2019 IEEE INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY, SIGNAL & POWER INTEGRITY

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ESD Generator Tip Current Reconstruction Using a Current Probe Measurement at the Ground Strap

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Motivation

- Monitoring ESD generator discharge current during IEC 61000-4-2 testing helps:
  - To document the current waveform which resulted in product failure.
  - To identify the presence of secondary ESD event.

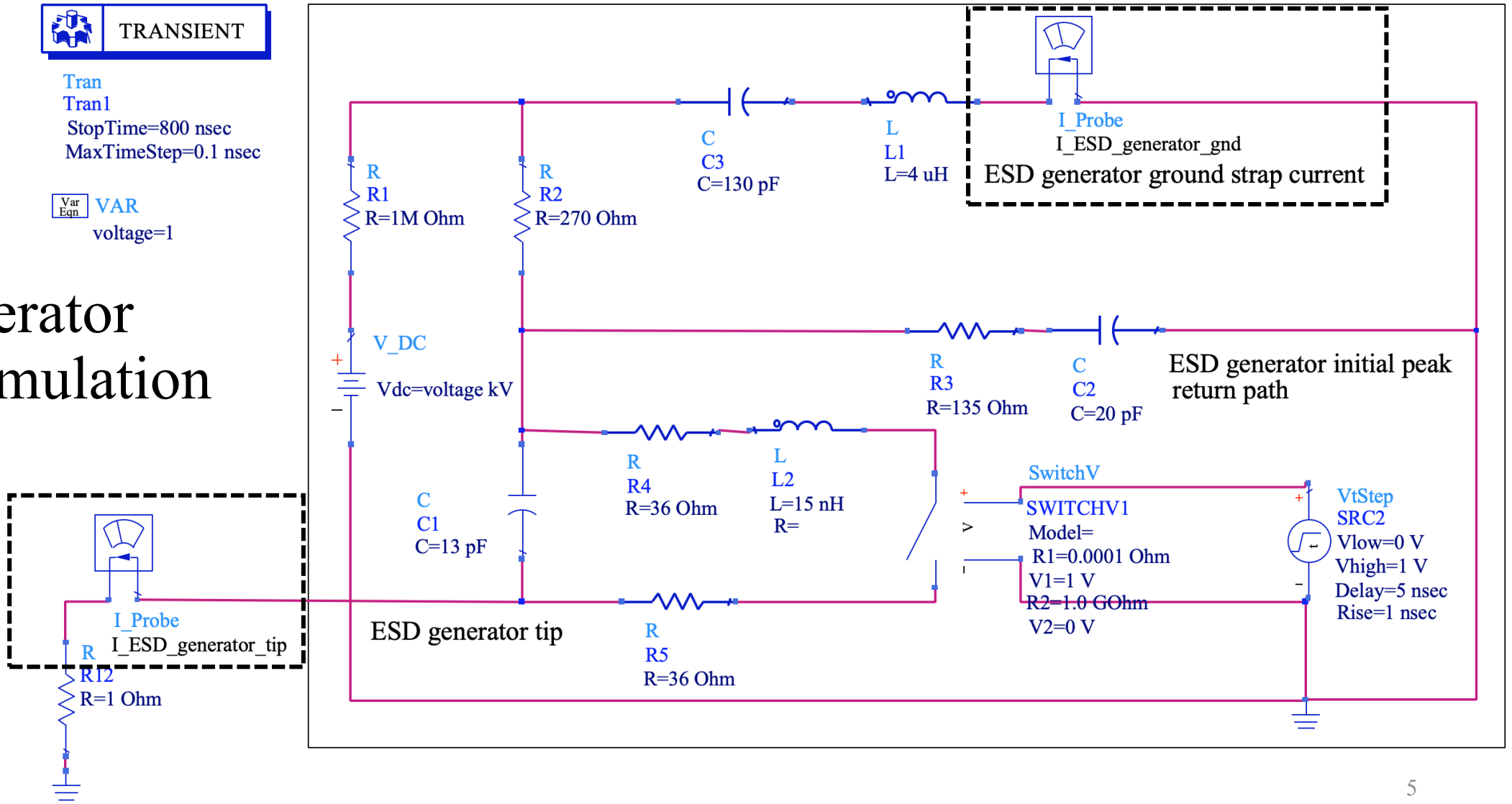
- Placing the F-65 current clamp at the tip of the ESD generator:
  - May change the discharge current waveform shape due to probe loading.
  - Adds weight to the front of the generator.

- The goal is to reconstruct the high frequency components of the discharge waveform using deconvolution on the measured ground strap current waveform.

Outline

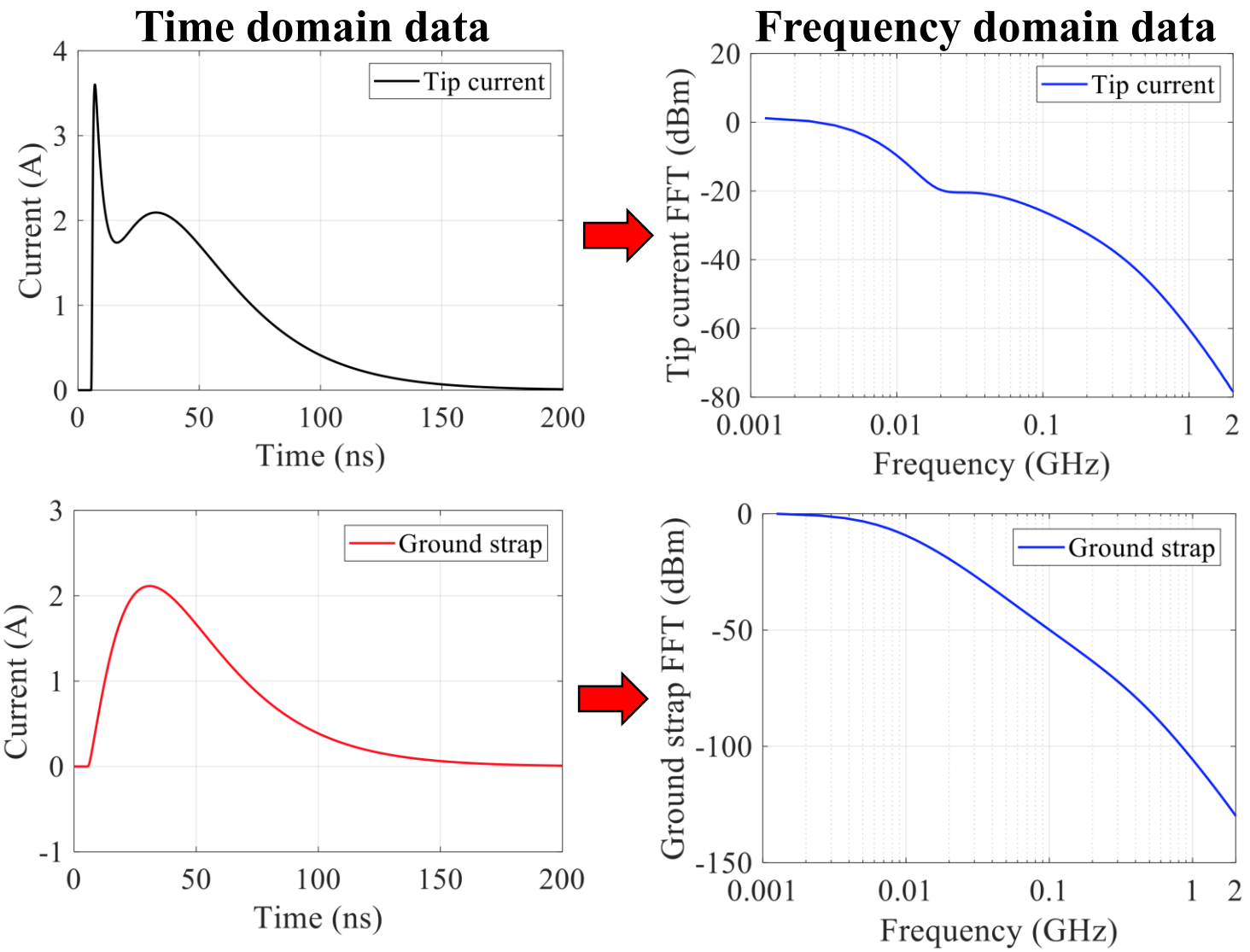
- Current reconstruction (Simulation results)
  - Deconvolution principle
  - ESD Generator circuit simulation model
    - Discharge to a large ground plane
    - Discharge to a resistive test point
    - Discharge to non-grounded test points (Secondary ESD events)
- Current reconstruction (Measurement results)
  - Effect of power cable on ESD generator return current
  - Effect of different ground strap routing
  - Effect on discharge current due to proximity to a ground plane
  - Effect of different ESD generators
- Discussion
- Conclusion

