TEXAS TECH UNIVERSITY
Center *for* Pulsed Power
& Power Electronics™

Interior Electromagnetic Fields of Buildings Struck by Lightning

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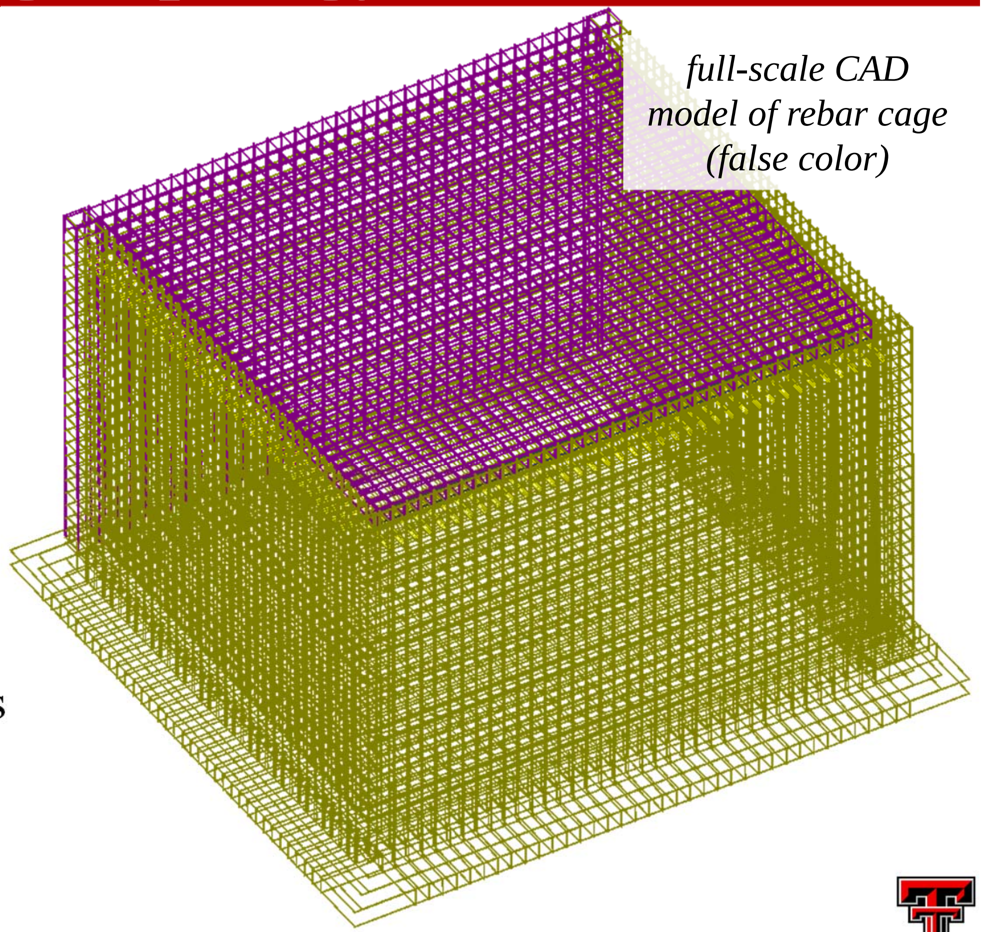
Introduction & Building Topology

- Double-layer rebar cage, common to steel-reinforced concrete structures, generally provides adequate protection against lightning strike events
  - Analogous to a Faraday cage
- The structure on interest in this study features a blast relief
  - Three walls feature no electrical connection to the roof
  - One wall is electrically connected (i.e. a hinge)
  - Does this affect induced interior fields in lightning strike events?
  - Are there more vulnerable strike locations?

