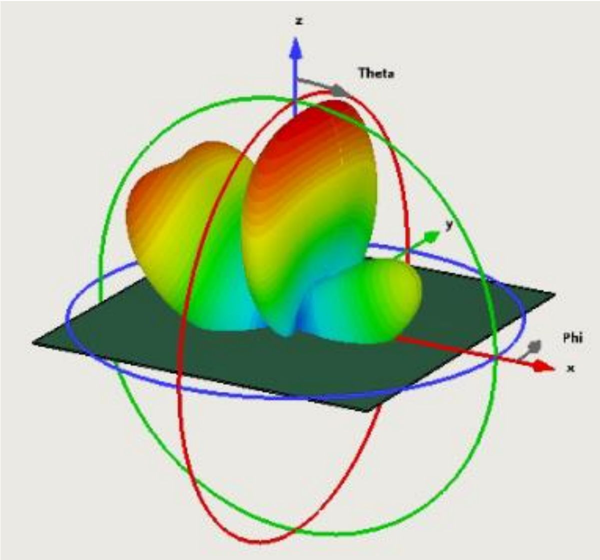


Validation: straight microstrip lines

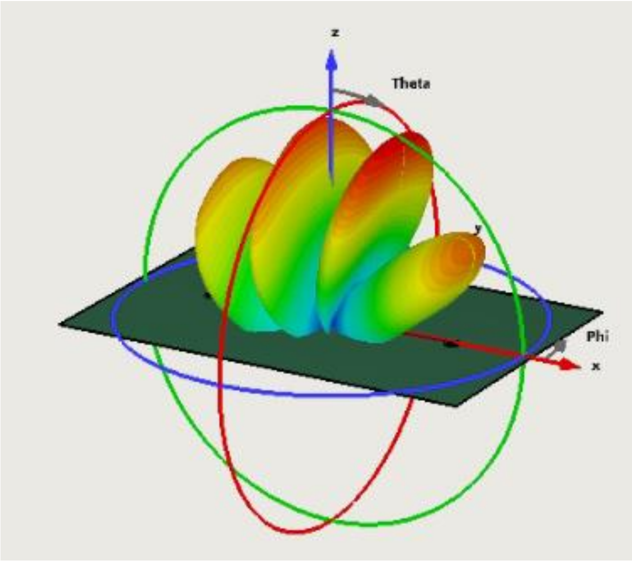
Rogers 4350B substrate
Z_{Load} = 50 Ω

Fabricated prototype

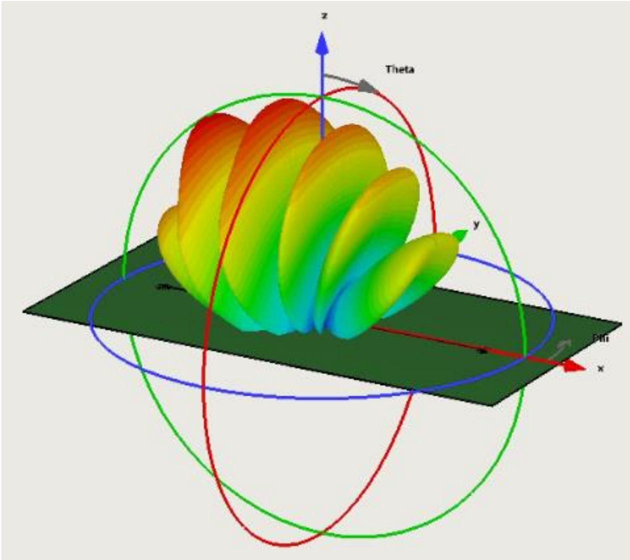
L = 50 mm



L = 100 mm