ESD Generator Circuit Simulation Model



Deconvolution Principle (1/4)

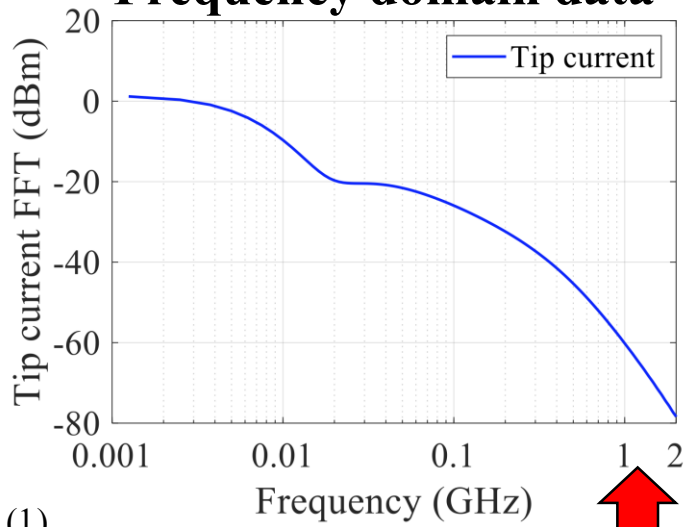
- Acquire the tip and the ground strap current.
- Perform FFT operation, to obtain the frequency domain data.

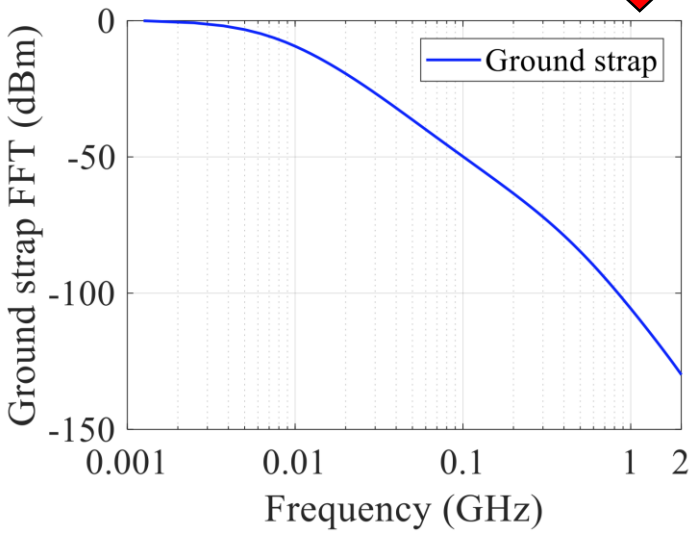


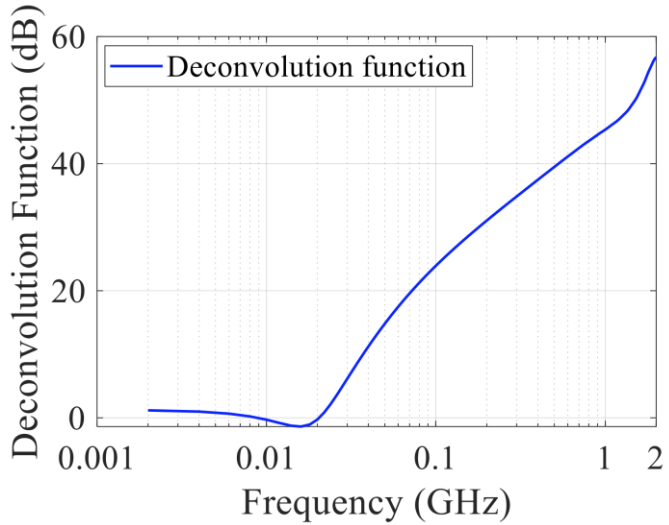
Deconvolution Principle (2/4)

$$Deconvolution\ function = \frac{FFT\ (ESD\_generator\_tip\_I)}{FFT\ (ESD\_generator\_gnd\_I)} \quad (1)$$

