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Near-Field Scanning

Searching for Root Causes

Apr. 10, 2018

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Outline

- Emission Scanning
  - Sniffer probes are smarter than they look
  - Electromagnetic lens: from near-field to far-field
- Susceptibility Scanning
  - Conducted susceptibility: where does ESD current go?
  - Near-field effects of electrostatic discharge events

Emission Scanning

Sniffer Probe

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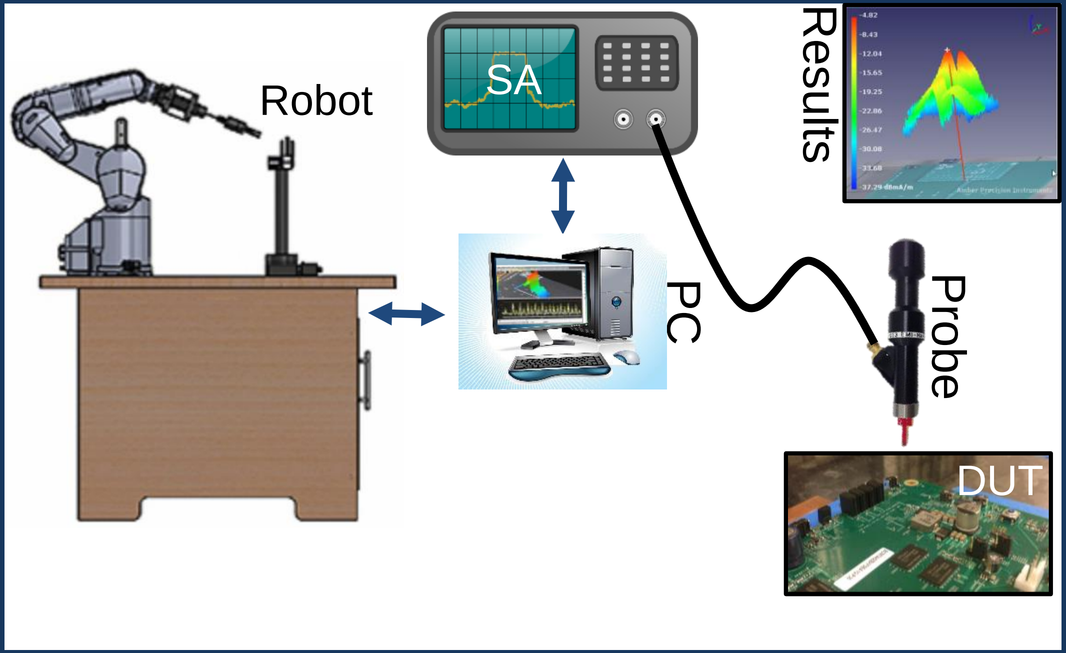
EMI Near-Field Probe

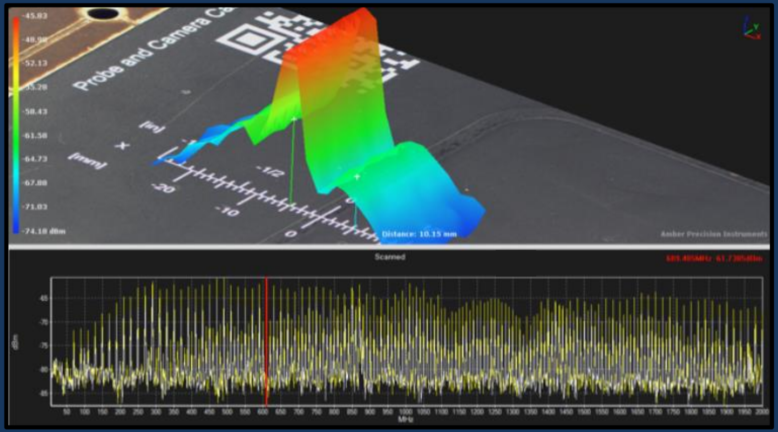
EMI Probes:
- Up to 40 GHz
- Down to 50 kHz

Optional EMI Probes; Choose:
- Size
- Frequency range
- Field Component

* EMI Hx 2 mm

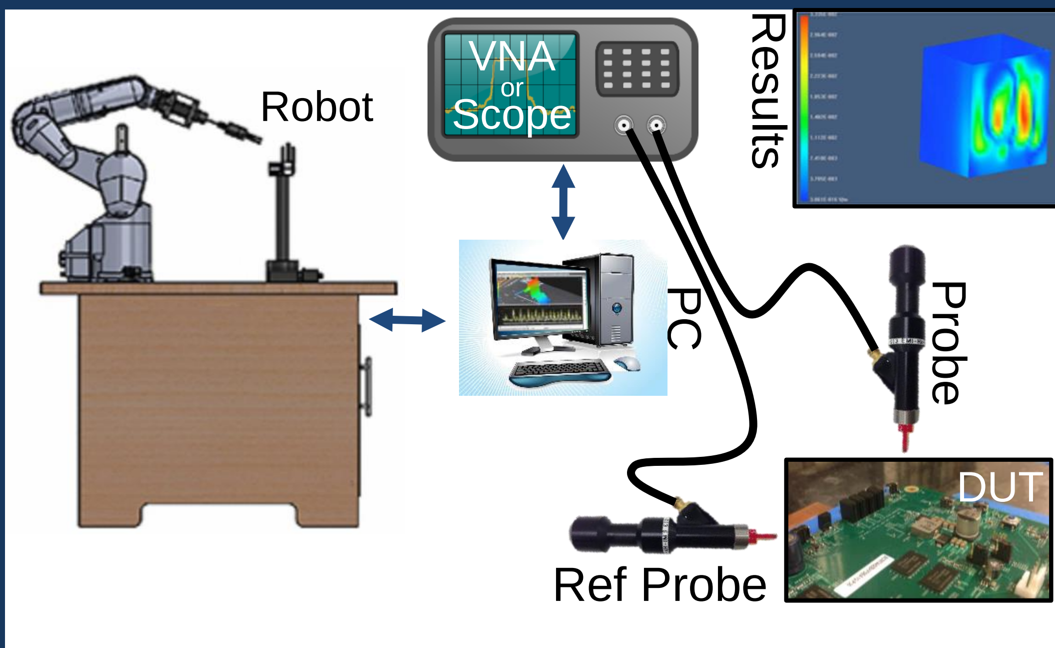
EMI Near-Field Scanning

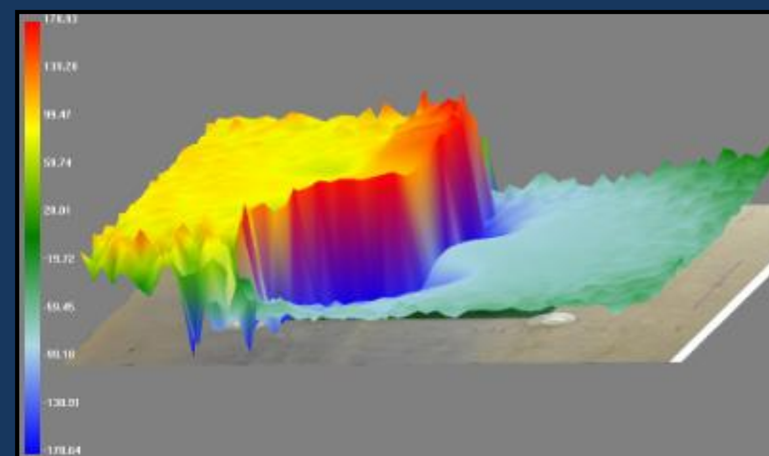




* IEC TS 61967-3

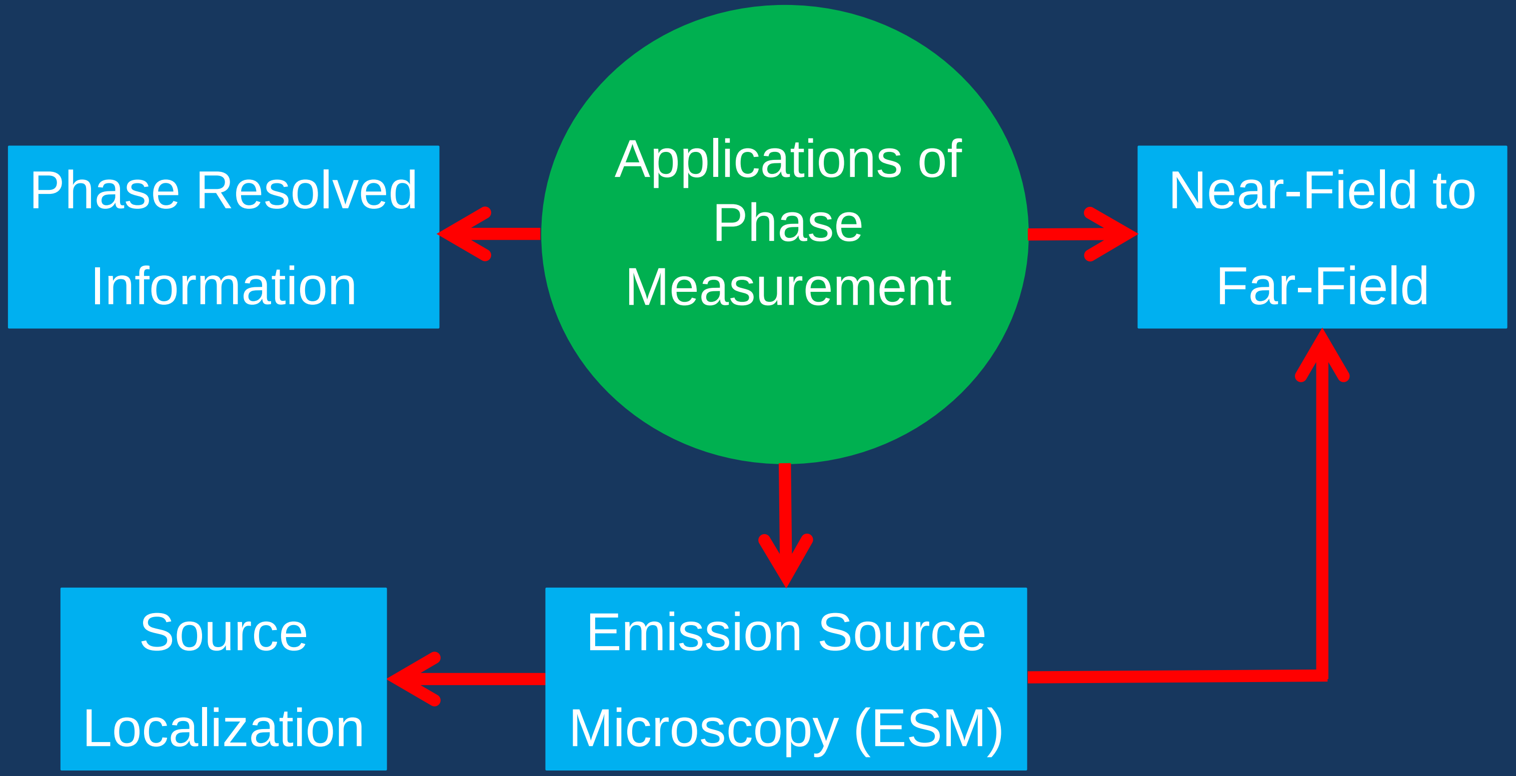
Phase Measurement Scanning





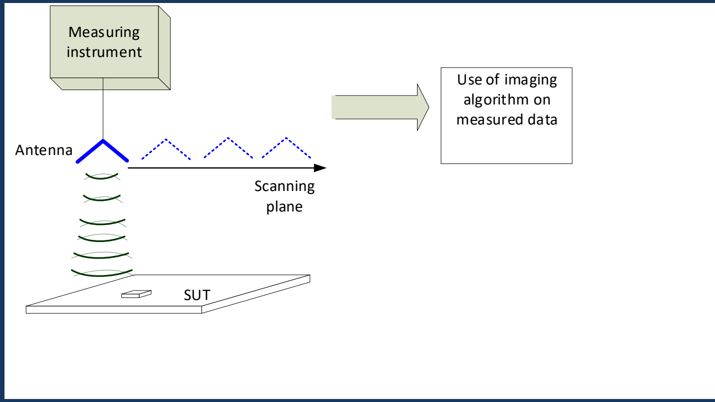
* IEC TS 61967-3

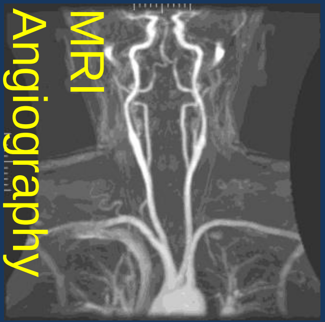
Applications of Phase Measurement



Applications of ESM:
- High speed data communication
- Data centers, servers, routers, cloud
- 5G mobile network
- Radar systems
- Phased arrays
- Electrically large structures

History of ESM: Synthetic Aperture Radar (SAR)





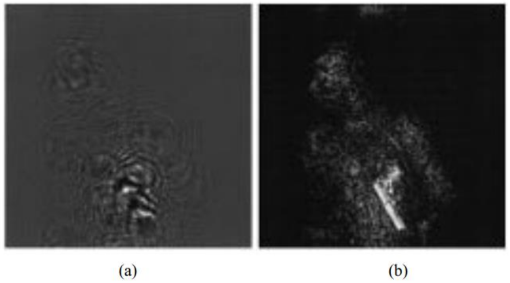
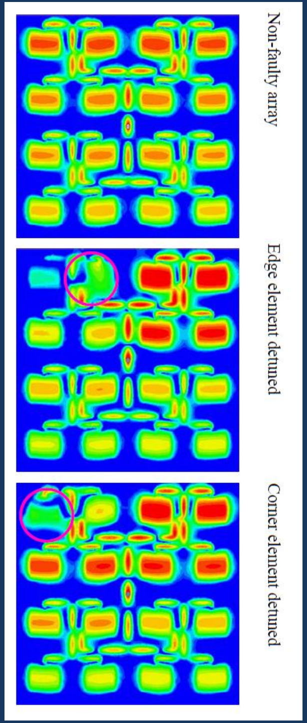
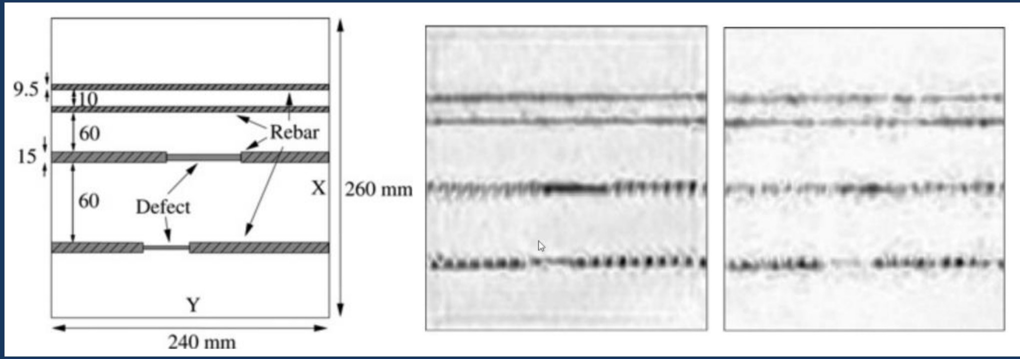


Fig. 5. (a) 35-GHz hologram and (b) reconstructed image of a mannequin carrying a concealed handgun.

Fig. 6. 350-GHz reconstructed image of a Glock-17 9-mm handgun.