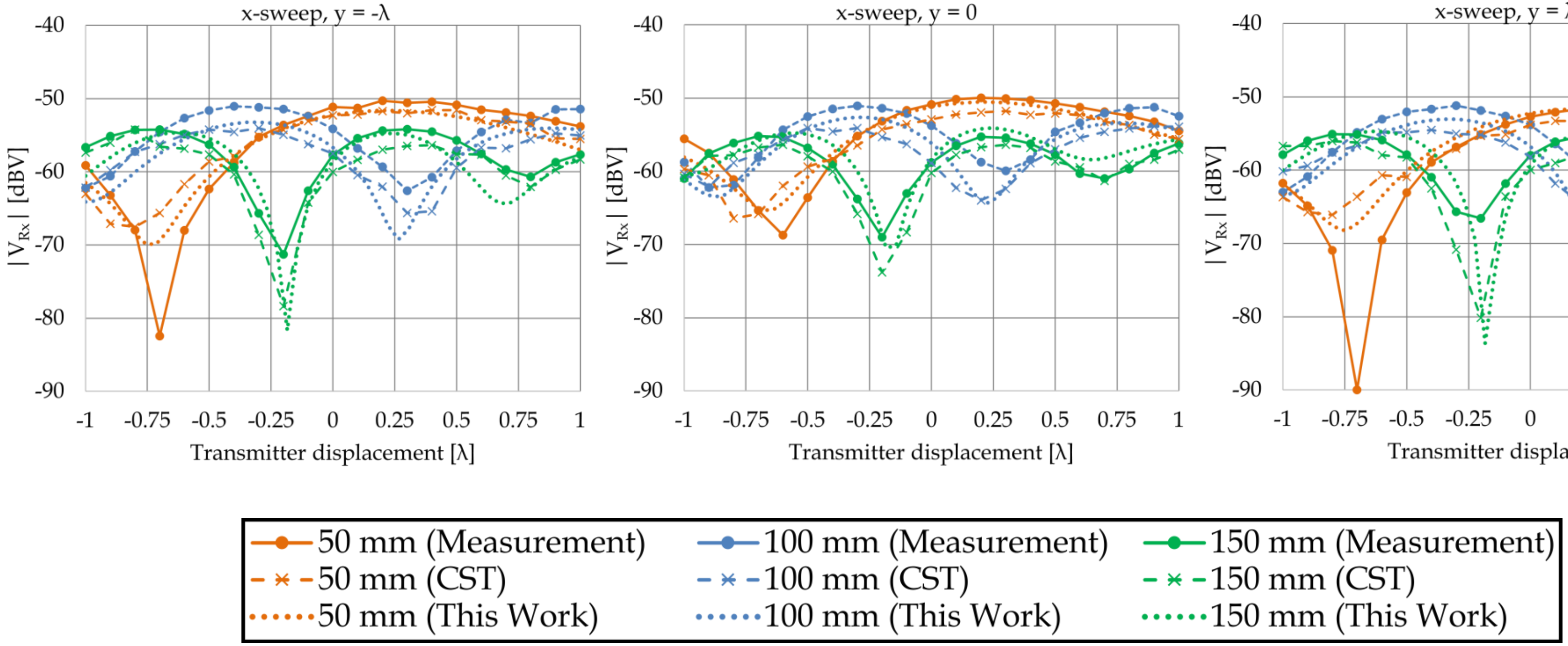


L = 150 mm



Validation: straight microstrip lines

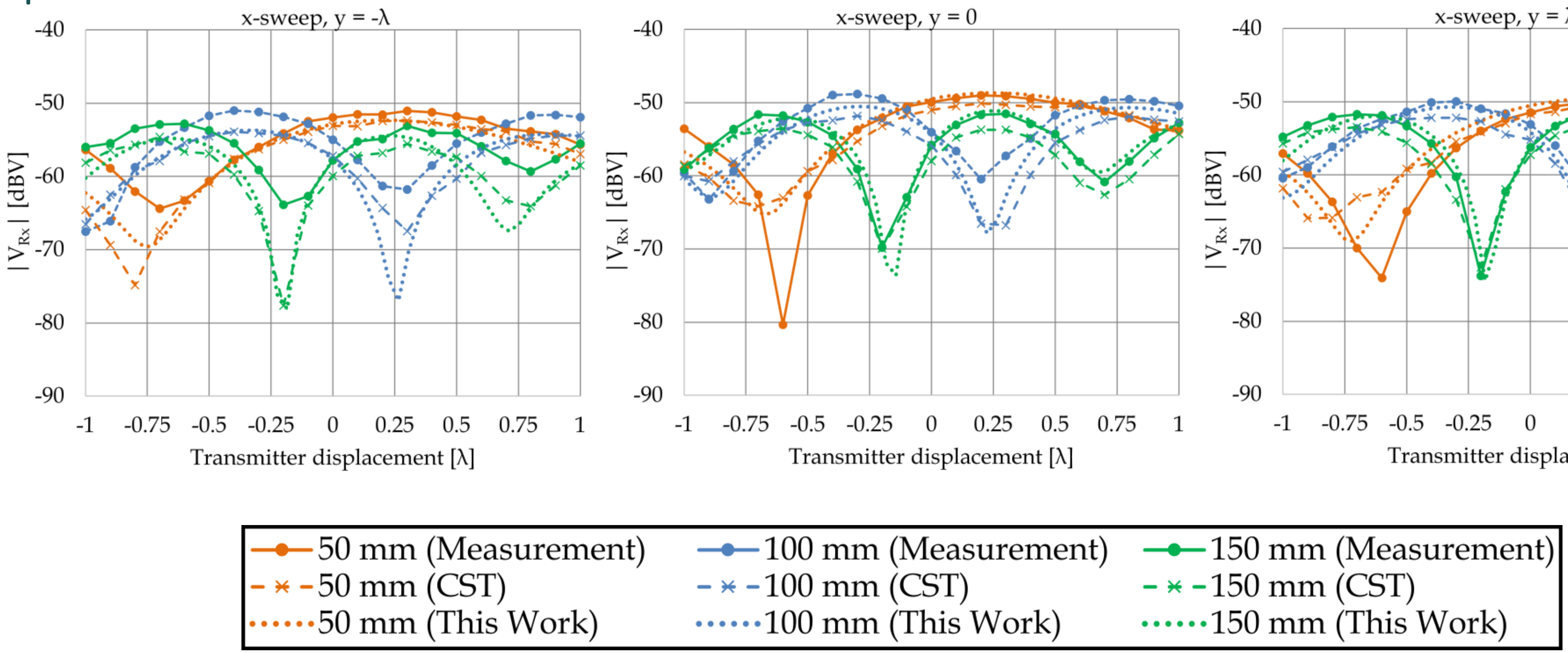
E-Dipole



Good match of novel method
with reference and measurements

Validation: straight microstrip lines