Frequency domain data



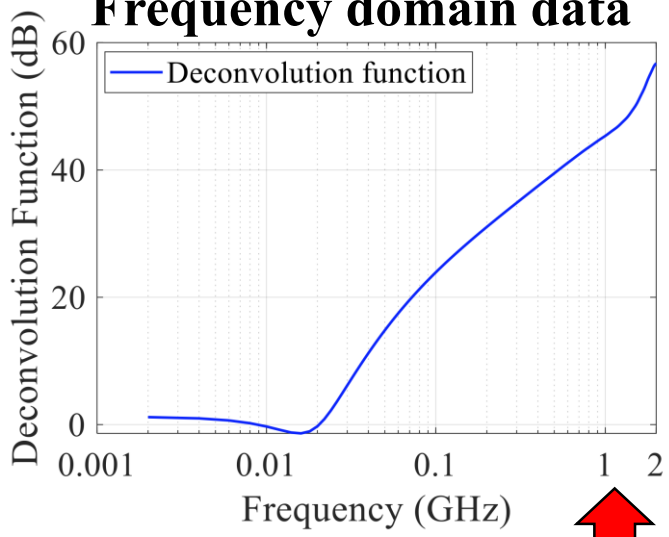


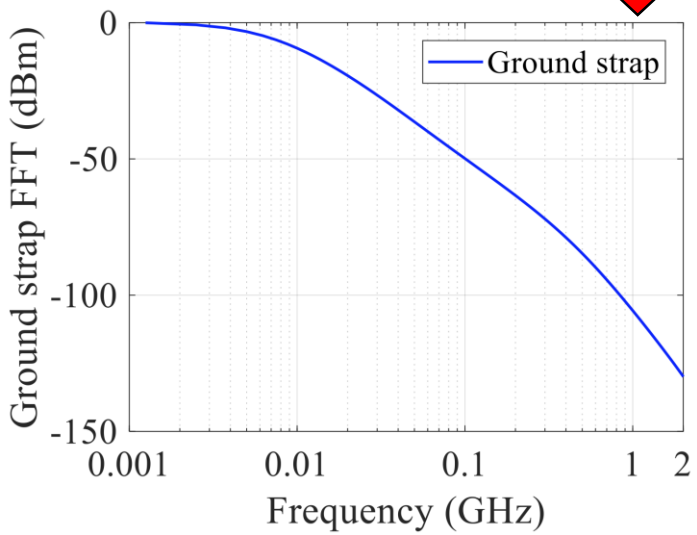


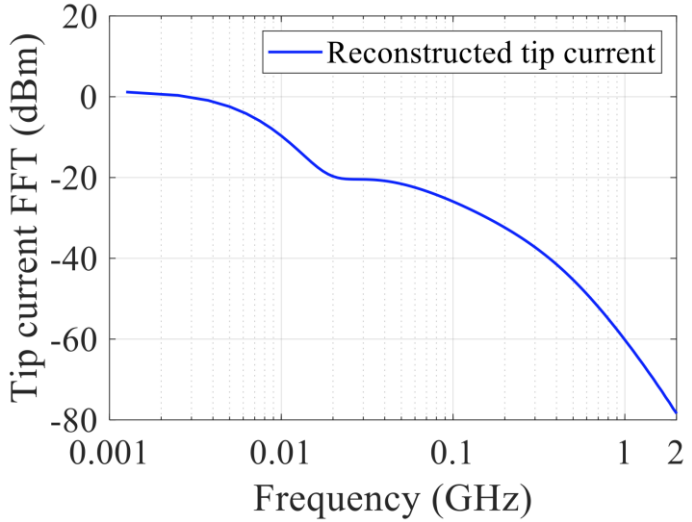
Deconvolution Principle (3/4)

$$ESD\_generator\_tip\_I\_DUT(j\omega) = (Deconvolution\ function)(FFT\{ESD\_generator\_gnd\_I\_DUT\}) \quad (2)$$

Frequency domain data

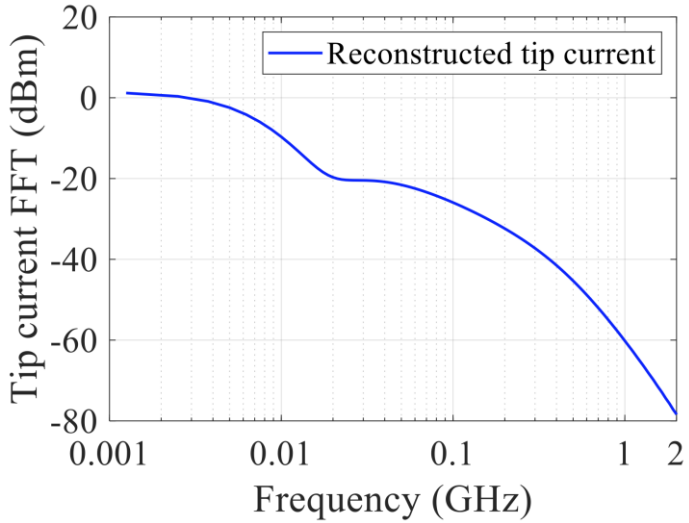


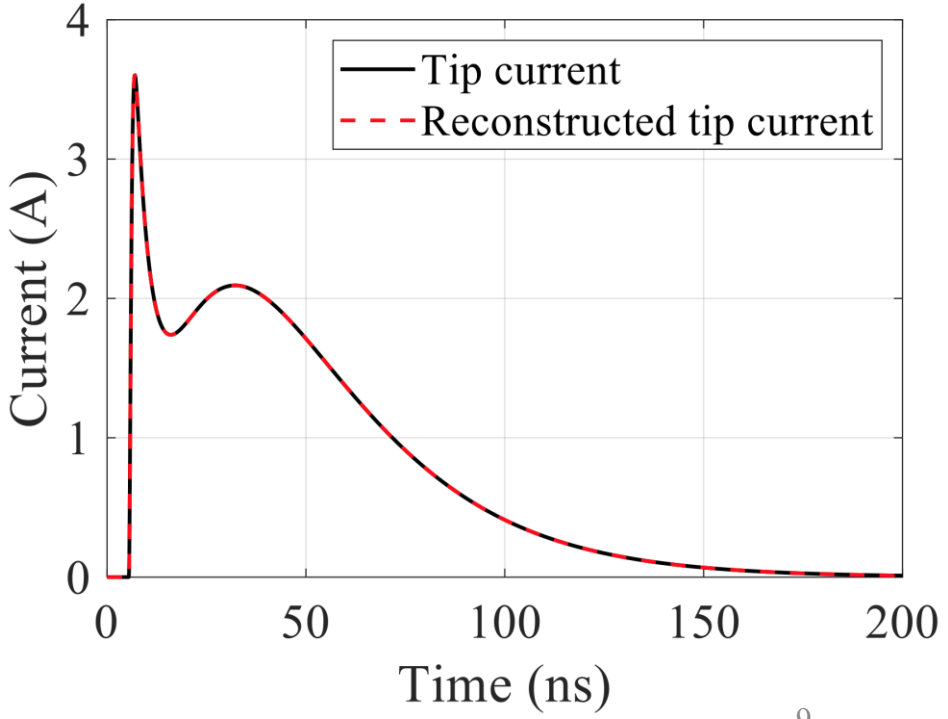




Deconvolution Principle (4/4)