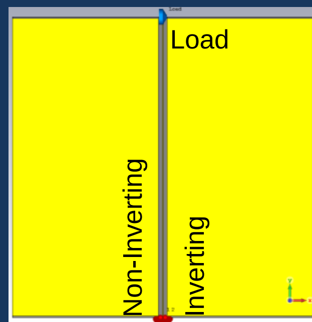


Applications of SAR:
- Airborne radar
- Medical imaging
- Concealed object detection
- Non-destructive testing
- Antenna diagnosis

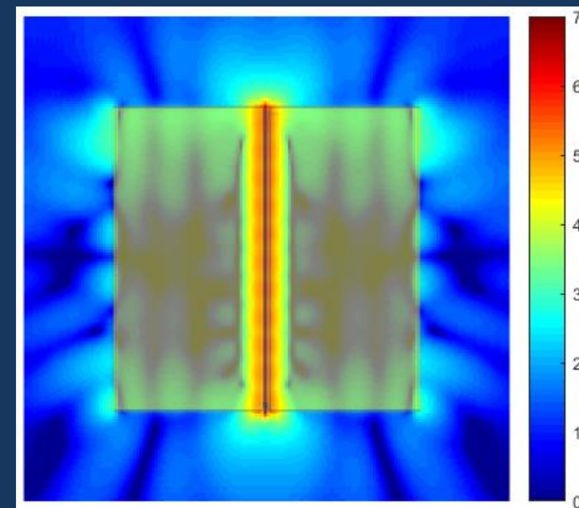


* Wikipedia, P.L. Ransom et al (1971), J.J Lee et al (1988), M. Soumekh (1991), D.M. Sheen et al (2001), B. Janice (2011), H. Kajbaf et al (2013)

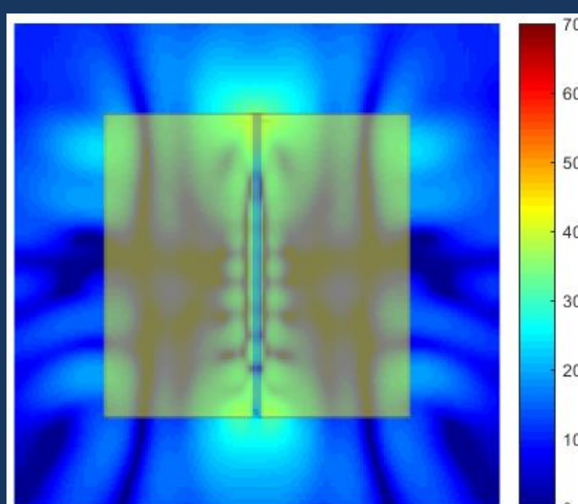
Symmetric Differential Microstrip



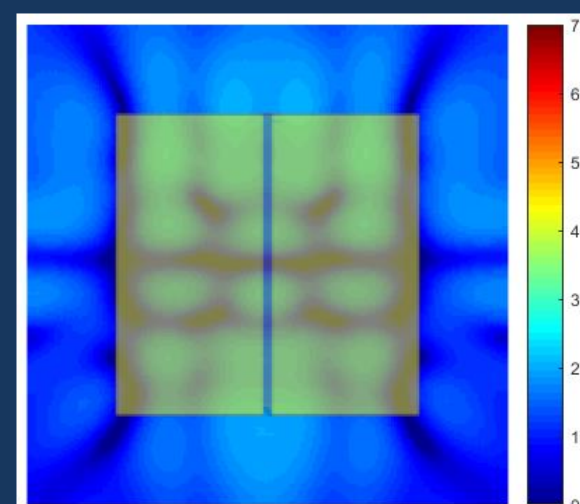
Full-wave simulation
Differential microstrip line
Differentially driven @ 10 GHz



Ex @ Z=1 mm (λ/30)

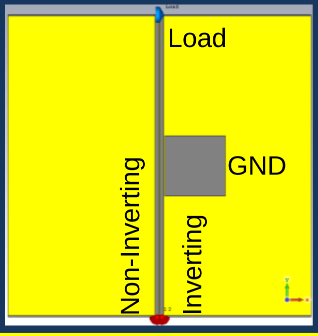


Ex @ Z=7.5 mm (λ/4)

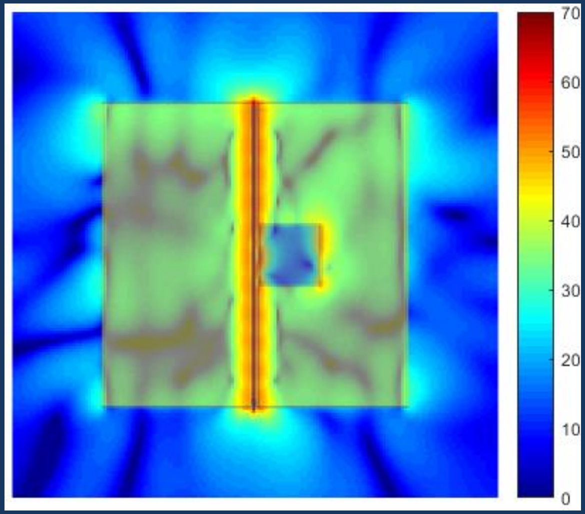


Ex @ Z=30 mm (λ)

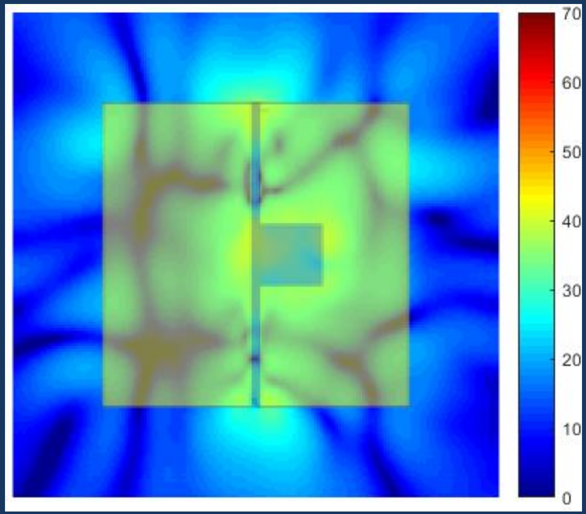
Asymmetric Differential Microstrip



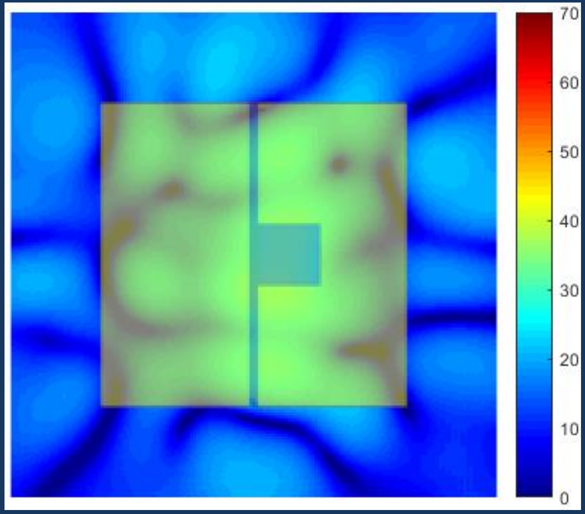
Asymmetric differential microstrip
12 mil gap between GND & line
Differentially driven @ 10 GHz



Ex @ Z=1 mm (λ/30)



Ex @ Z=7.5 mm (λ/4)



Ex @ Z=30 mm (λ)

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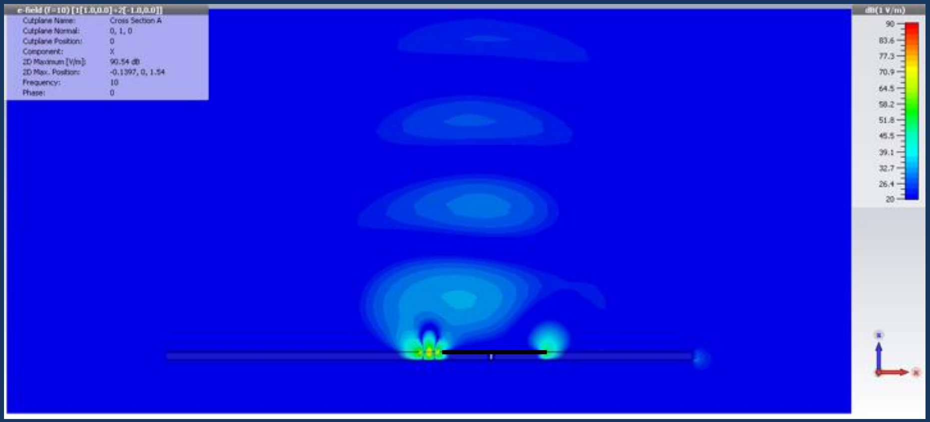
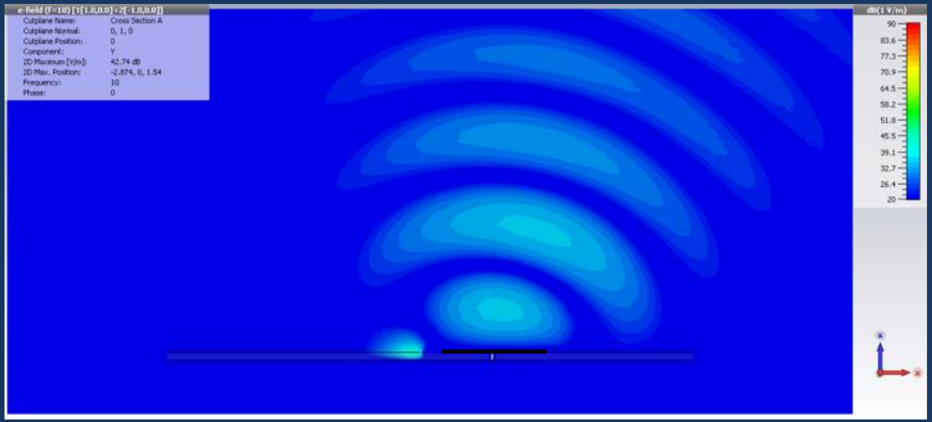
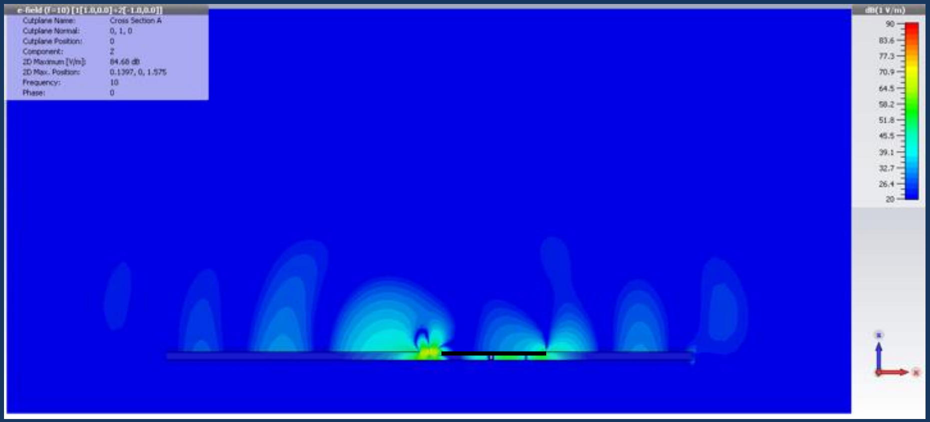
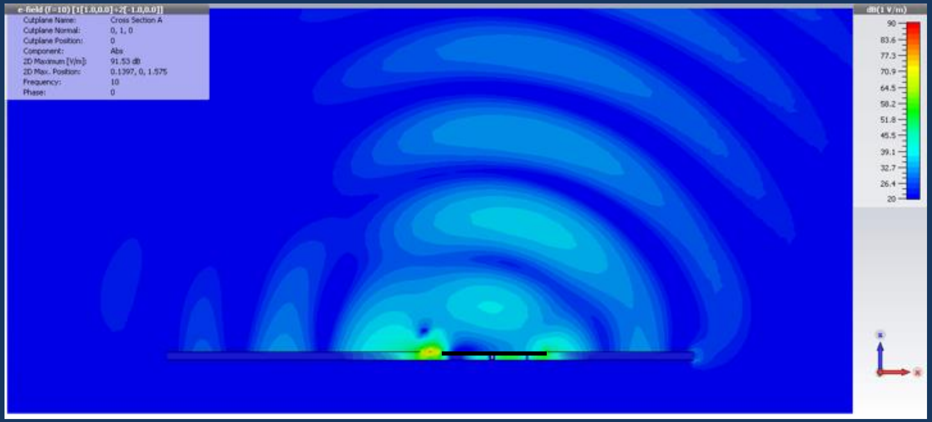
Wave Propagation