H-Dipole



Good match of novel method
with reference and measurements

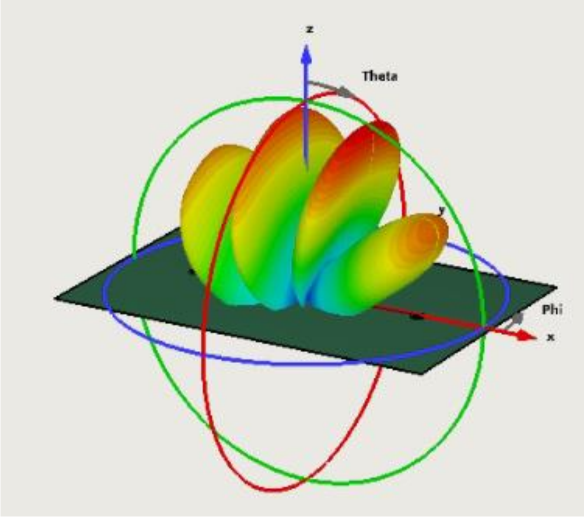
Application: load mismatch

Fabricated prototype

Rogers 4350B substrate
Length = 100 mm

Matched Load

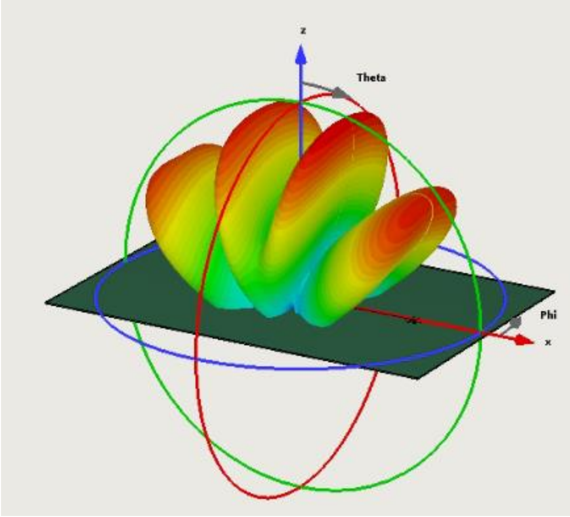