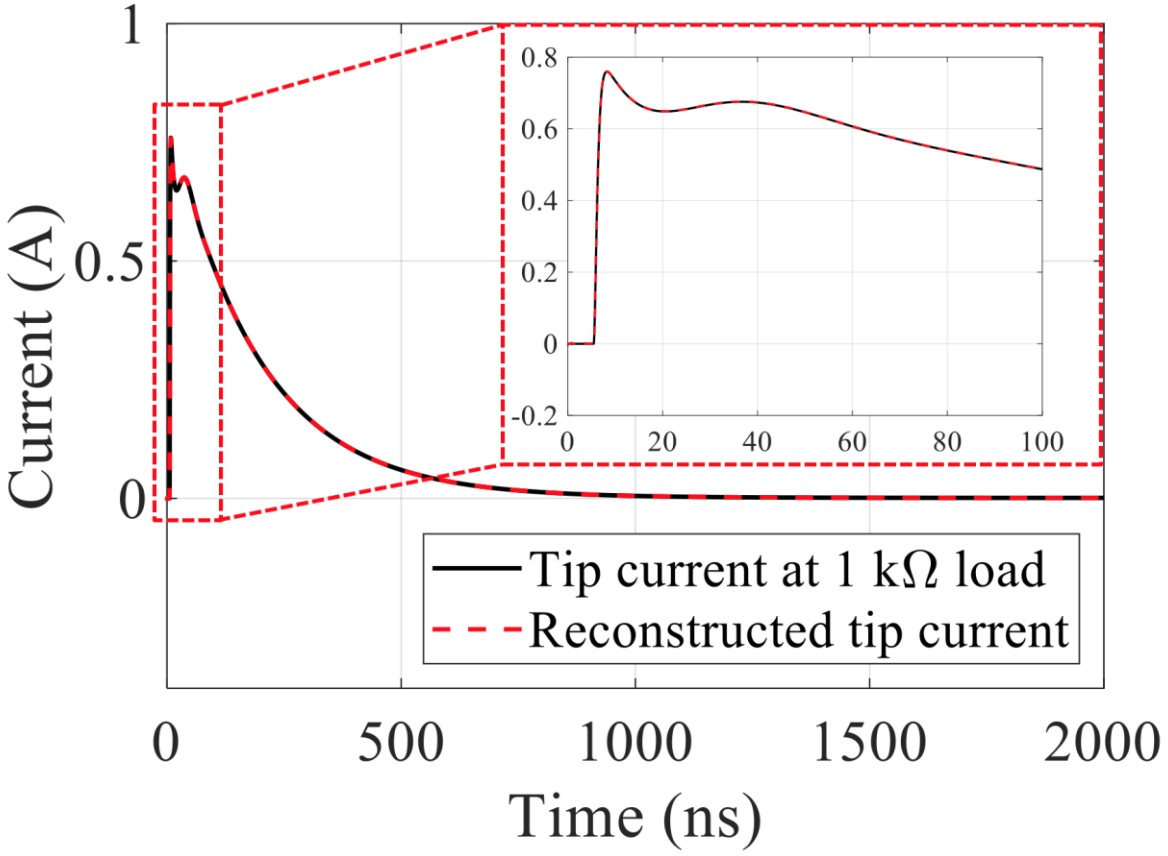
$$Reconstructed\_ESD\_generator\_tip\_I\_DUT = iFFT\{ESD\_generator\_tip\_I\_DUT(j\omega)\} \quad (3)$$





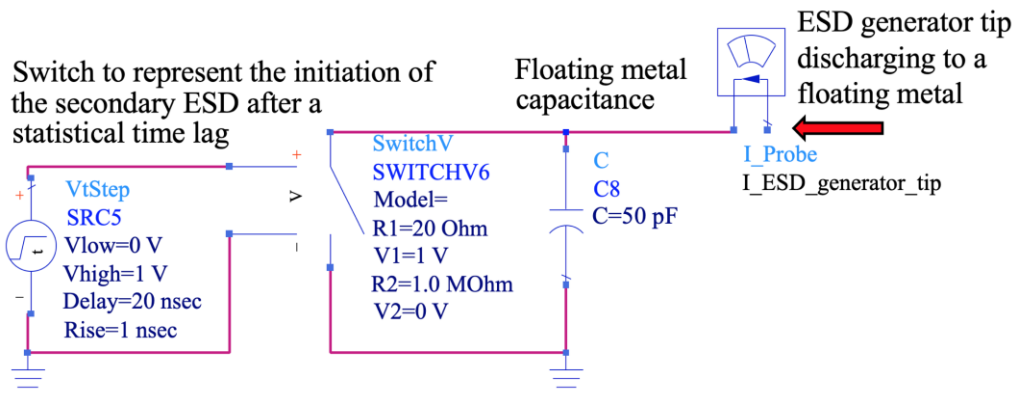
Resistive Test Point

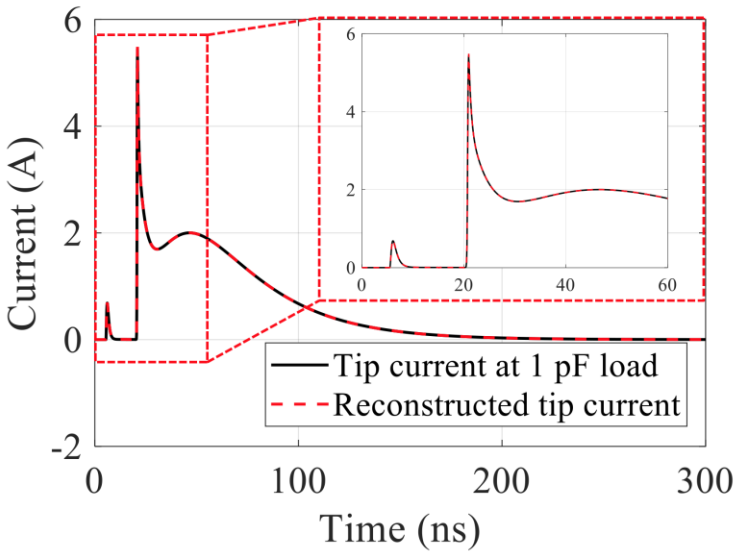
- The deconvolution function obtained at a 1 Ω load reconstructs the tip current for a discharge to a resistive load of 1 kΩ.
- The simulation time must be sufficiently long to allow the waveform to reach a zero-amplitude level.

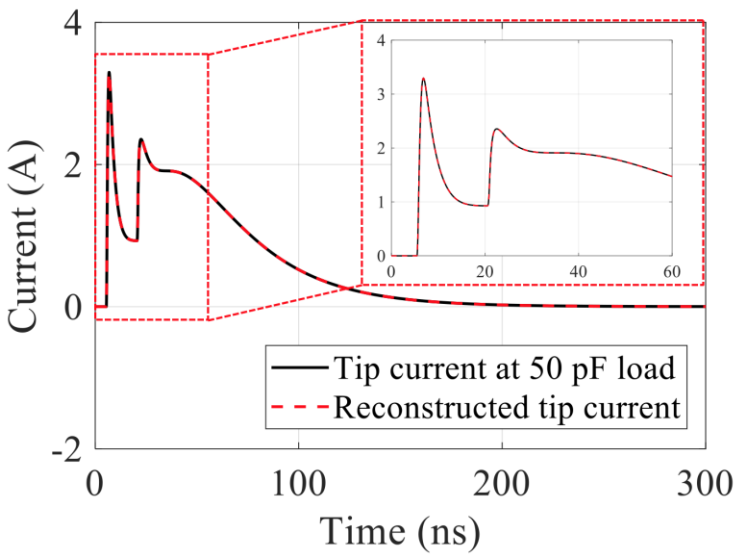


Secondary ESD Events

The reconstruction works well for both the primary and secondary waveforms for 1 pF and 50 pF load.