Ex

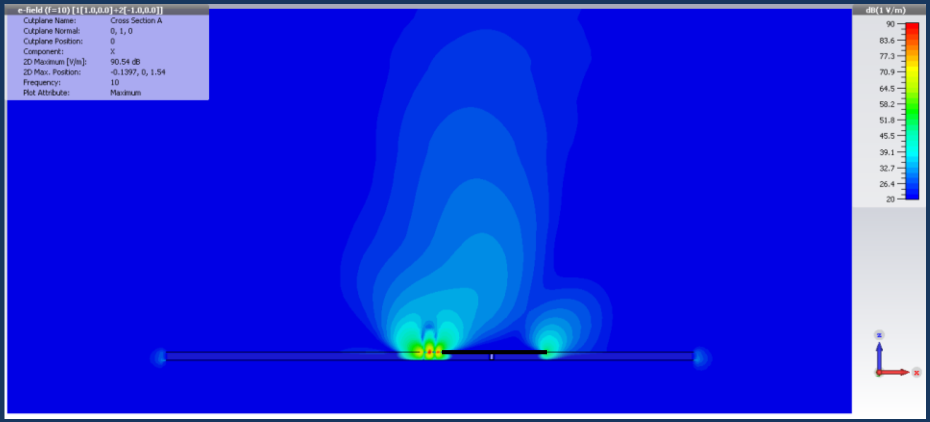

Ey


Ez

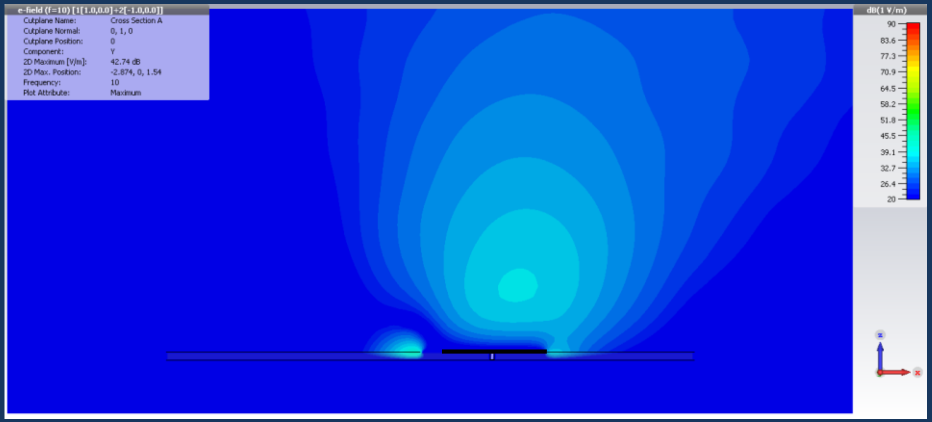

|E|

* Asymmetric differential microstrip @ 10 GHz

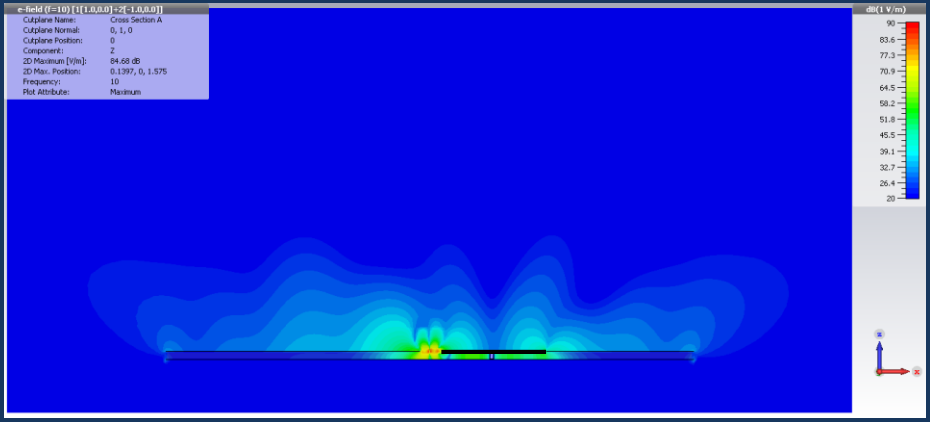
Wave Propagation



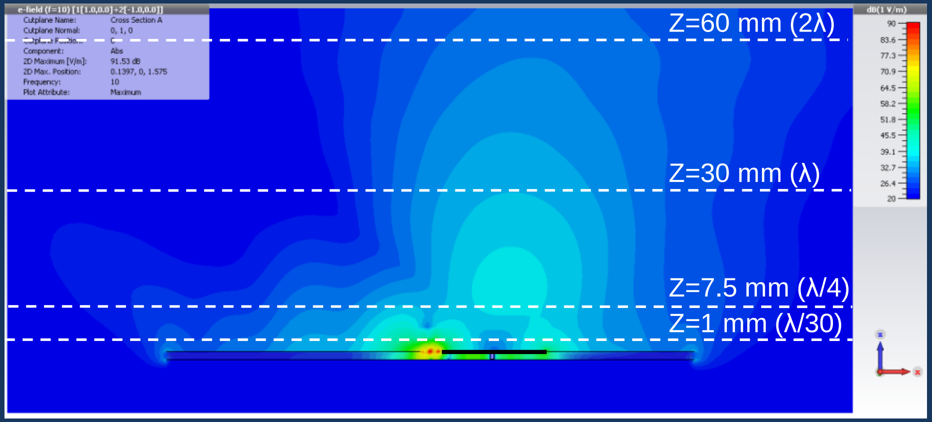
Max Ex



Max Ey



Max Ez



Max |E|

* Asymmetric differential microstrip @ 10 GHz

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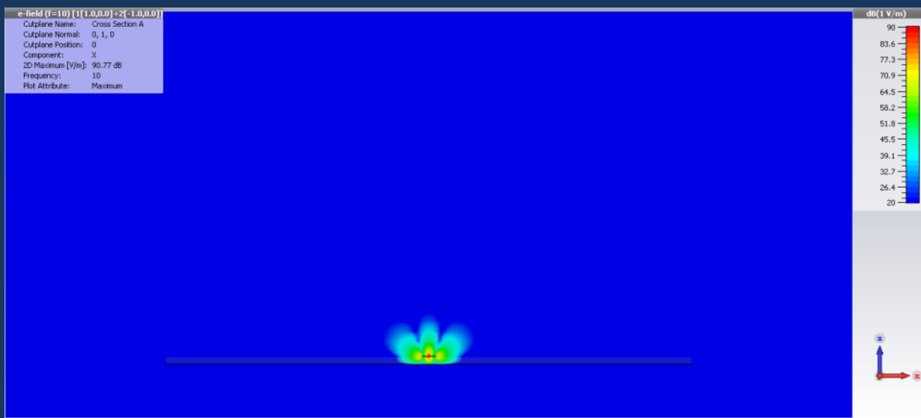
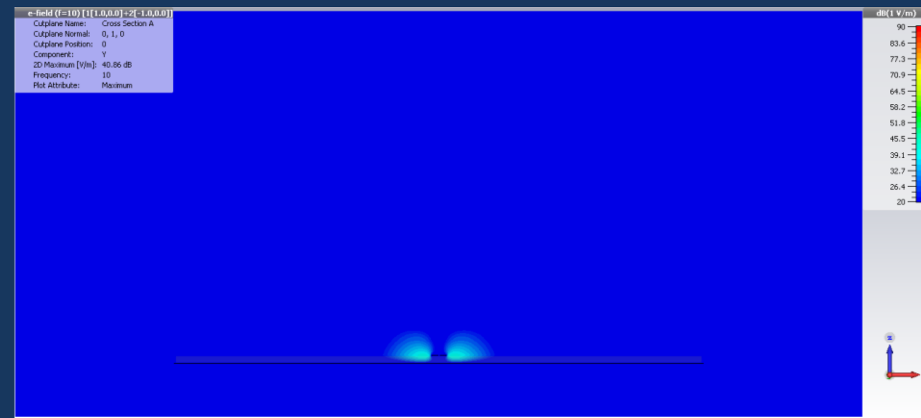
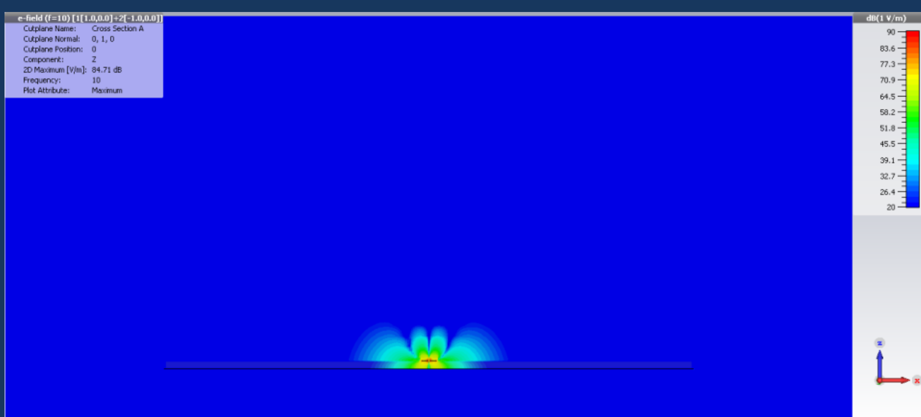
Wave Propagation



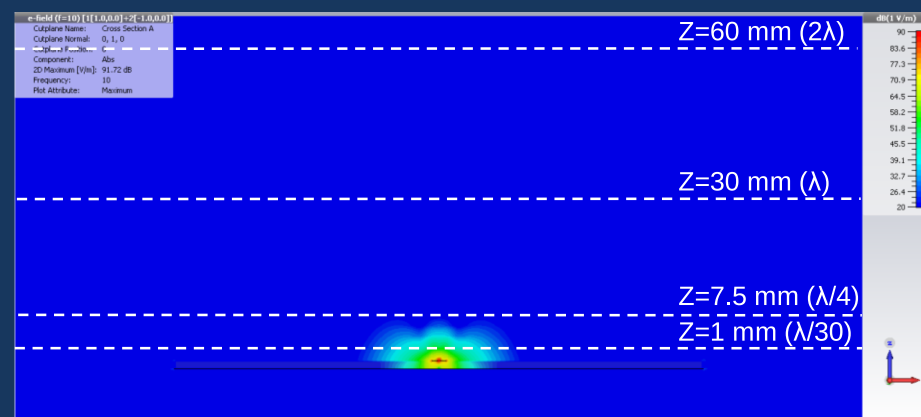
Max Ex



Max Ey



Max Ez



Max |E|

* Symmetric differential microstrip @ 10 GHz

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Emission Source Microscopy (ESM)

$$f(x,y) = F_{2D}^{-1}\left\{F_{2D}\{s(x,y)e^{-jk_z z_0}\}\right\} \qquad k_z = \sqrt{k^2 - k_x^2 - k_y^2}$$

Measure at Radiative Near-Field (~1-2λ away from DUT)

→ Back-Calculate to DUT Location (Phase Adjustment)*

→ Localize Sources Contributing to Far-Field

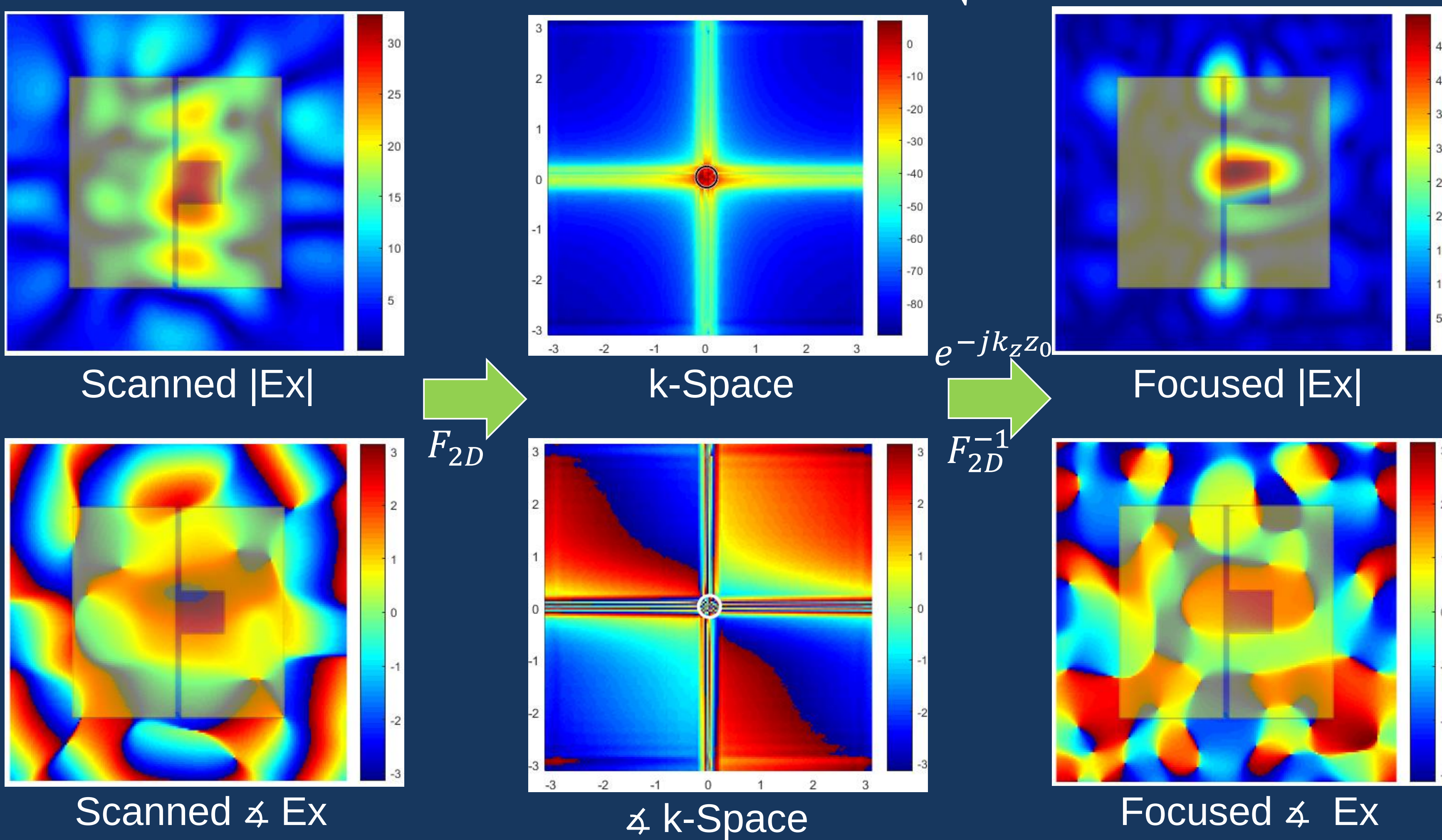
↑ Optional: Calculate Far-Field Pattern

↓ Optional: Calculate TRP

* Using Range Migration Algorithm (RMA) or Synthetic Aperture Radar (SAR)

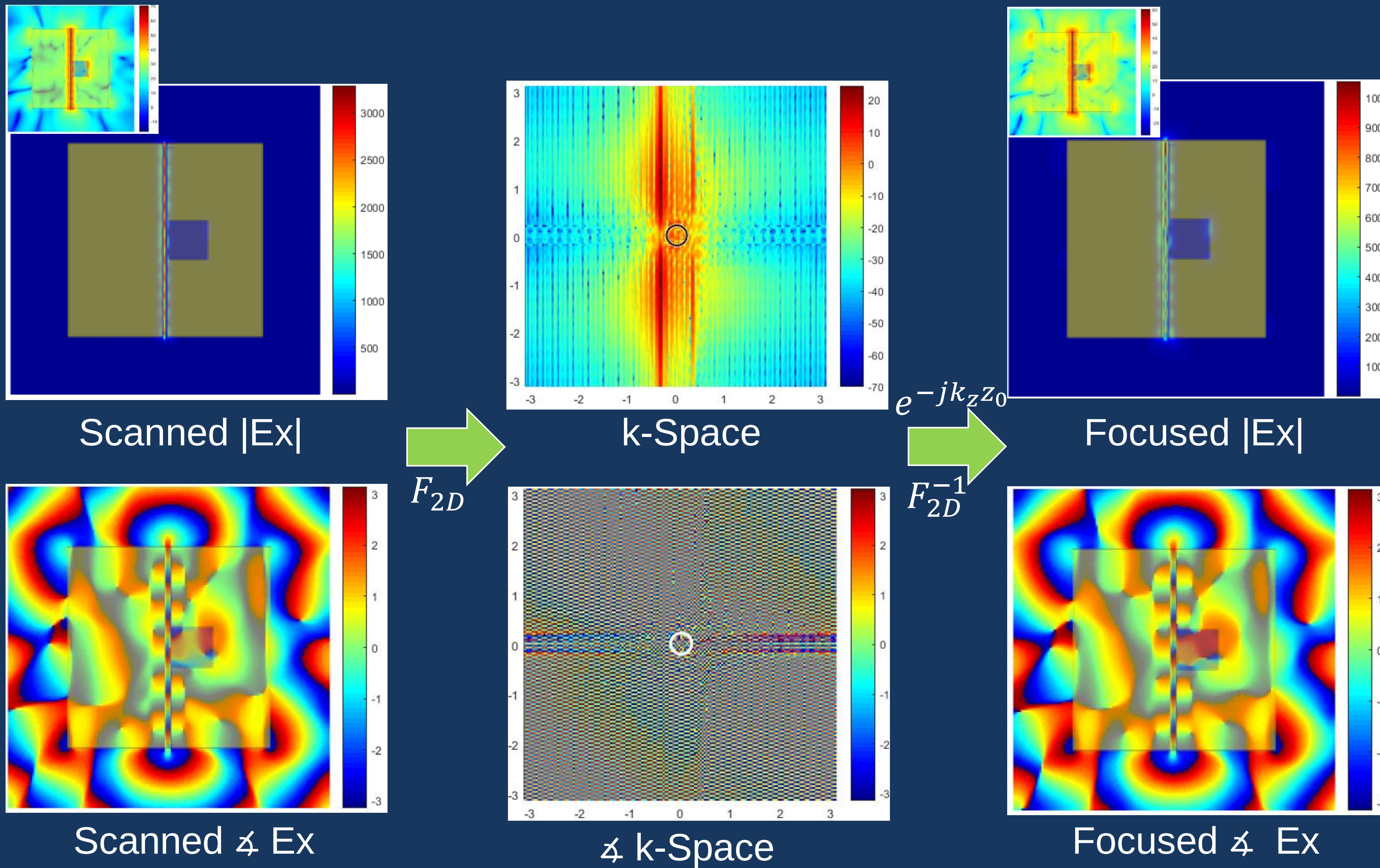
k-Space and Propagating Wave

$$f(x,y) = F_{2D}^{-1}\left\{F_{2D}\{s(x,y)e^{-jk_z z_0}\}\right\} \qquad k_z = \sqrt{k^2 - k_x^2 - k_y^2}$$