Z_{Load} = 50 Ω



Max: 0.6 V/m

Short Circuited

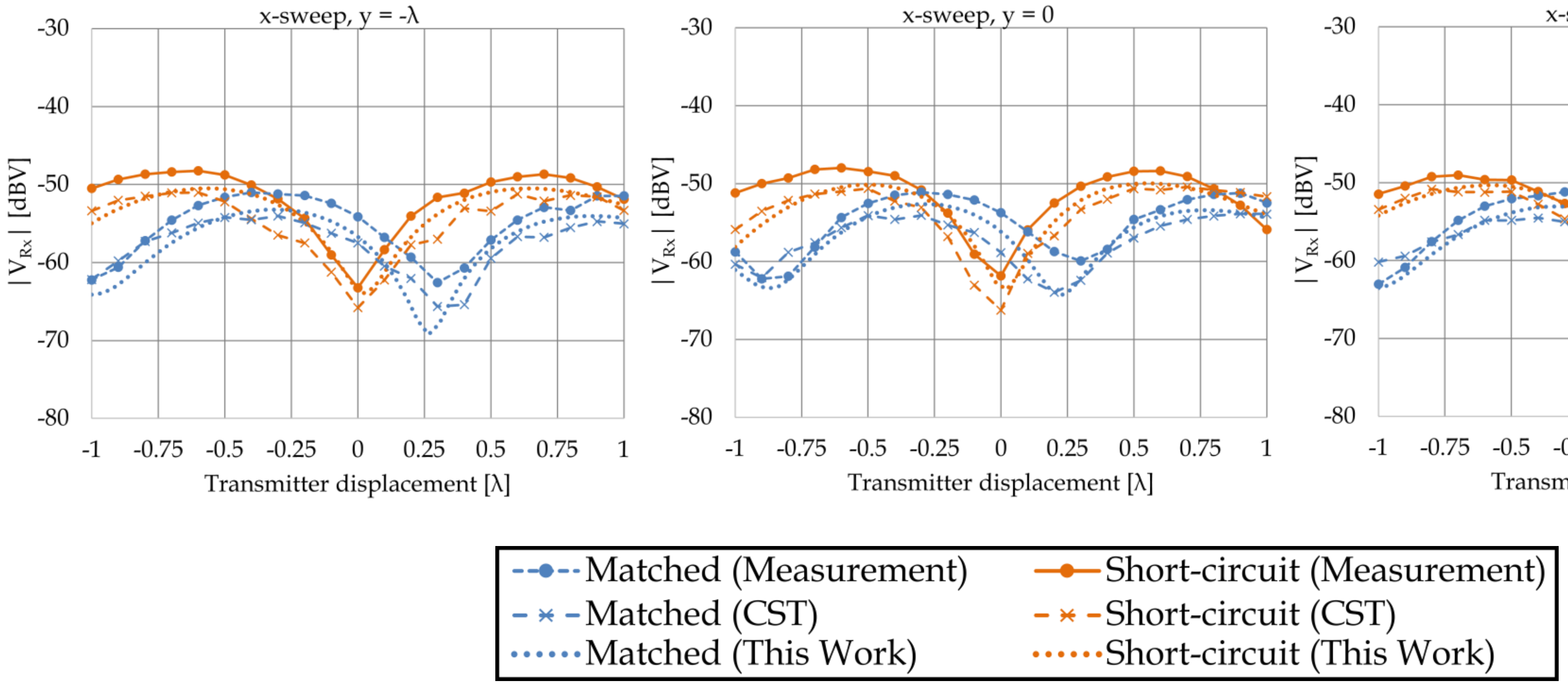
Z_{Load} = 0 Ω



Max: 0.8 V/m

Application: load mismatch

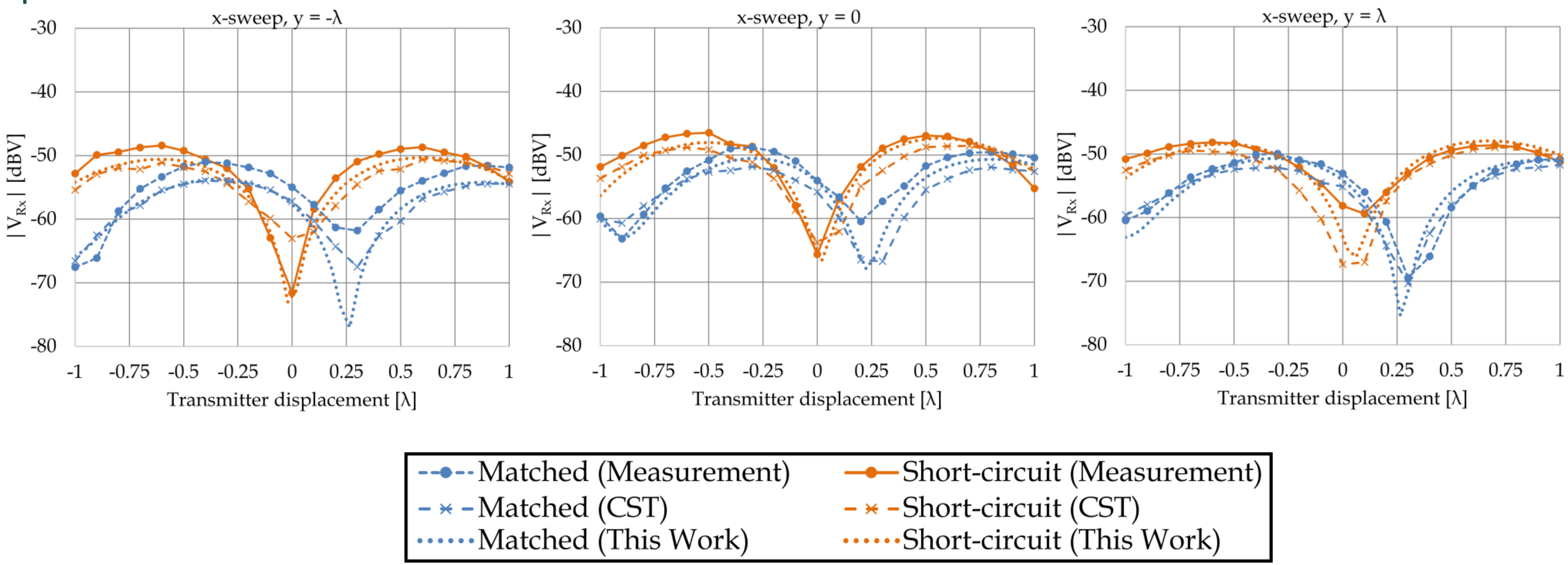
E-Dipole



Mismatch increases radiation levels and shifts extrema