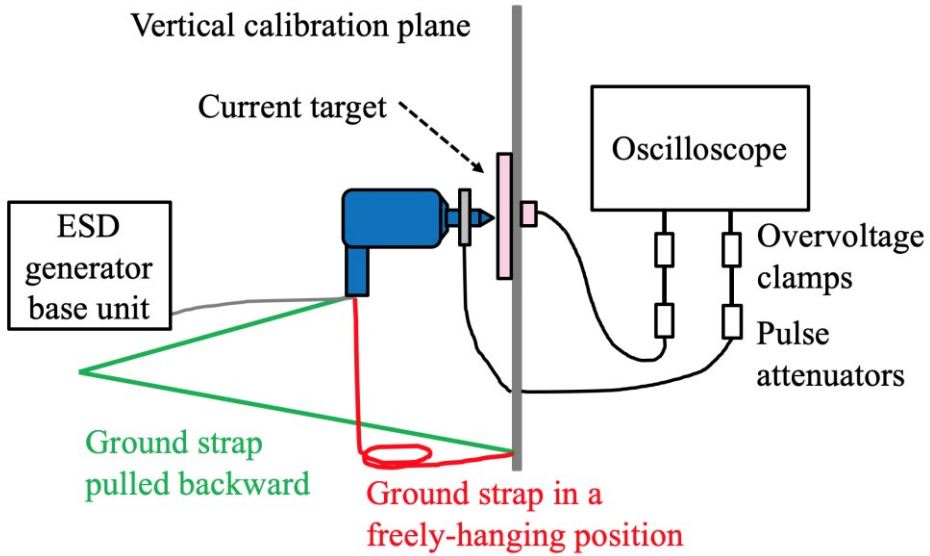


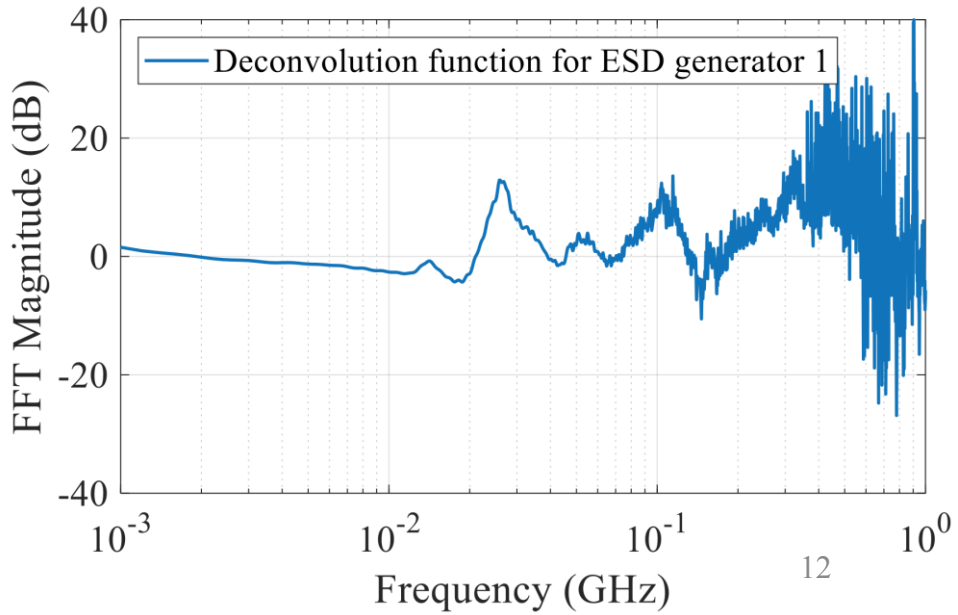




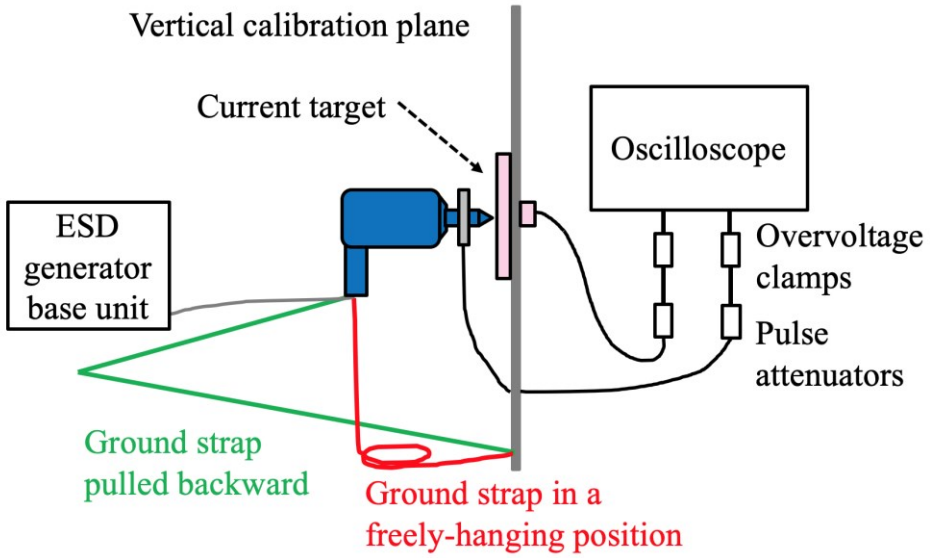
Measurement-based Current Reconstruction