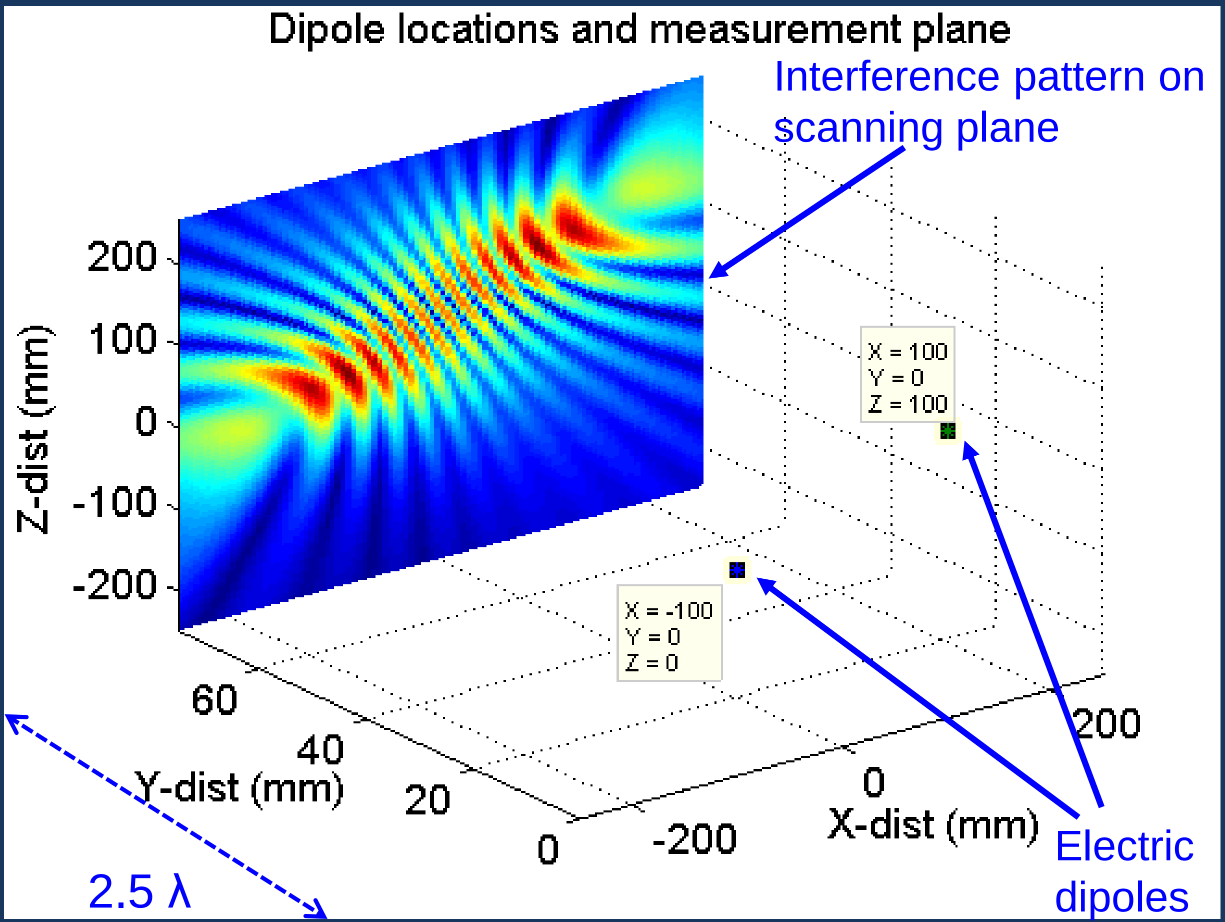
* Asymmetric differential microstrip @ 10 GHz, Z=30mm (λ)

k-Space and Evanescent Wave



* Asymmetric differential microstrip @ 10 GHz, Z=1mm (λ/30)

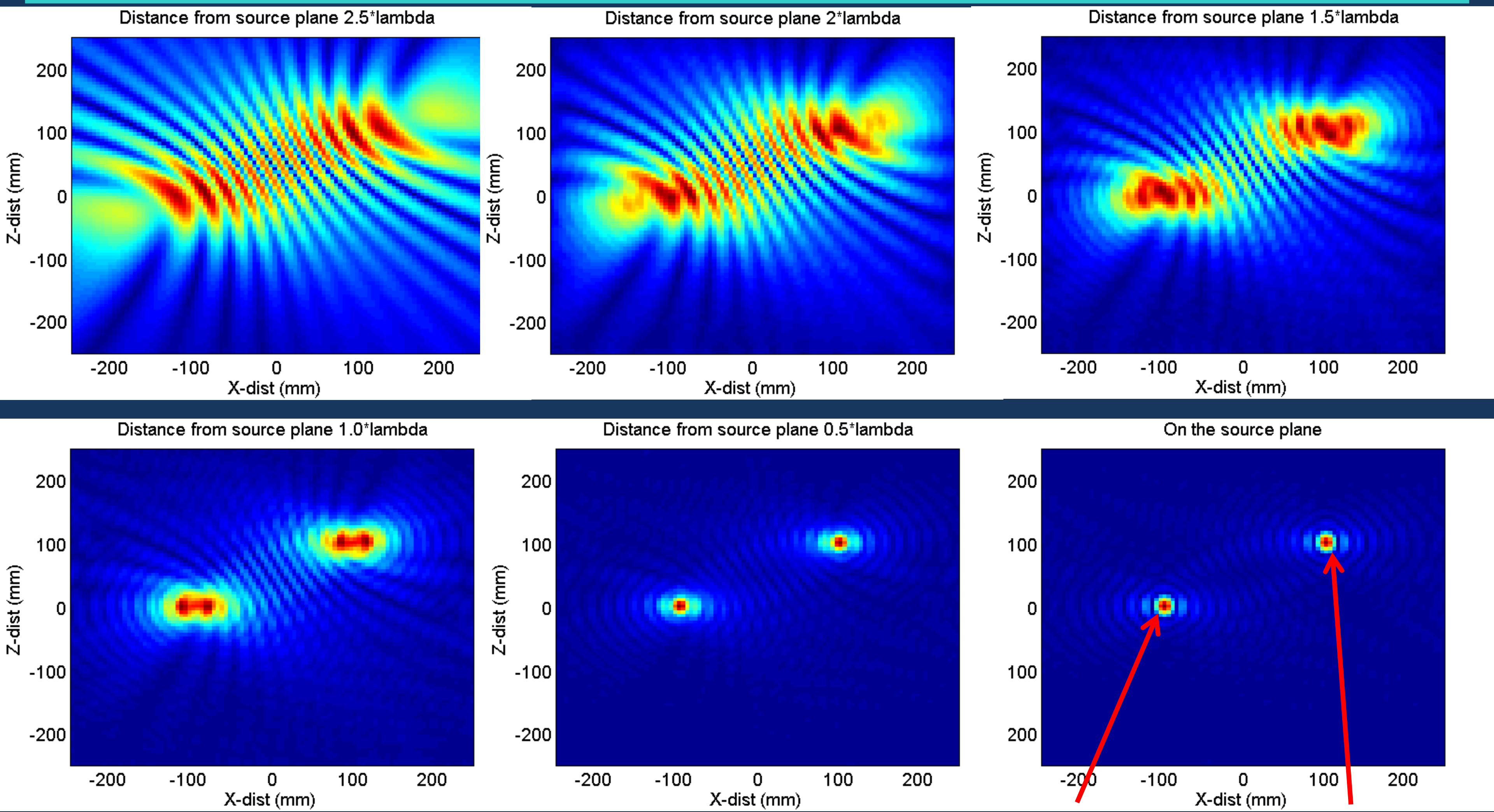
Ideal Dipole



Two dipoles are placed
Dipole 1 at (-100,0,0) mm,
Dipole 2 at (100,0,100) mm

E fields components
Frequency = 10 GHz
Grid spacing = 0.5 mm
Distance = 2.5λ
Resolution ~ 15 mm

Focusing Lens at Different Distances



Correct location of dipoles is determined

Dipole 1 at (-100,0,0) mm

Dipole 2 at (100,0,100) mm

Applications of ESM

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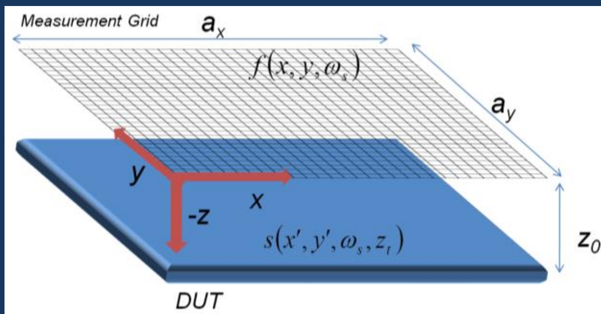
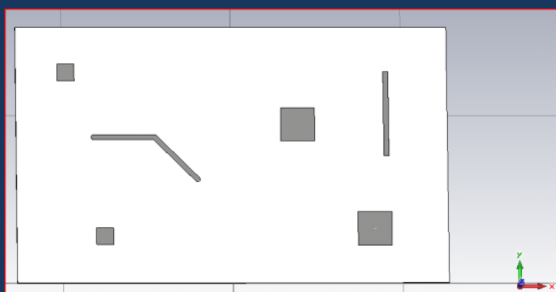
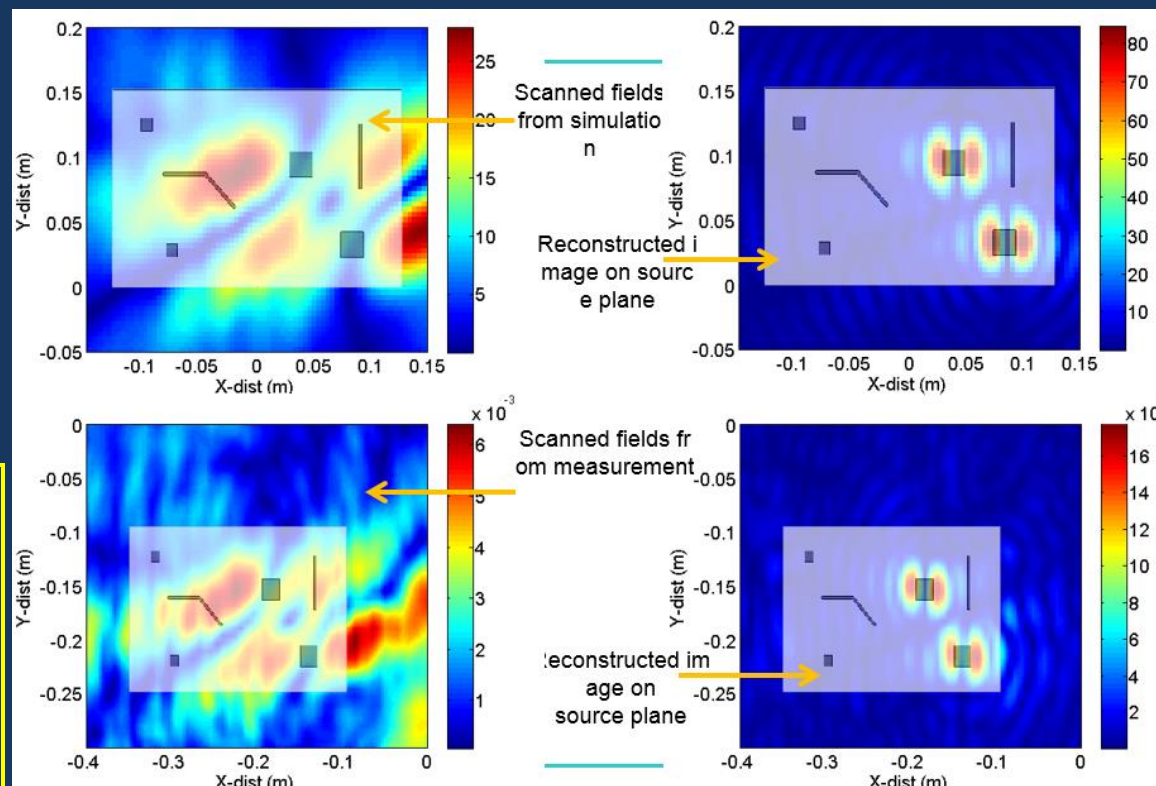




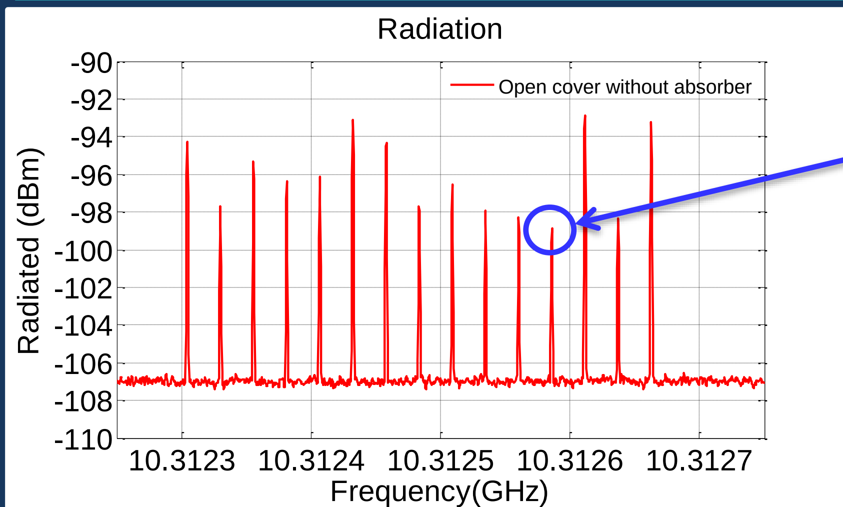
ESM Application of Synthetic Aperture Antenna (SAR) to EMC
- Identification of emission source
- FF estimation
- Total radiated power calculation

5 cm Away from DUT | Focused Image

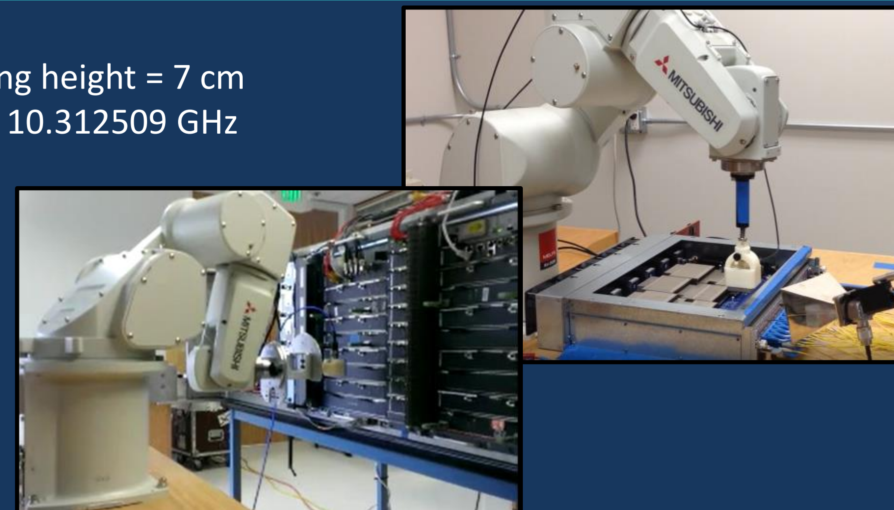


Measurement Setup:
- The measurement is performed at 8.2 GHz and at 5 cm away from DUT.
- Using VNA and open-ended waveguide used.