Application: load mismatch

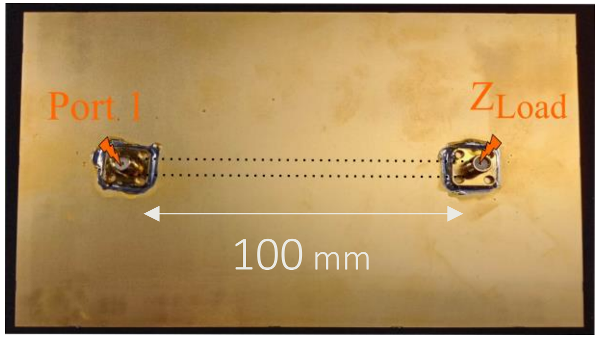
H-Dipole

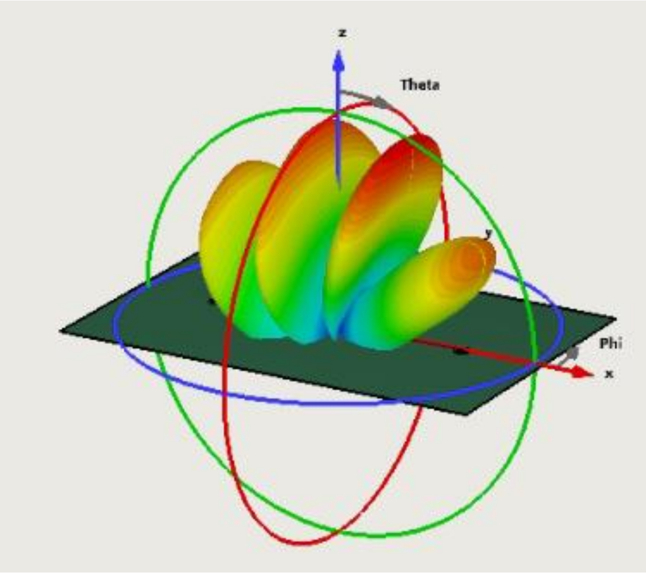


Mismatch increases radiation levels and shifts extrema

Application: defective ground structure (GDS)