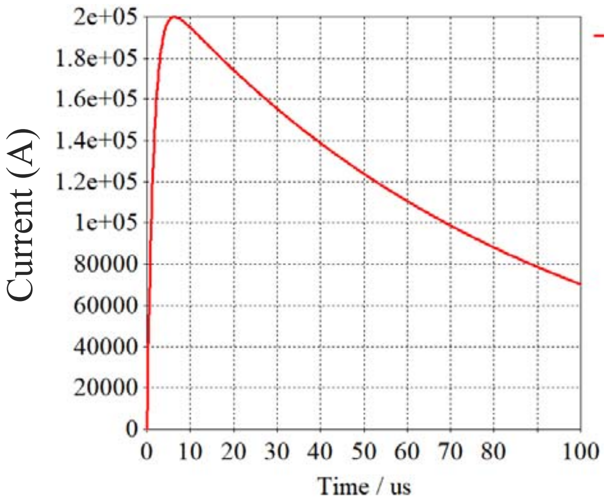


full-scale CAD model of rebar cage (false color)

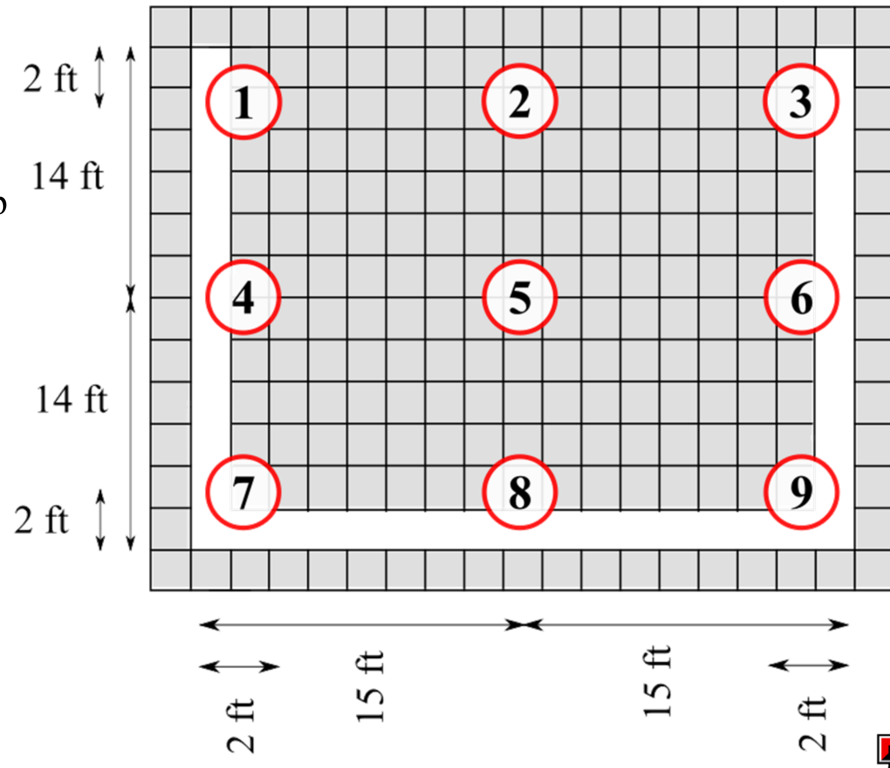
SZC6

Simulation Details and Probe Layout

- IEC 62305-001 LPL 1, positive strike waveform (200 kA, ~6 µs rise)
  - Accounts for 99% of all lightning strike events
- Probes arranged in a 3x3 matrix
- Unless otherwise noted, probes are 3’ above the foundation
  - Some instances of probes near the electrical gap are noted