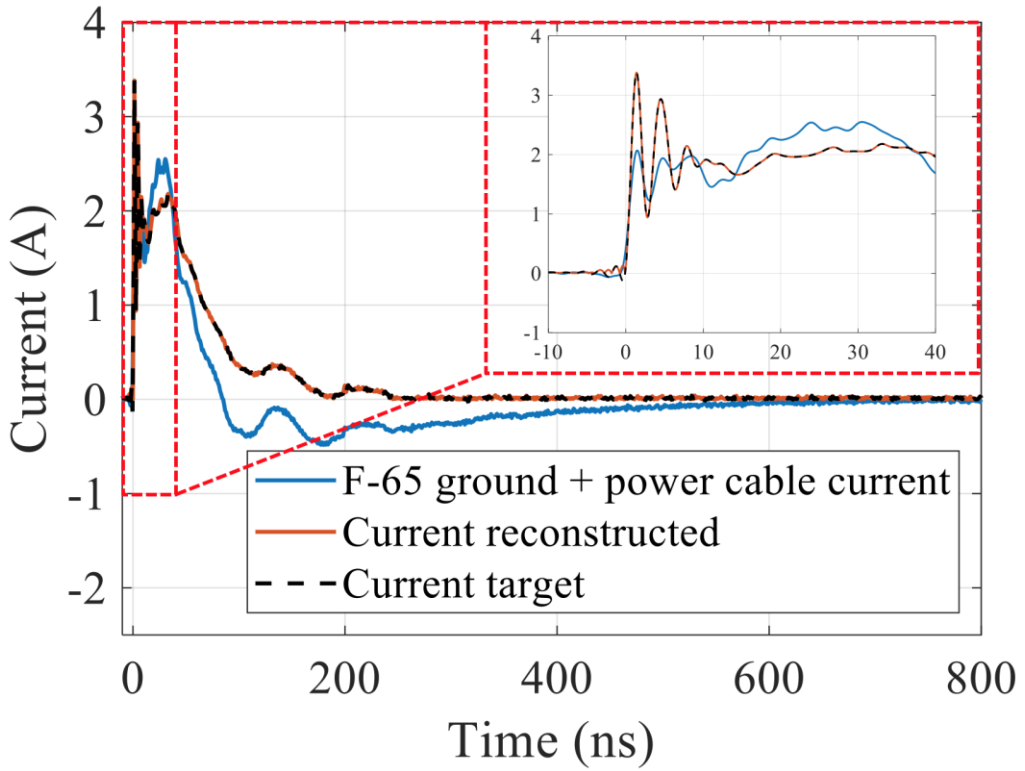
- Noise-free simulation results demonstrate that the deconvolution method works well.
- The current on the ESD generator ground strap, and power cable was measured using an F-65 clamp. The tip current was measured using a current target.