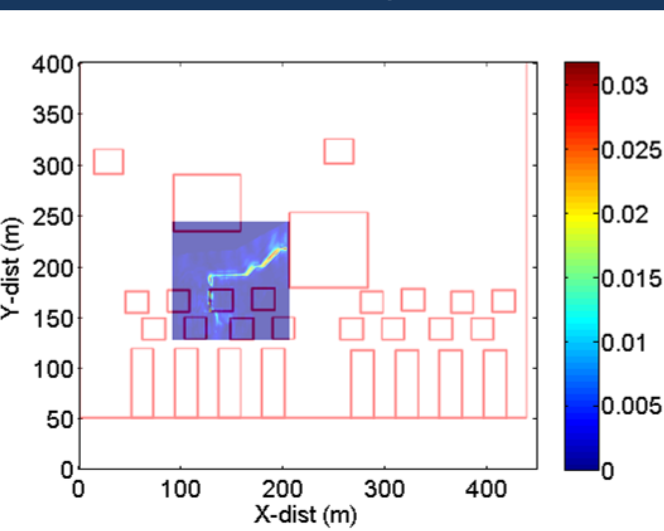
Applications of ESM



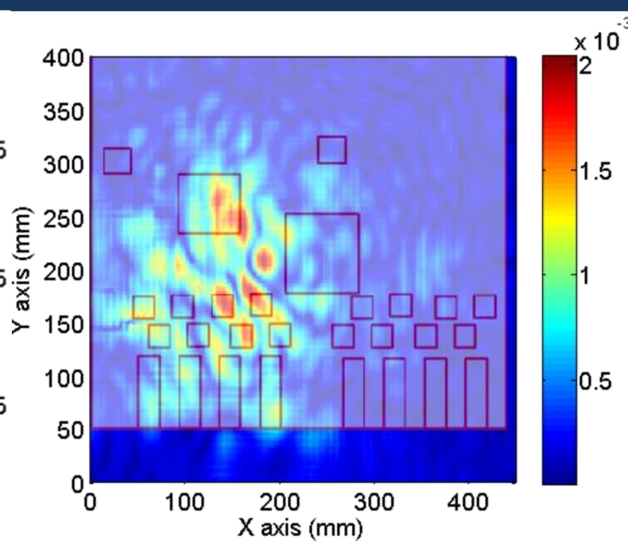
Scanning height = 7 cm
Freq = 10.312509 GHz



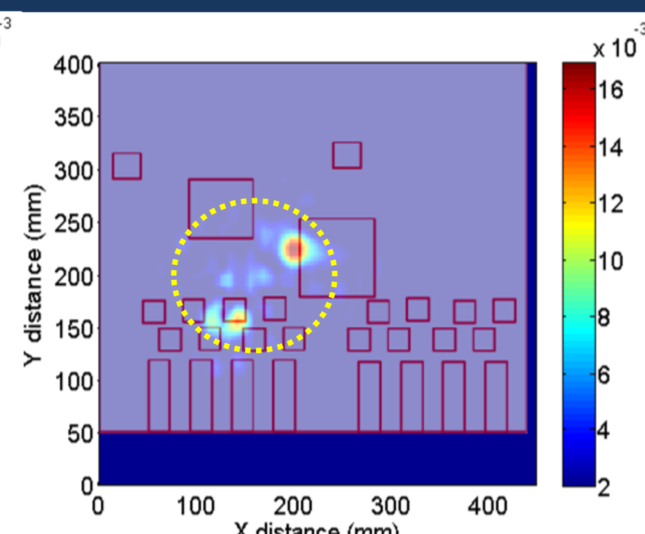
Near-Field Hx @ 2 mm



Scanned Ex @ 7 cm

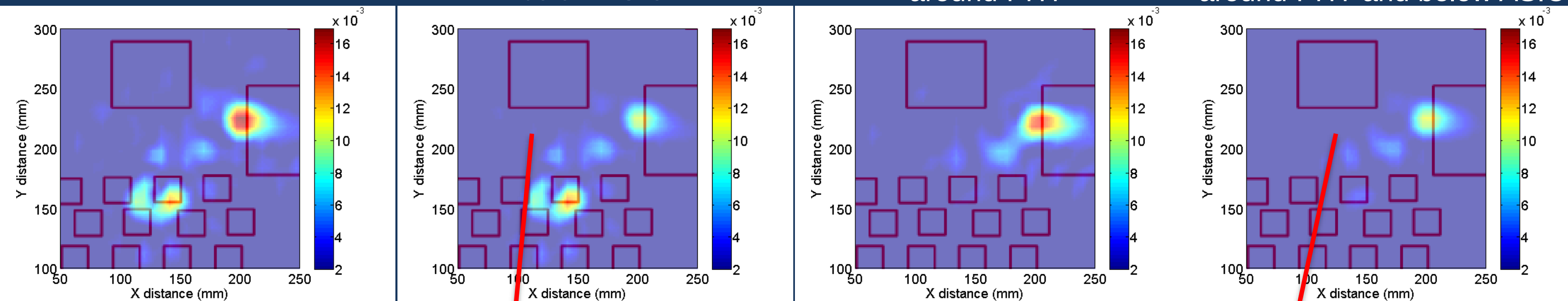


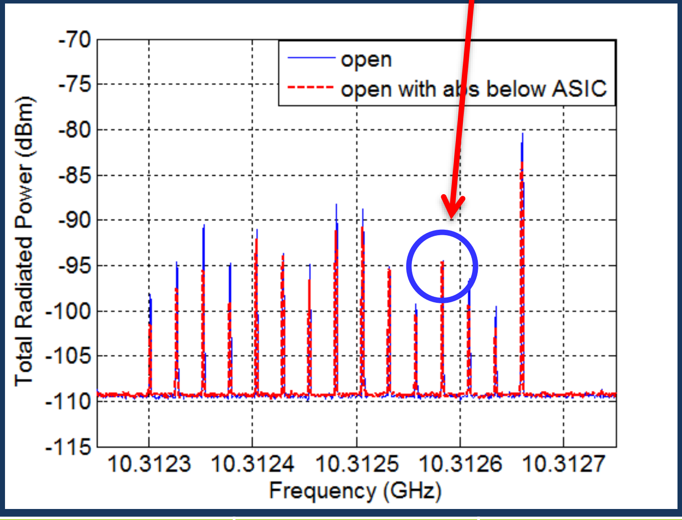
Focused Ex @ 0 cm

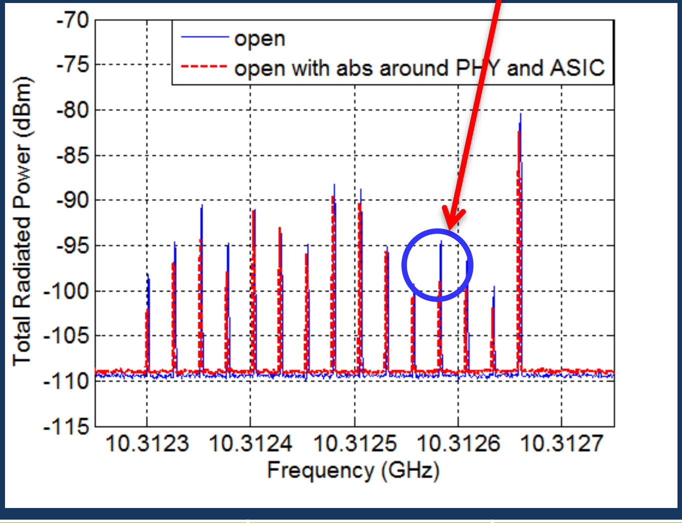


Applications of ESM

Without absorbing material	With absorbing material below ASIC	With absorbing material around PHY	With absorbing material around PHY and below ASIC







	TRP from R-Chamber	Calculated From ESM
Reduction in TRP	0-1 dB	0-1 dB

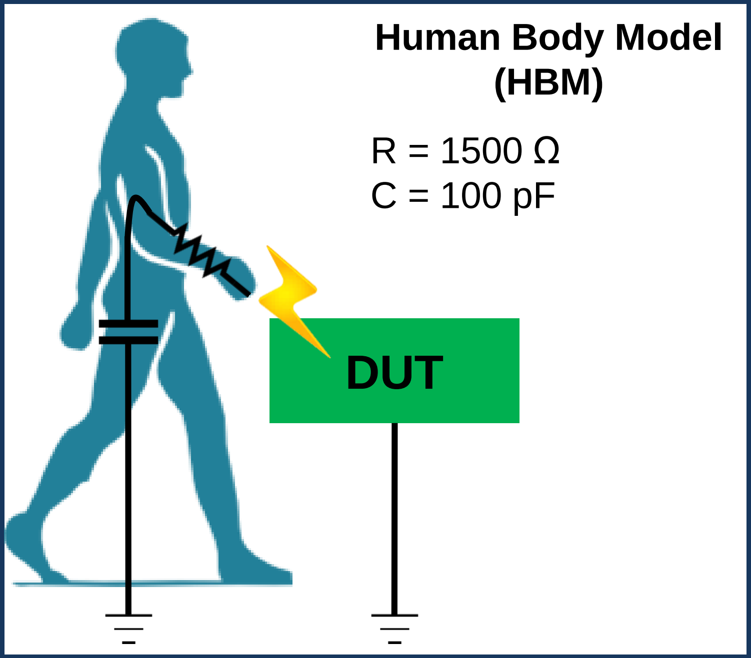
	TRP from R-Chamber	Calculated From ESM
Reduction in TRP	4-5 dB	4-5 dB

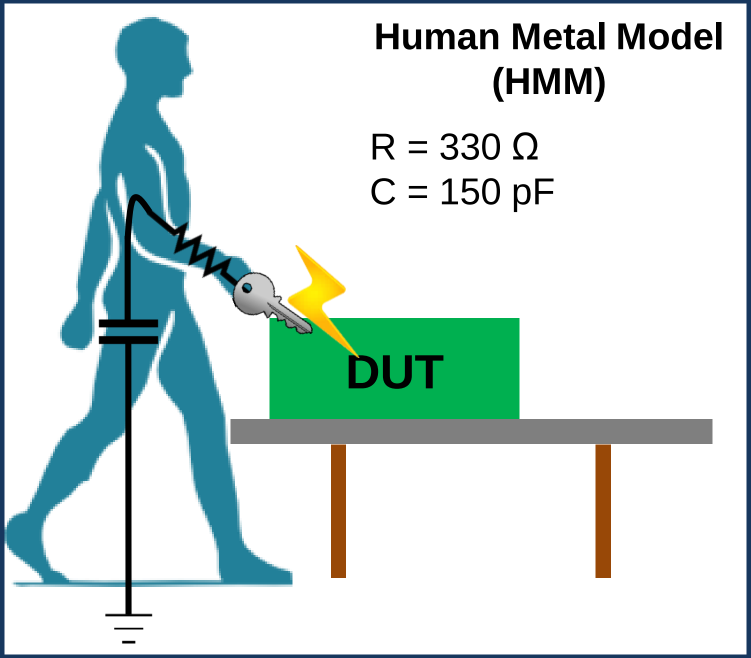
Emission Scanning: Conclusion

- EMI scanning is a powerful tool for identifying near-field sources.
- Measuring the phase distribution, in addition to magnitude, helps with identifying sources that contribute to far-field using ESM.
- Near-field to far-field transformation and total radiated power estimation are useful applications of phase measurement.

ESD Susceptibility Scanning

Electrostatic Discharge (ESD)





HBM Waveform

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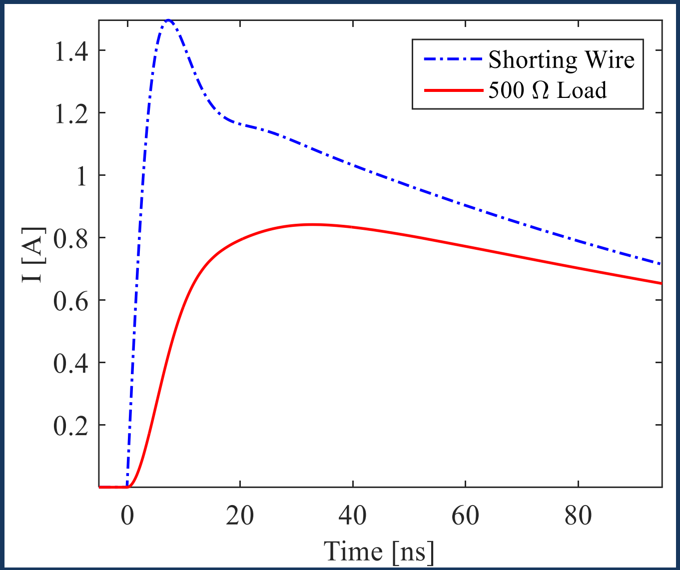