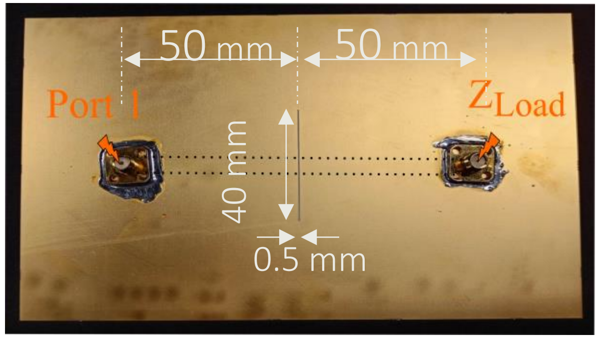
no DGS

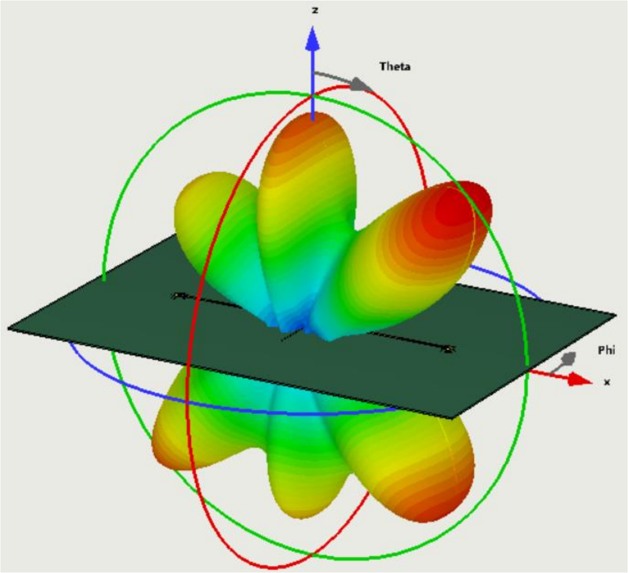




Max: 0.06 V/m

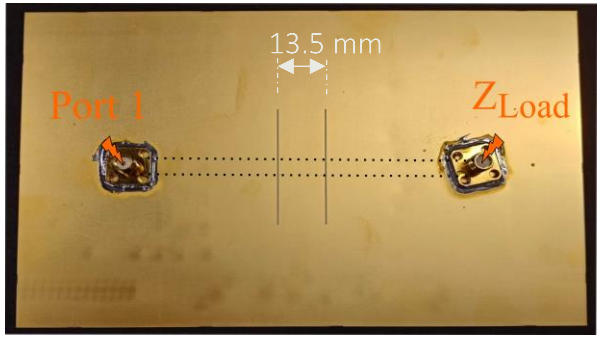
single DGS

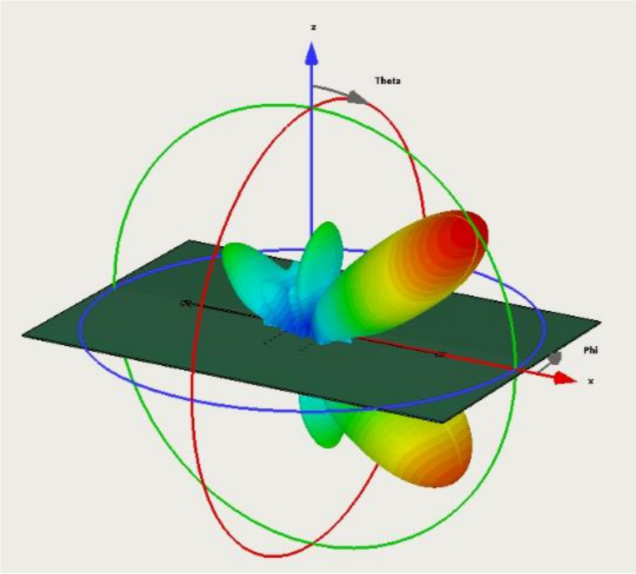




Max: 0.36 V/m

double DGS

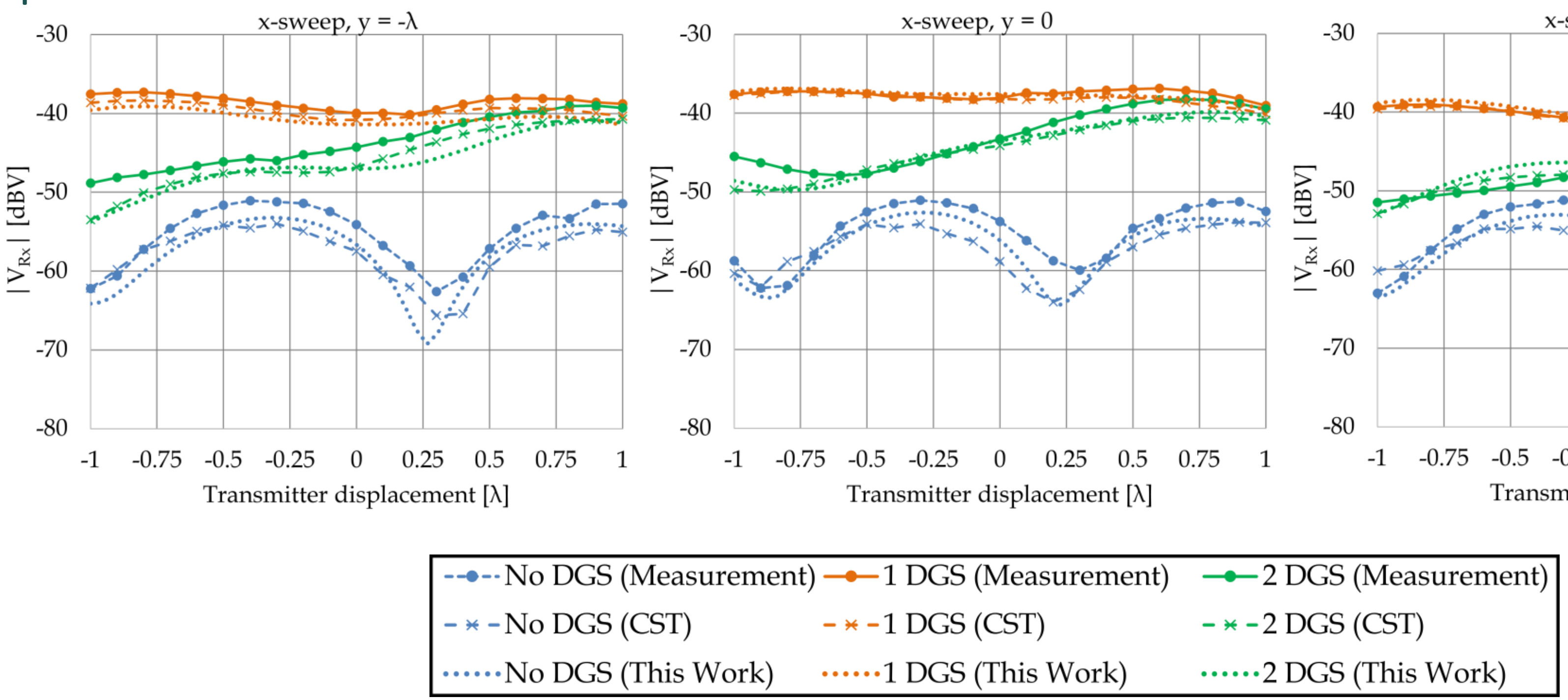




Max: 0.5 V/m

Application: defective ground structure (GDS)