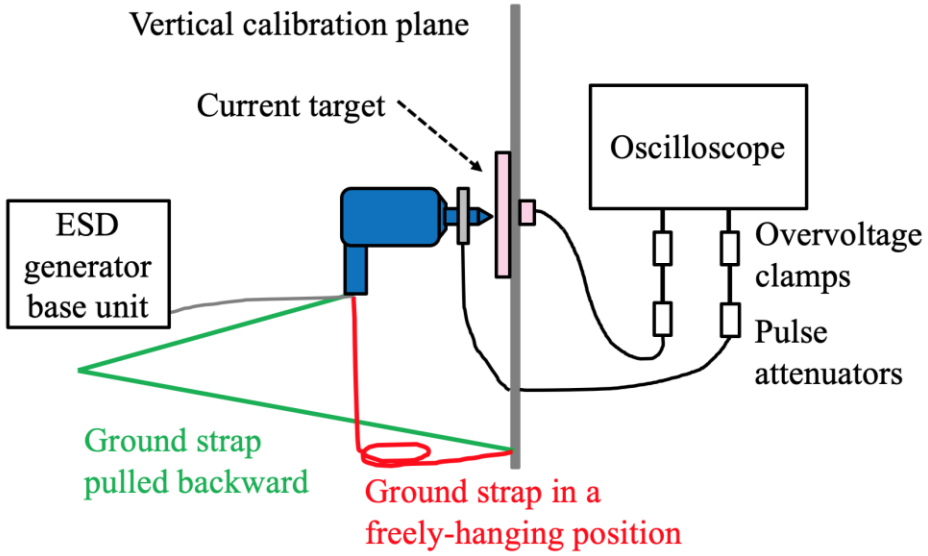
Current Reconstruction

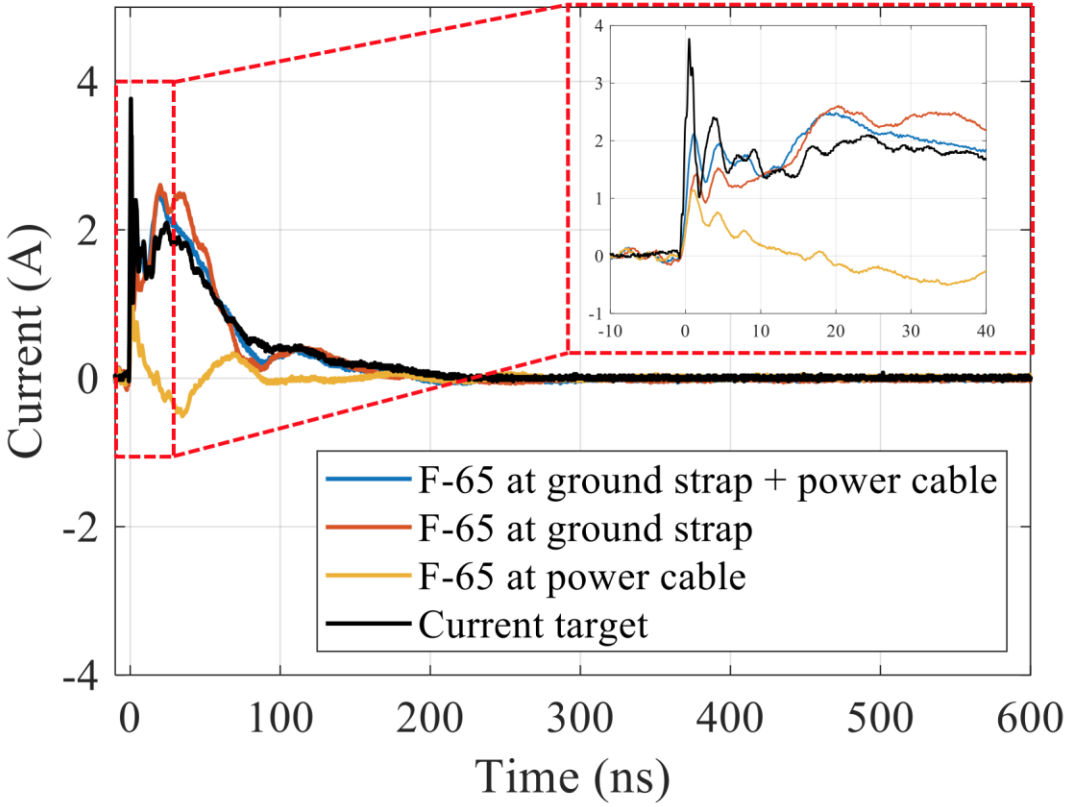




Effect of Power Cable on ESD Generator Return Current

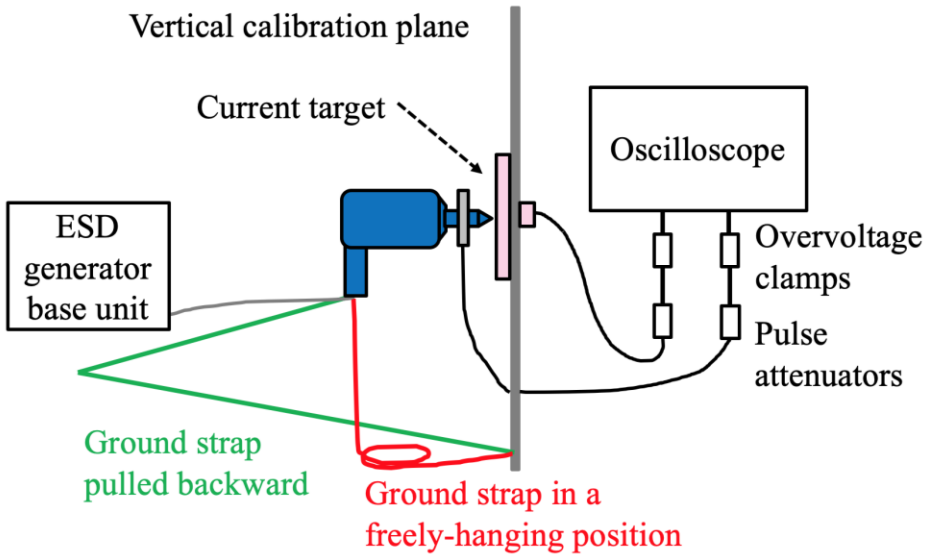
- Typically, an ESD generator can be battery powered or connected to a high voltage source by a power cable.
- In the power cable case, the ESD generator return current may also flow partially through the power cable.

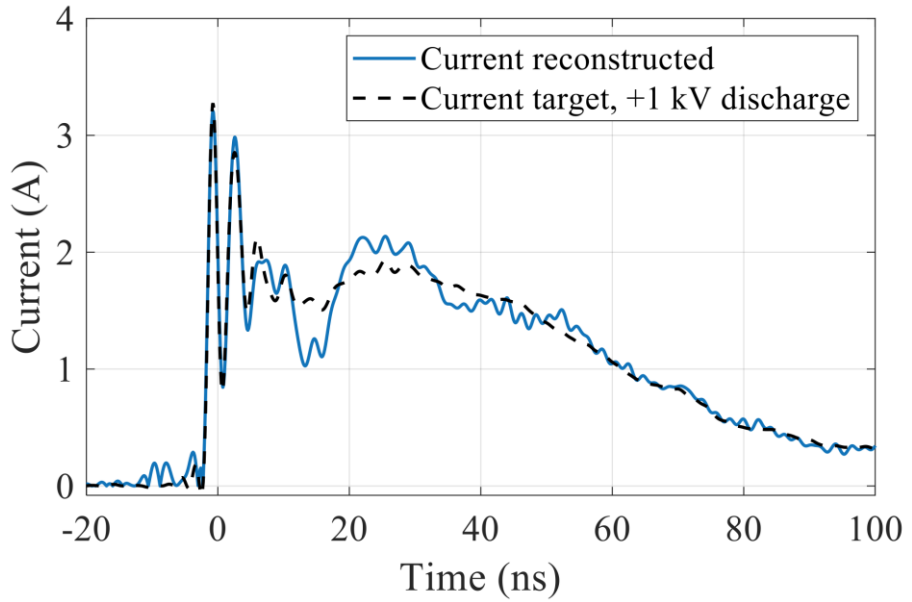




Effect of Different Ground Strap Routing

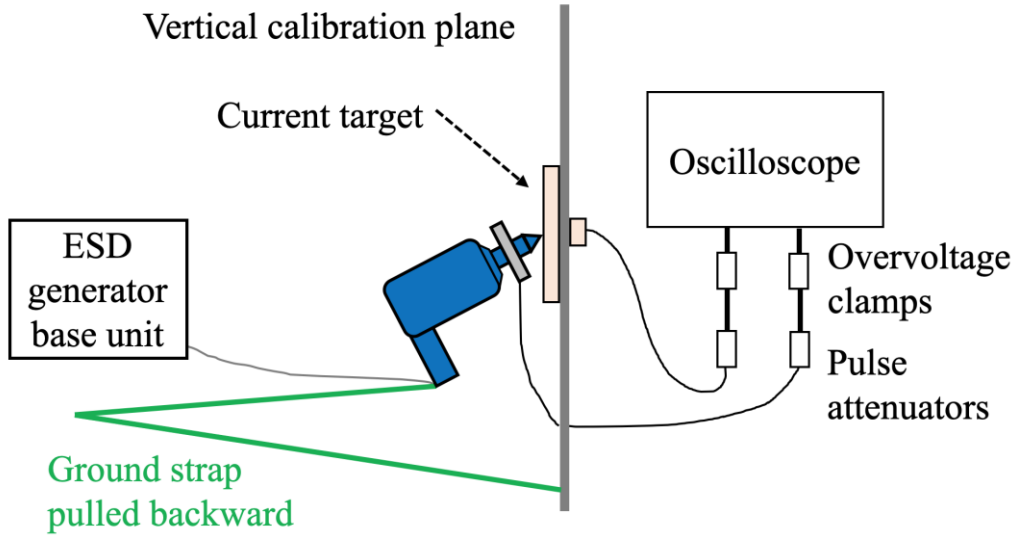
- The deconvolution function was obtained using the ground strap in pulled-backward routing.
- This deconvolution function is re-applied to the measured ground strap in a freely-hanging position and power cable current.