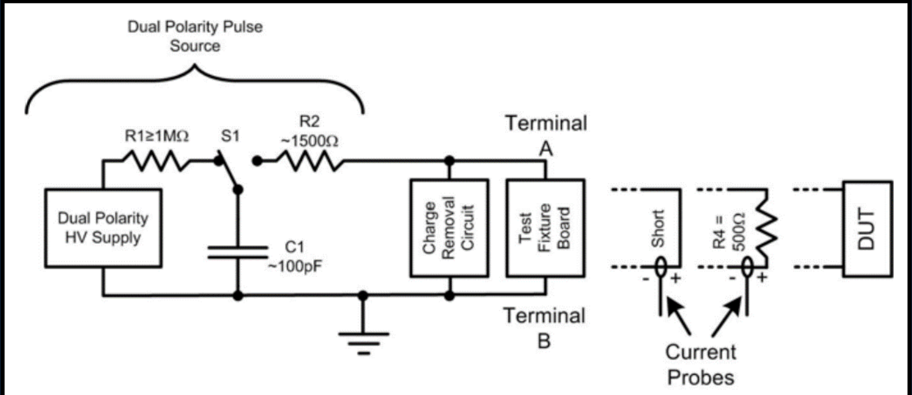
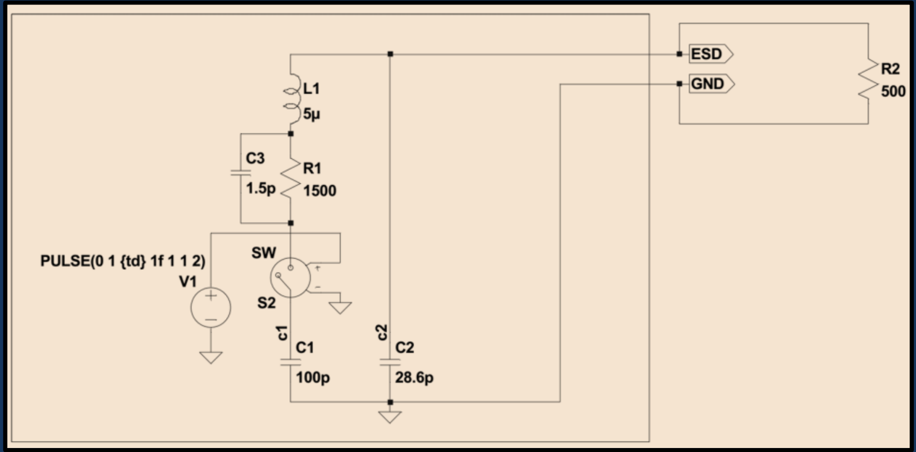
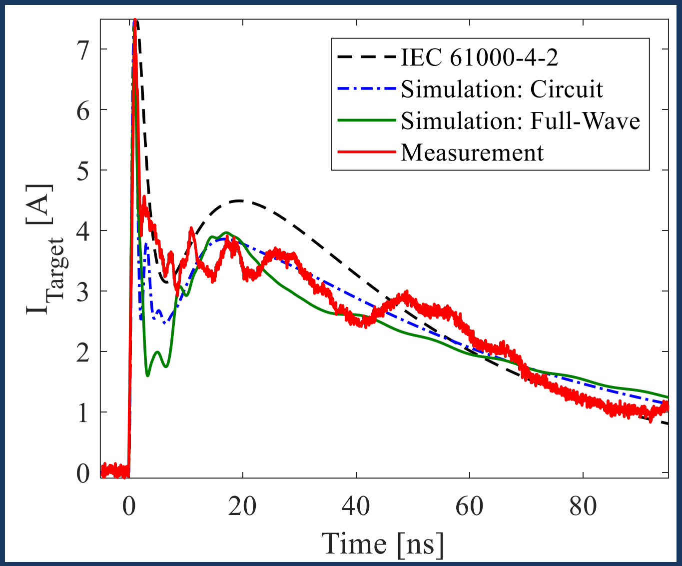


Figure 1 — Simplified HBM Simulator Circuit with Loads

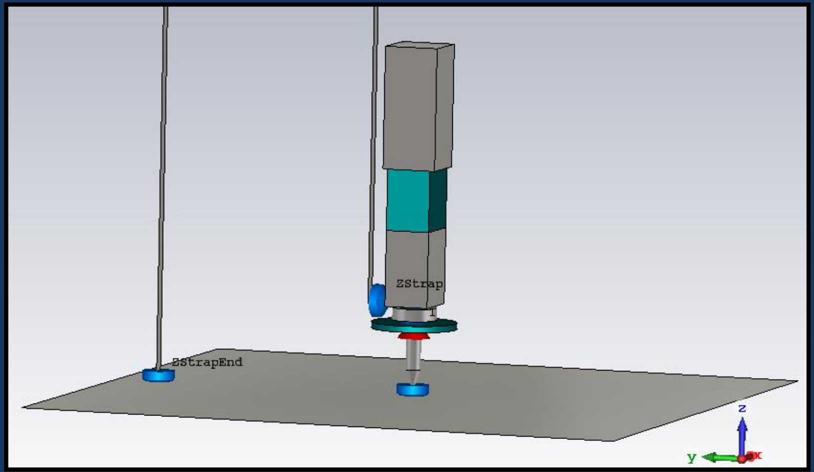


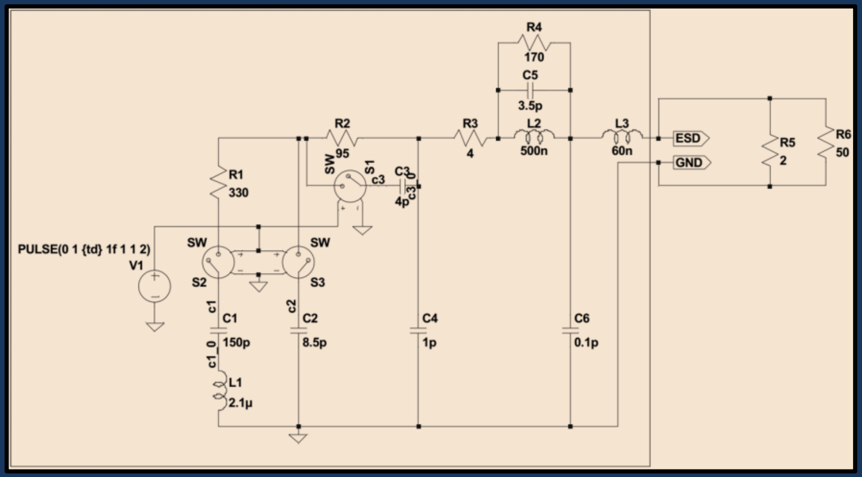
* ANSI/ESDA/JEDEC JS-001-2010, MIL-STD-883J Method 3015.9
** https://www.thermofisher.com/order/catalog/product/CUSPID0000019

HMM Waveform



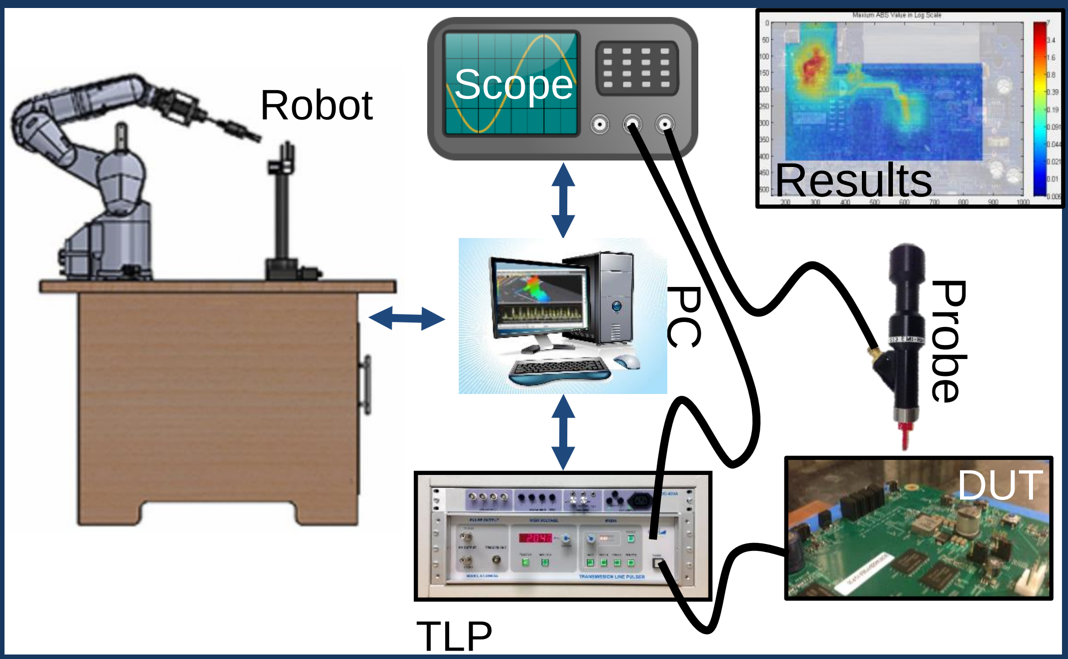
$$I(t) = \frac{I_1}{k_1} \cdot \frac{\left(\frac{t}{\tau_1}\right)^n}{1 + \left(\frac{t}{\tau_1}\right)^n} \cdot e^{\left(\frac{-t}{\tau_2}\right)} + \frac{I_2}{k_2} \cdot \frac{\left(\frac{t}{\tau_3}\right)^n}{1 + \left(\frac{t}{\tau_3}\right)^n} \cdot e^{\left(\frac{-t}{\tau_4}\right)}$$

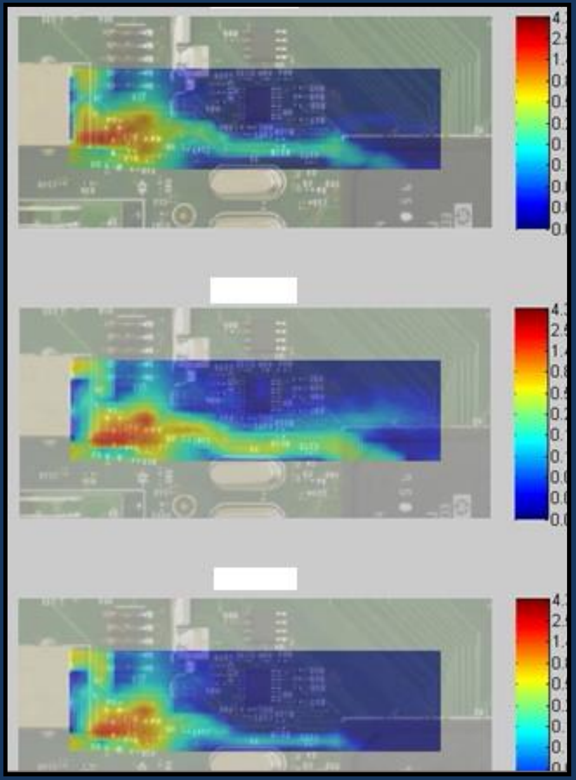




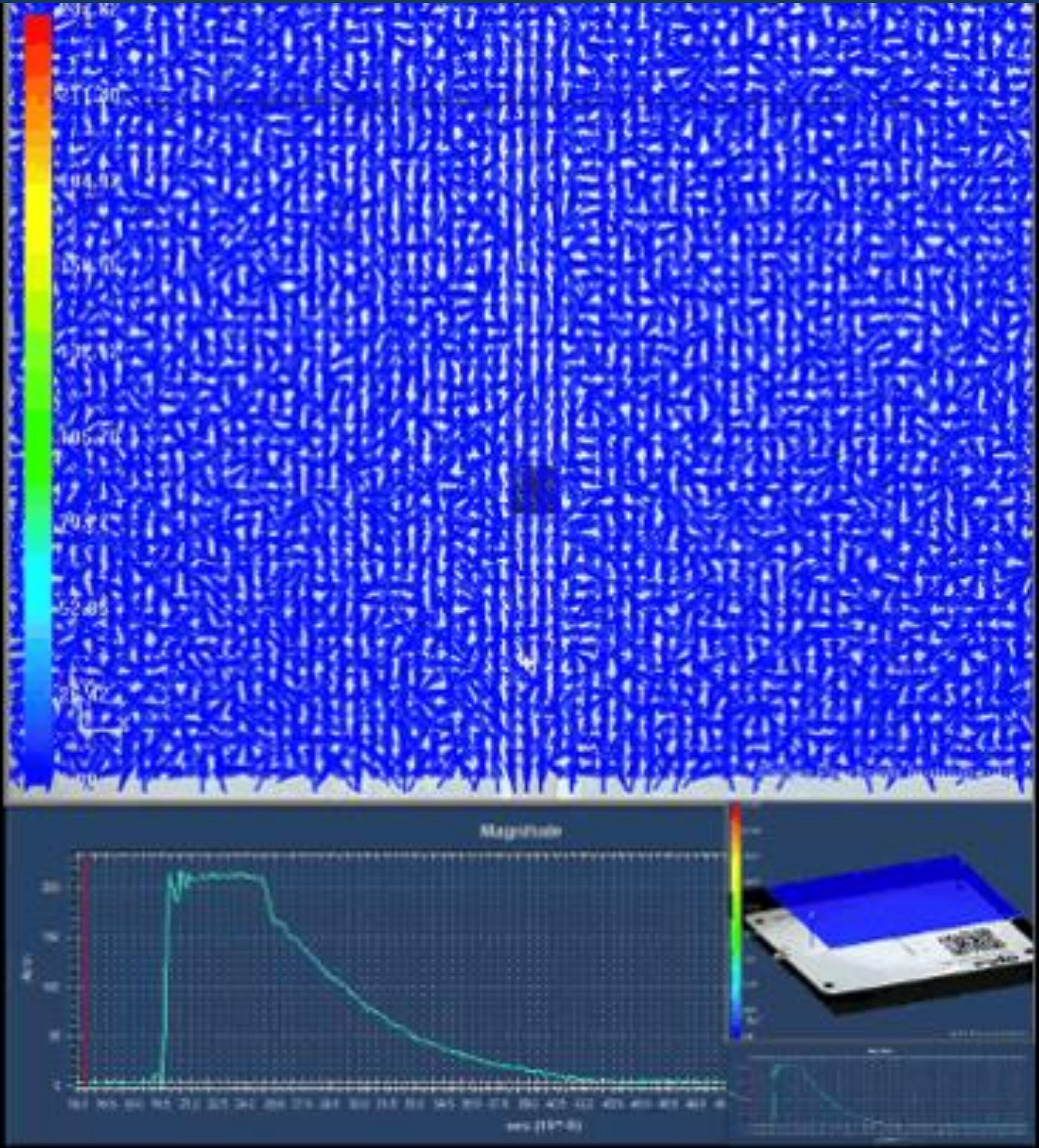
* IEC 61000-4-2, ISO 10605, MIL-STD-461G CS118, ANSI/ESD SP5.6-2009

ESD Current Spreading Scanning

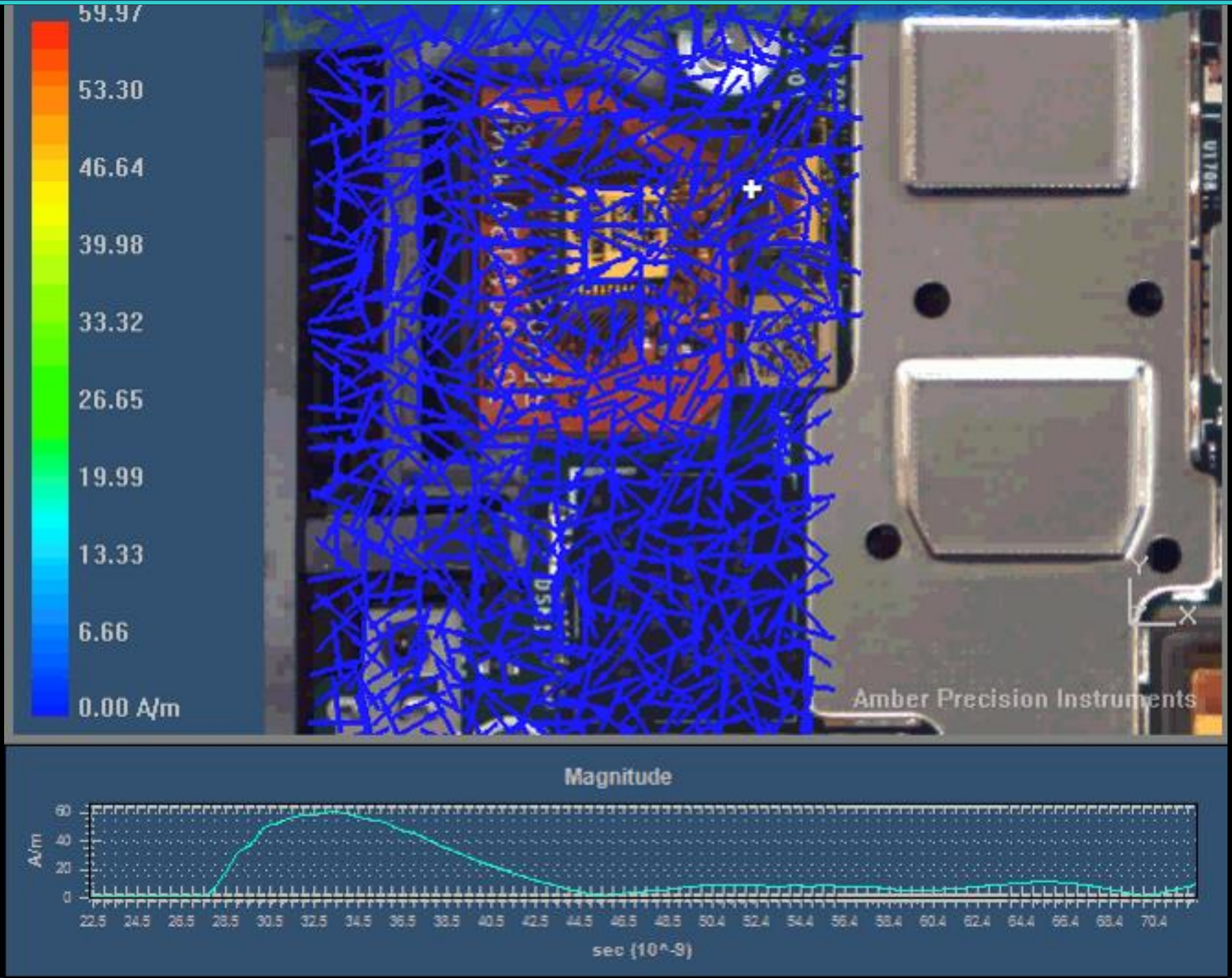




Current Spreading on Microstrip



Current Spreading on Flex PCB



ANSI/ESD SP14.5-2015

From ESDA:

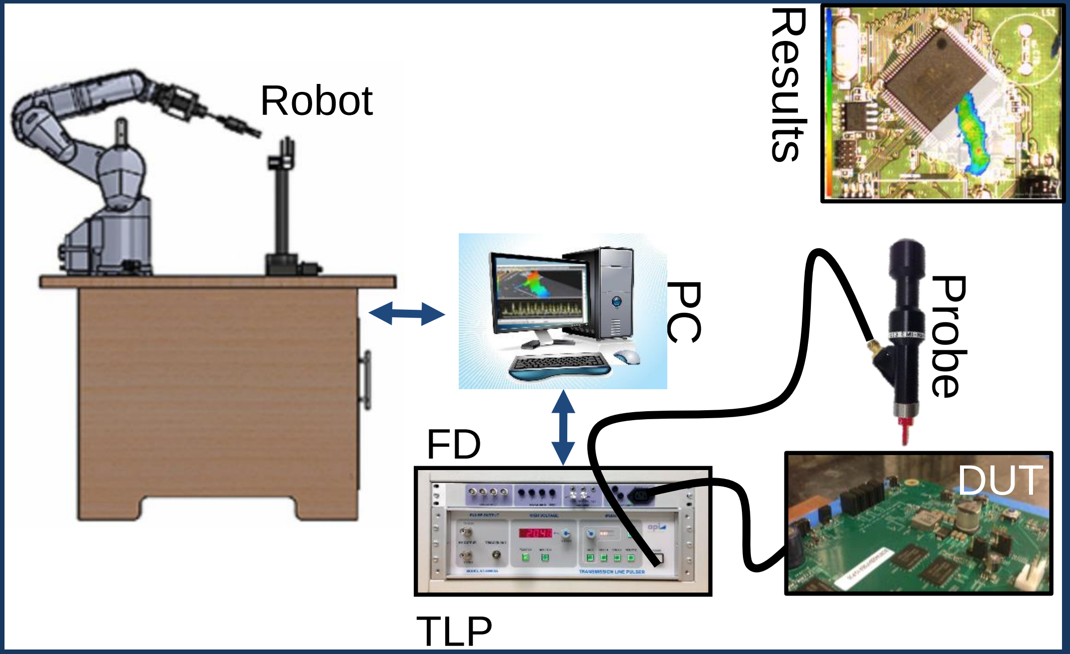
For Electrostatic Discharge Sensitivity Testing – Near-Field Immunity Scanning – Component/Module/PCB Level

An American National Standard
Approved September 14, 2015

ESD scanning technology is widely accepted as a powerful tool for root cause analysis and screening high immunity components, modules and systems

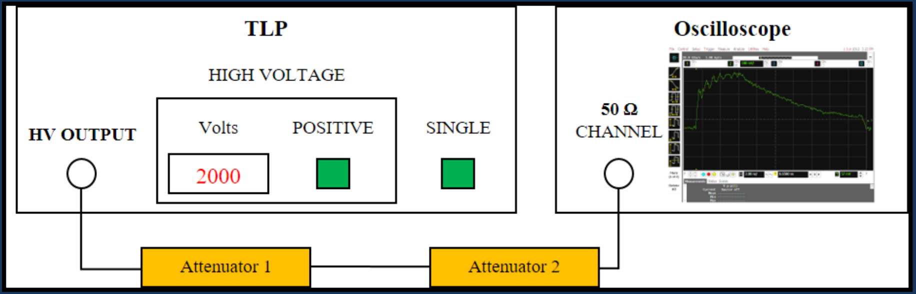
* ANSI/ESD SP14.5-2015

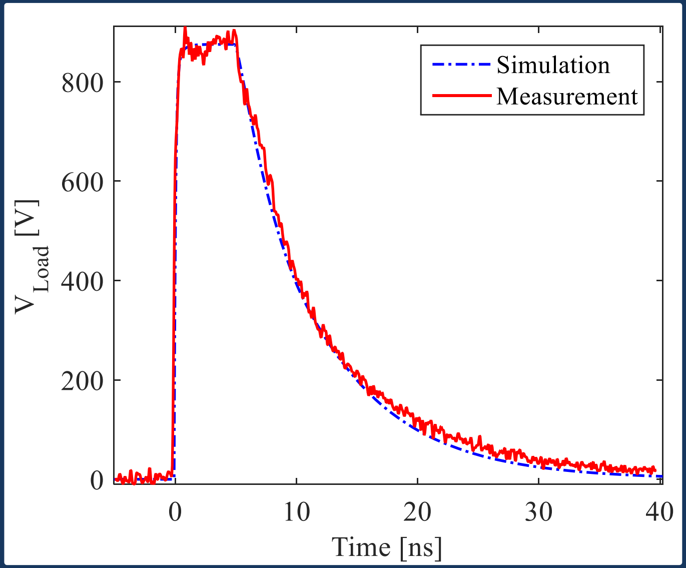
ESD Immunity Scanning



* ANSI/ESD SP14.5-2015

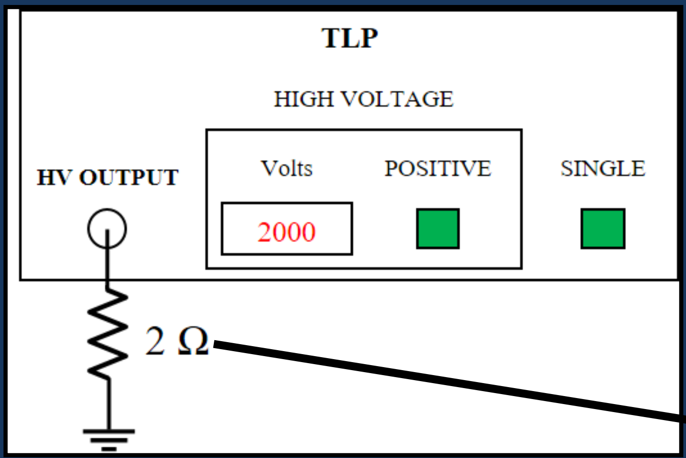
TLP Waveform



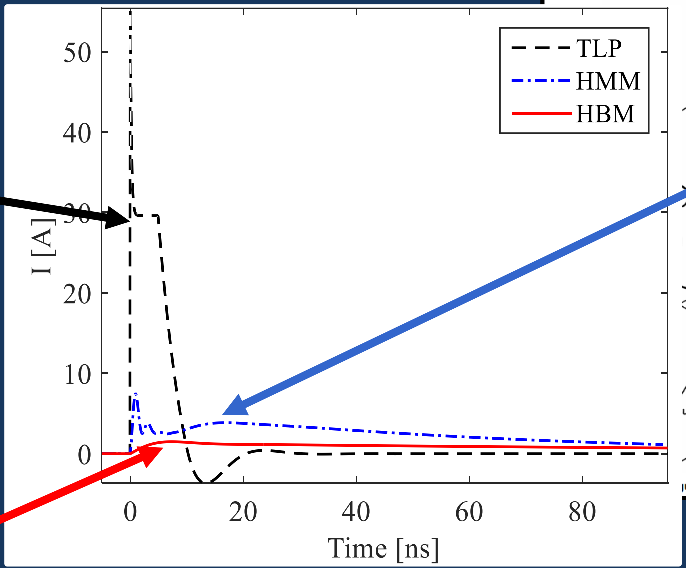


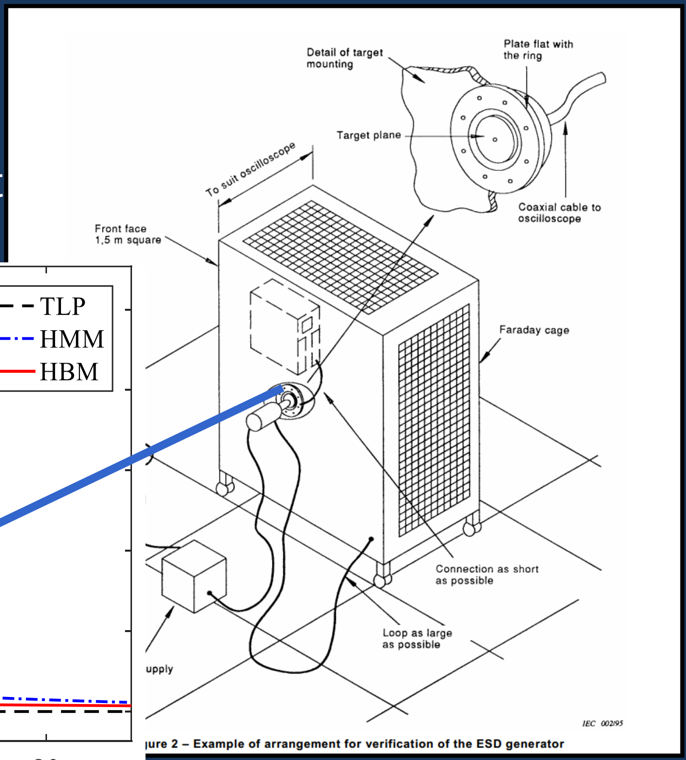
V_{TLP} = 2 kV
T_r = 500 ps
T_f = 33 ns

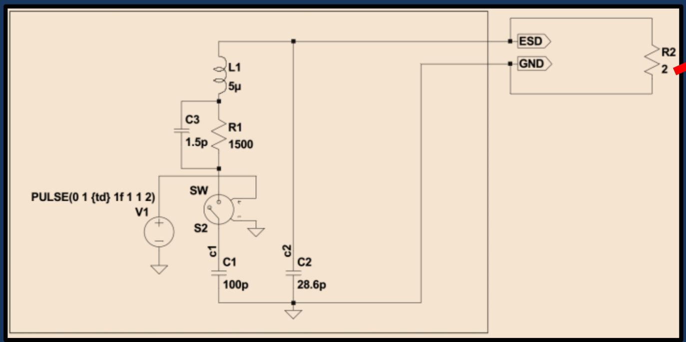
Current Waveforms: HBM vs HMM vs TLP



Simulated discharge current waveform on 2 Ω load

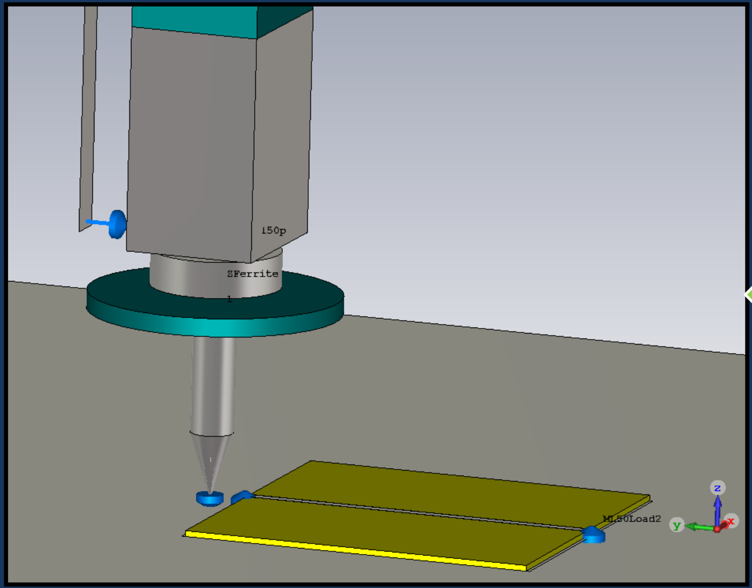


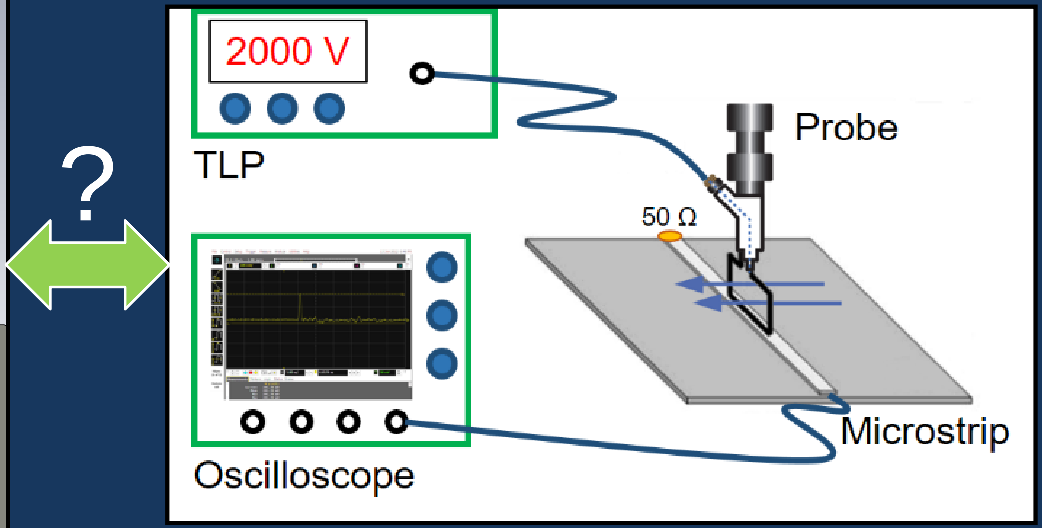




* IEC 61000-4-2

HMM vs ANSI/ESD SP14.5-2015 Simple Structure



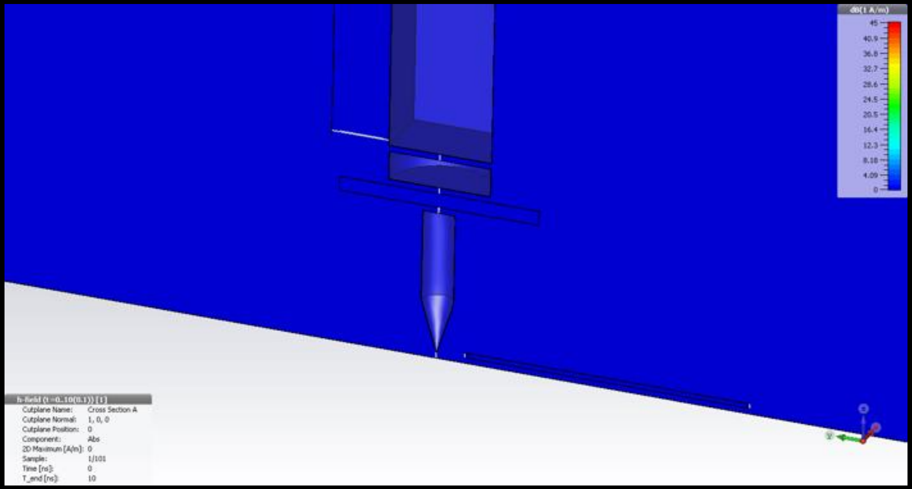


50 ohms microstrip (3 mm wide trace)
Board dimension: 100 x 100 mm^2
Board elevation from HCP: 1 mm
ESD generator distance to board: 10 mm
ESD generator setting: 2 kV CD