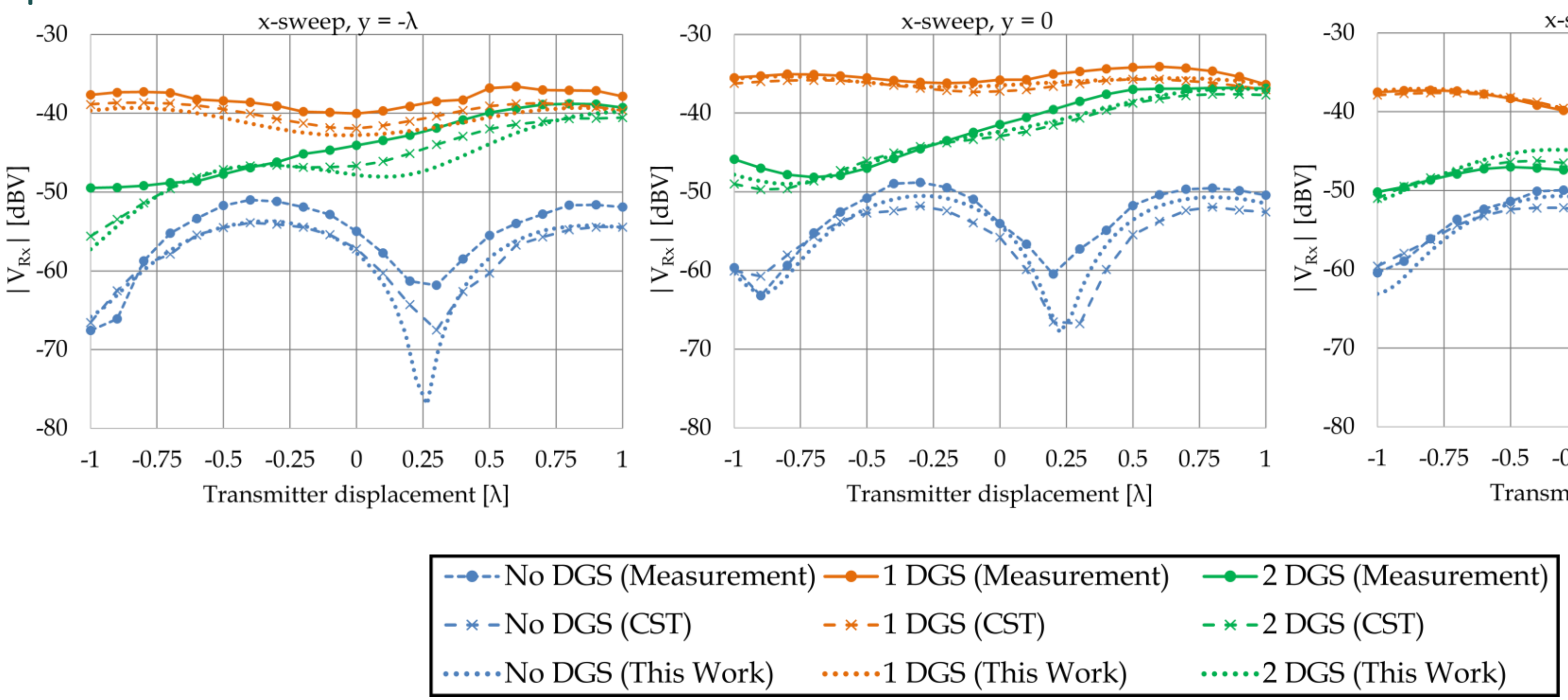
E-Dipole



GDS drastically increases emitted radiation

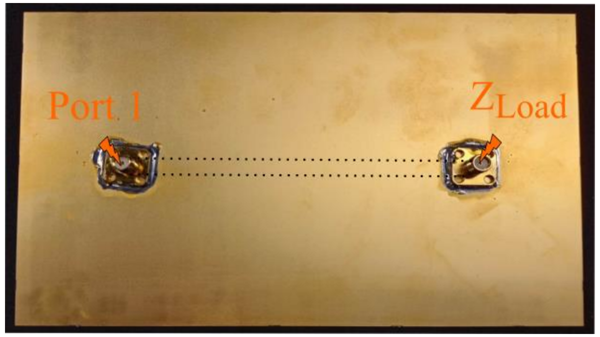
Application: defective ground structure (GDS)

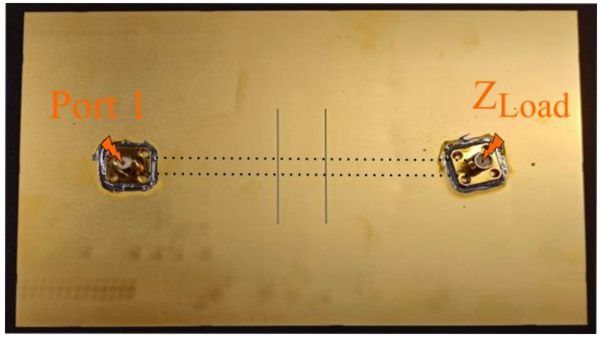
H-Dipole

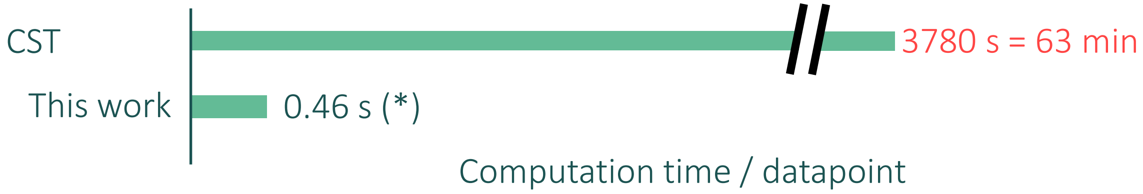


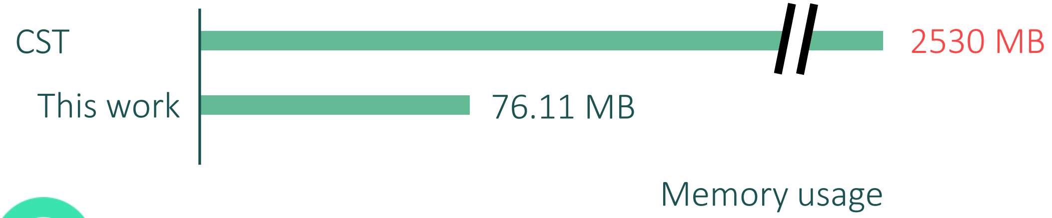
GDS drastically increases emitted radiation

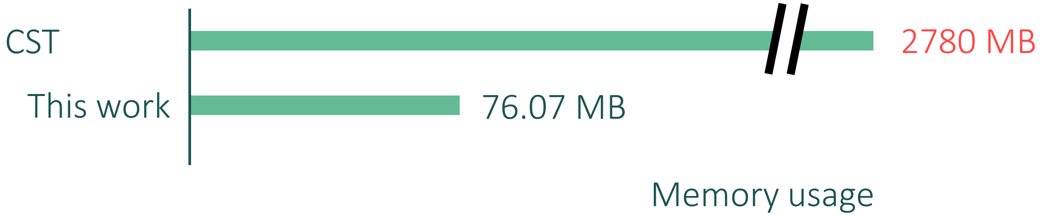
Performance











(*) + 1 time rad. pattern computation of 537 s

Conclusion

Fast and **efficient** method to assess radiative EMC performance

Only requires **in-situ far-field data** of **individual** components

Computation time **independent** of distance

Accuracy validated with commercial software and measurements

Vastly outperforms reference simulation in time and memory requirements

quest.
Quantum Mechanical &
Electromagnetic Systems
Modelling Lab

GHENT UNIVERSITY
imec

Technologiepark – Zwijnaarde 126, B-9052 Gent, Belgium
T +32 9 264 33 54

Martijn Huynen

Martijn.Huynen@UGent.be
+32 9 264 33 27