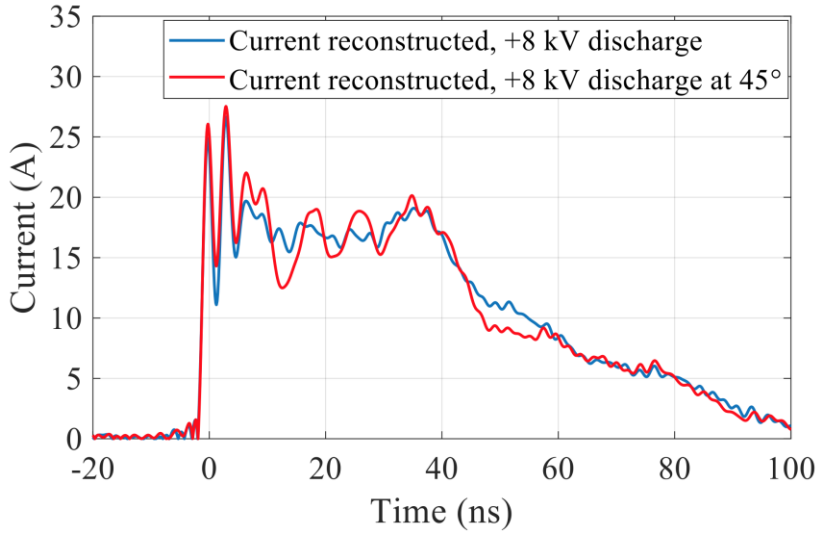


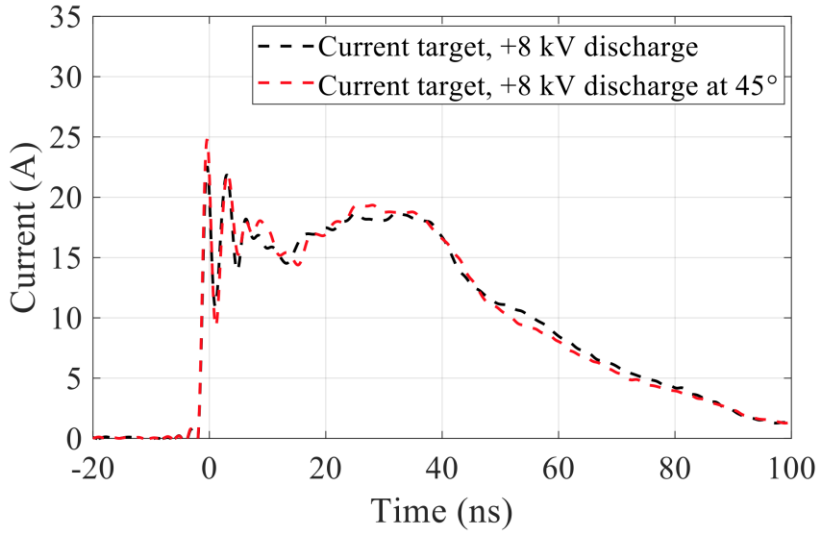


Effect on Discharge Current Due to Proximity to a Ground Plane

- The initial peak of the ESD generator discharge current returns via the body of the ESD generator to the system ground.
- This current does not return through the ground strap or the power cable of the ESD generator.

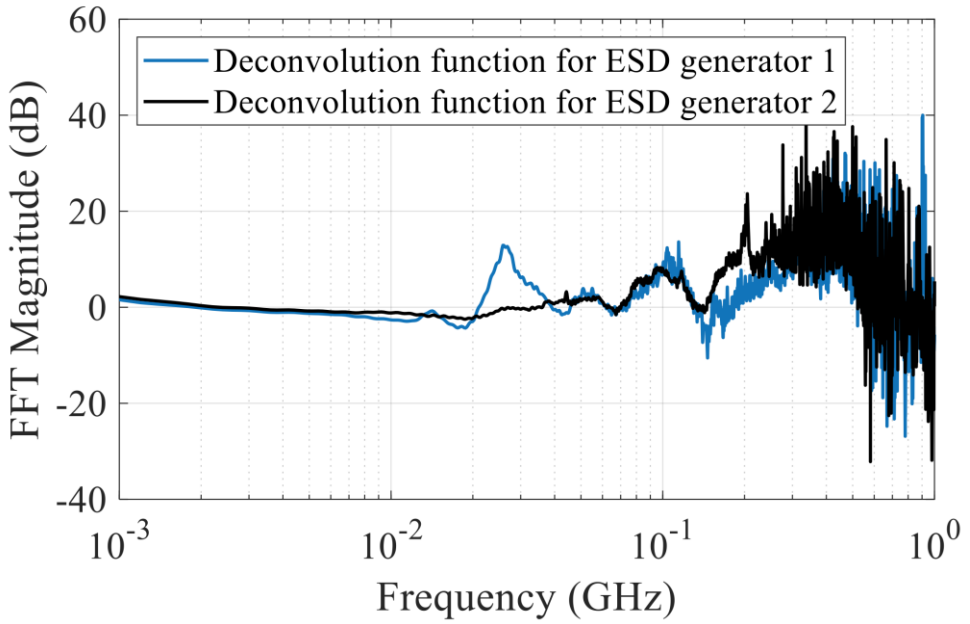


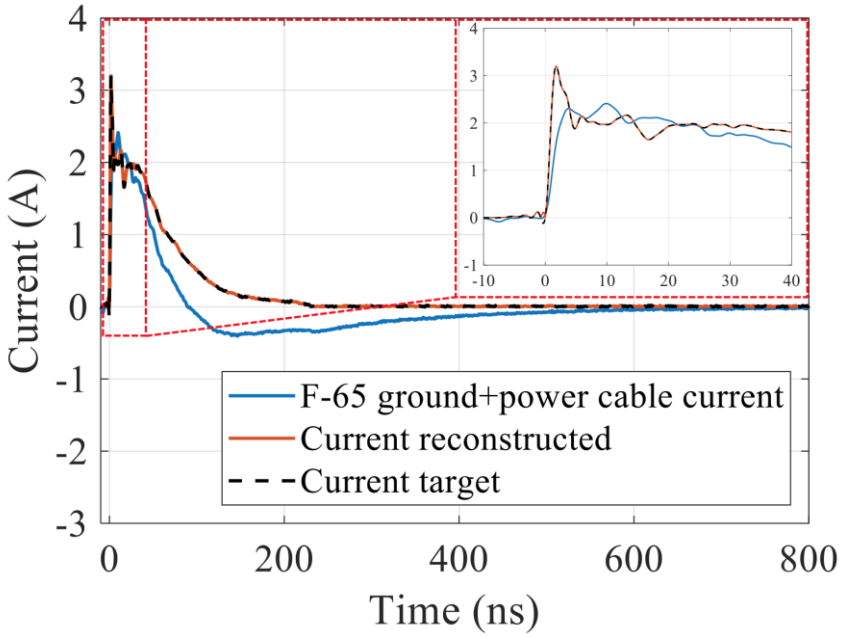




Effect of Different ESD Generators

- The deconvolution function obtained for a ESD generator will not be valid for another vendor's ESD generator.
- The measurement-based deconvolution function must be determined for a different ESD generator.





Discussion

- ESD generator tip current reconstruction was implemented using deconvolution. The noise-free ADS environment allows testing the accuracy of the algorithms.
- Measured data from two ESD generators, and their corresponding deconvolution functions have been created and tested on real waveforms.
- The reconstruction methodology is shown for contact mode discharges.
- For air discharges, further testing will be needed to determine the effectiveness of the proposed algorithm.

Discussion

The measurement-based current reconstruction is not straightforward. There are several factors to be considered:

- F-65 current clamp bandwidth (1 GHz low pass filter).
- Unwanted field coupling.
- Volt/division setting of the oscilloscope, to best utilize the A/D converter range.
- Zero-padding during the data processing.
- A detrending process is additionally needed to remove any DC bias from the time-domain waveform.

Conclusion

- A non-intrusive measurement method is proposed, in which the ground strap and power cable currents are captured to reconstruct the tip current using deconvolution.
- The current reconstruction methodology is first validated using an ADS ESD generator model.
- Further, the methodology is tested in measurements using different ESD generators and at different discharge settings.
- The proposed deconvolution method reconstructs the ESD generator tip current waveforms within 10%.

Thank you.