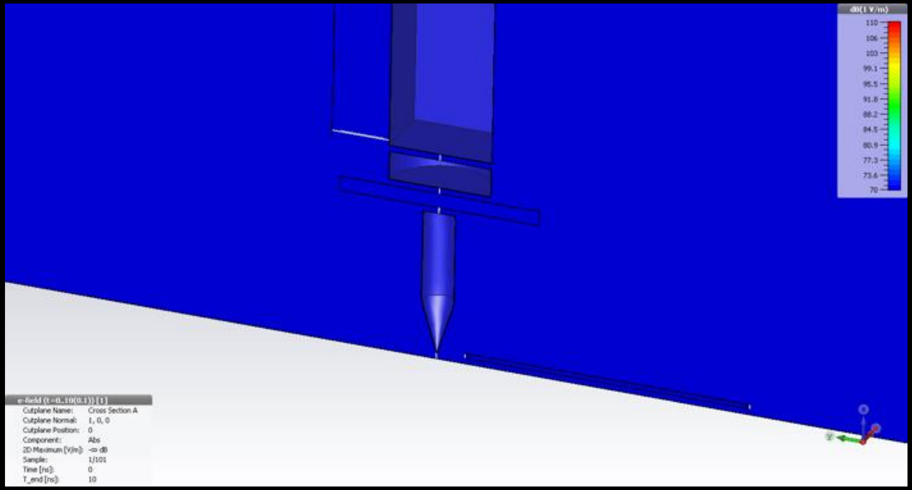
50 ohms microstrip (3 mm wide trace)
Board dimension: 100 x 100 mm^2
Probe: 2 mm or 5 mm loop H-field
Mechanical probe height from trace: 0 mm
TLP setting: 2 kV

Field Coupling to Microstrip

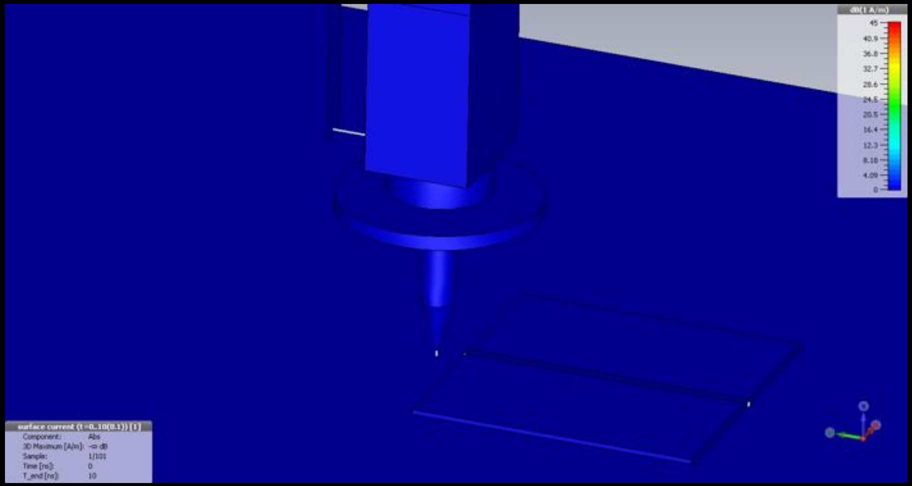
H-Field



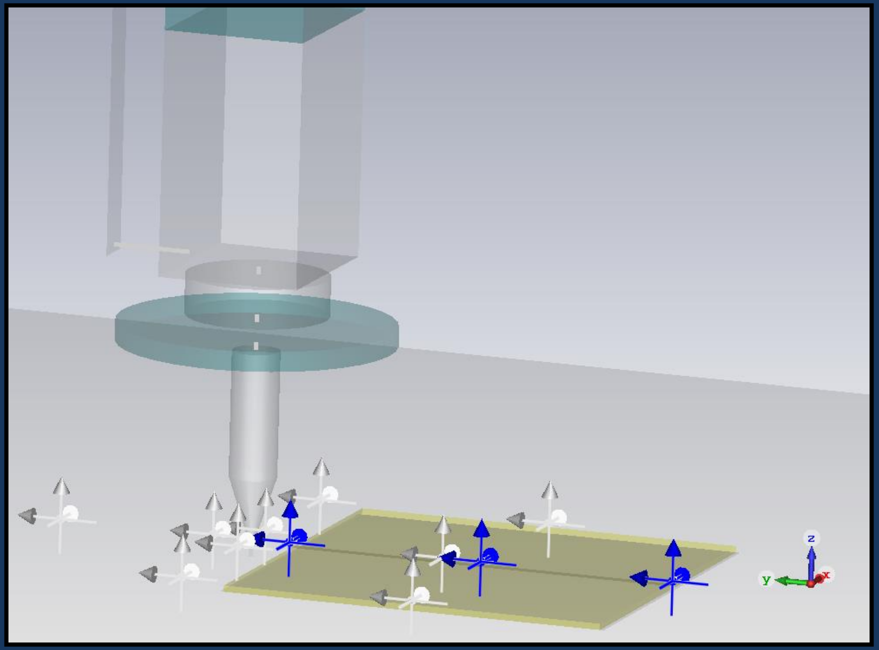
E-Field

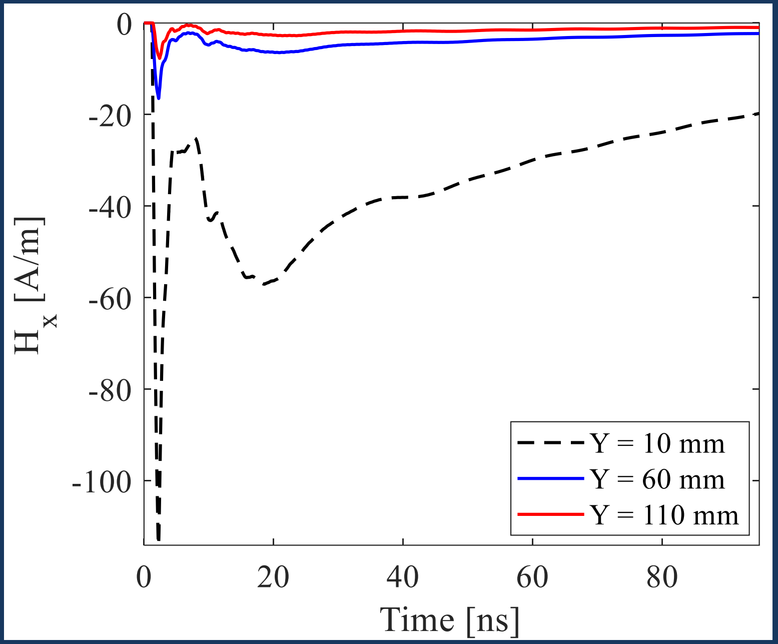


Surface Current Density

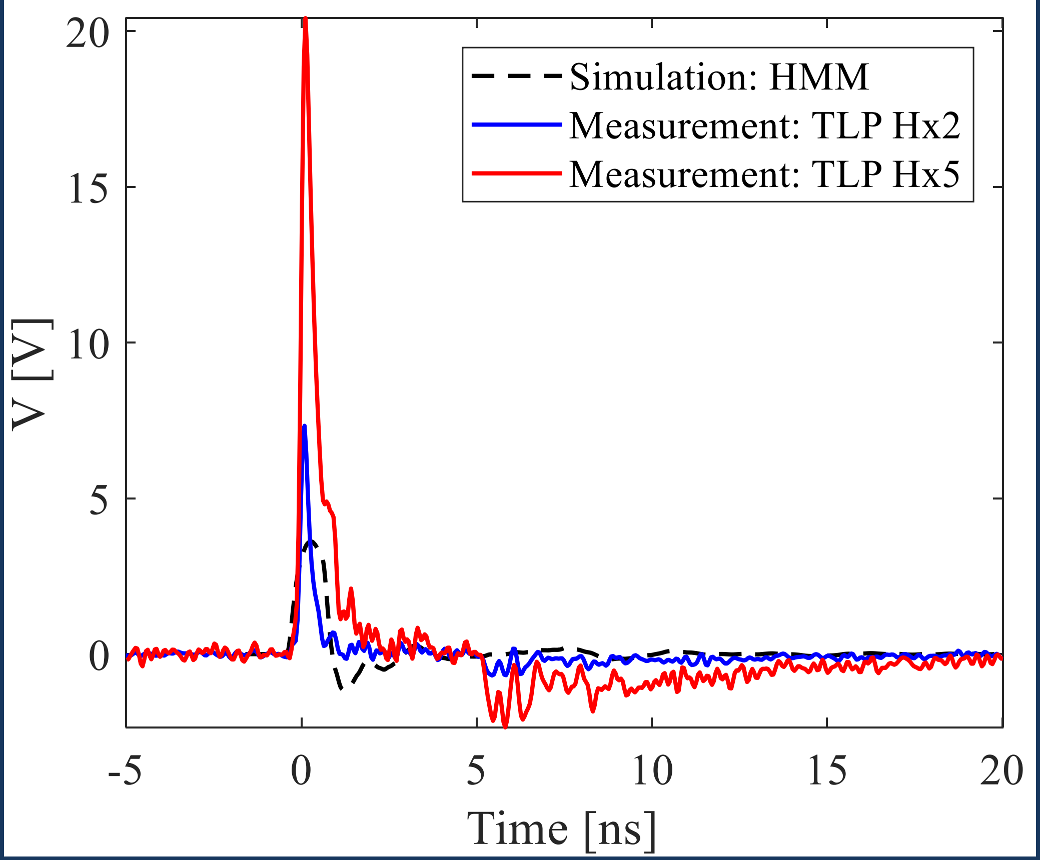


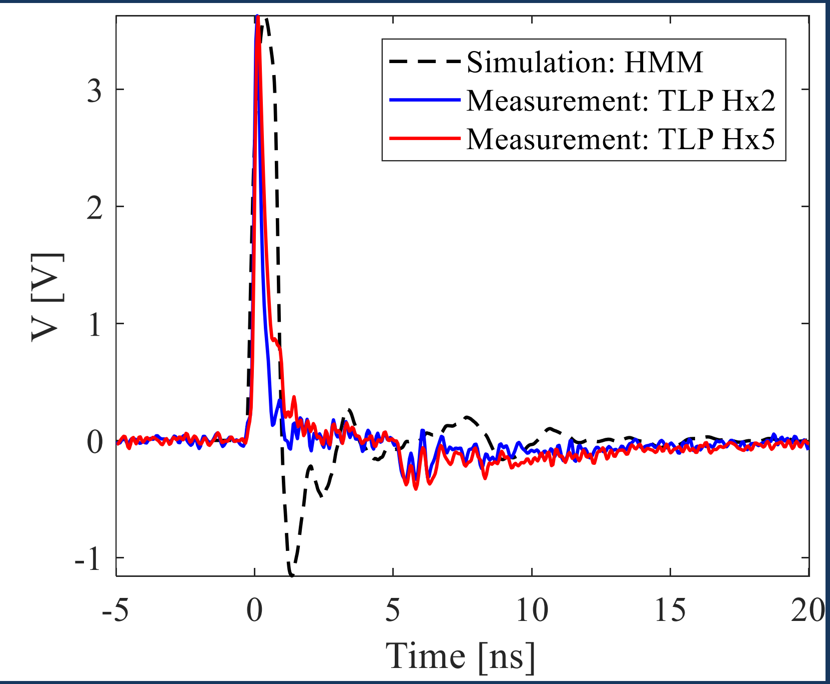
Field Attenuation from ESD





HMM vs Near-Field Injection





$$V_{eq} = \frac{1.98 \times V_{ESD}}{A_{ef}} \left(\frac{r}{2.4} \right)^{\alpha} \cdot \left(\frac{60}{R} \right)^{\beta}$$

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Effect of IC Fab on ESD

White Paper 3 Part II specifically covers in detail **an overview of system ESD stress app lication methods, system diagnostic techniques to detect hard or soft failures, and the application of tools for susceptibility scanning.** For example, as illustrated in Figure 2, these types of advanced tools can be used to differentiate the characteristics of products and enable proper system protection methodology*.

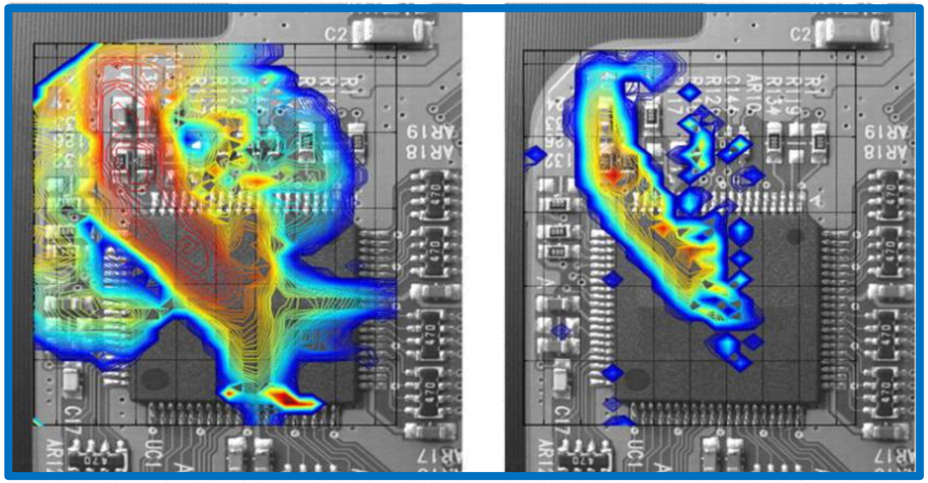

Figure 2: Susceptibility scanning using pulse techniques on Product A (left) and Product B (right)
(Courtesy of Amber Precision Instruments)

* Quote from the ESDA White paper 3, Part II, page 18.
** Product A and Product B are functionally identical ICs from different vendors.

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Susceptibility Scanning: Conclusion

- Conducted susceptibility to an ESD even can be analyzed by measuring and visualizing scanned surface current density on the DUT.
- Susceptibility to near-field effects of an ESD event can be emulated with near-field injection.
- Near-field injection per ANSI/ESD SP14.5-2015 reproduces same failures as IEC 61000-4-2.

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Thank You!

Questions?

Contact us: amberpi@amberpi.com
www.amberpi.com

References

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- Wikipedia: Synthetic Aperture Radar [Link]

* http://amberpi.com/library_papers.php