Top-down view of the probe layout locations



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SZC6 What happened to negative strike?
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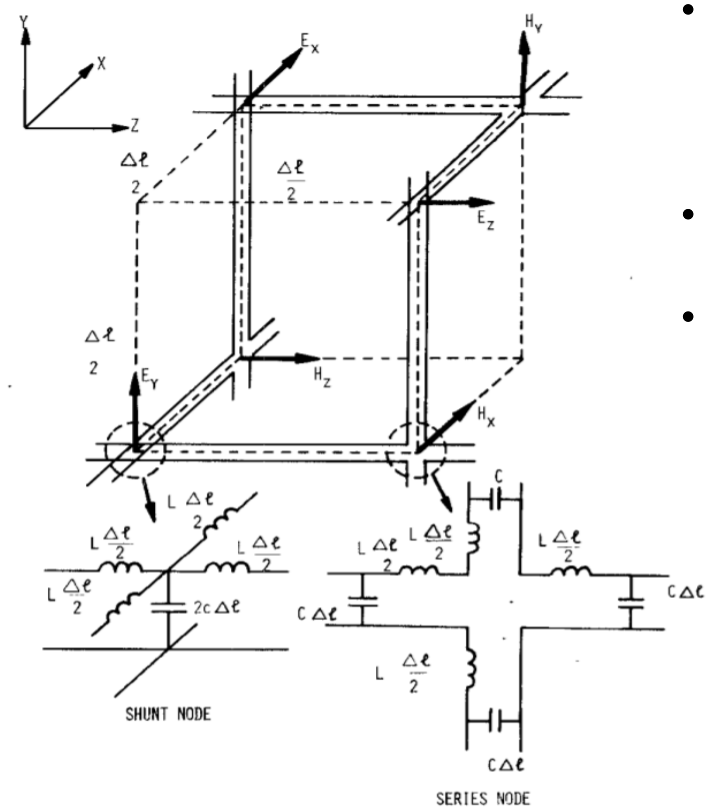
Algorithm and Computational Details



- Simulations incorporate a time-domain, transmission line matrix (TLM) model
  - CST Microwave Studio
- ~100M element typical mesh size
- Two, NVIDIA QUADRO RTX6000 GPUs
  - 24-48 hour typical simulation time

SPECIFICATIONS

GPU Memory	**24 GB GDDR6**
Memory Interface	**384-bit**
Memory Bandwidth	**Up to 672 GB/s**
ECC	**Yes**
NVIDIA CUDA Cores	**4,608**
NVIDIA Tensor Cores	**576**
NVIDIA RT Cores	**72**
Single-Precision Performance	**16.3 TFLOPS**
Tensor Performance	**130.5 TFLOPS**
NVIDIA NVLink	**Connects 2 Quadro RTX 6000 GPUs[1]**
NVIDIA NVLink bandwidth	**100 GB/s (bidirectional)**
System Interface	**PCI Express 3.0 x 16**

[*]Source: NVIDIA QUARDRO RTX6000 Datasheet

Hoefer, Wolfgang JR. "The transmission-line matrix method-theory and applications." *IEEE Transactions on Microwave Theory and Techniques* 33.10 (1985): 882-893.

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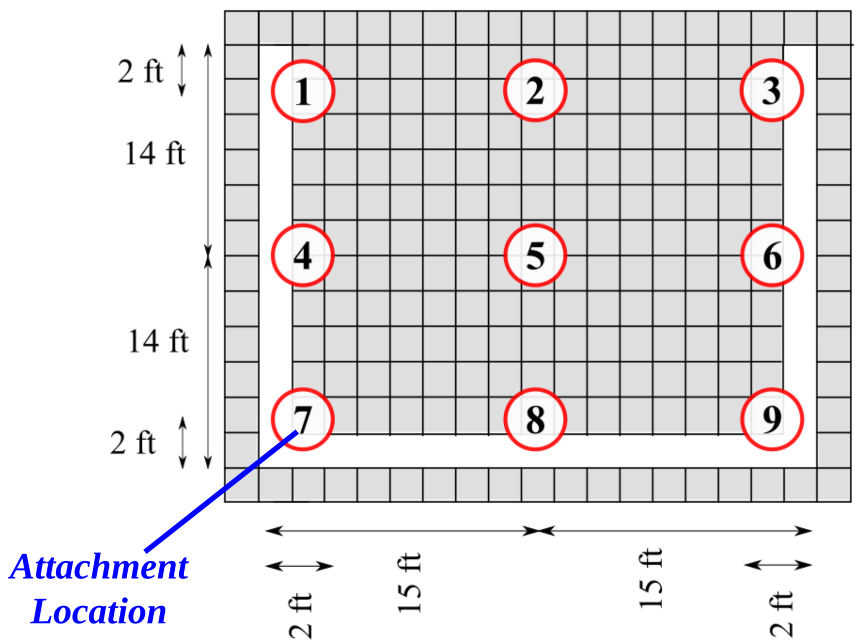
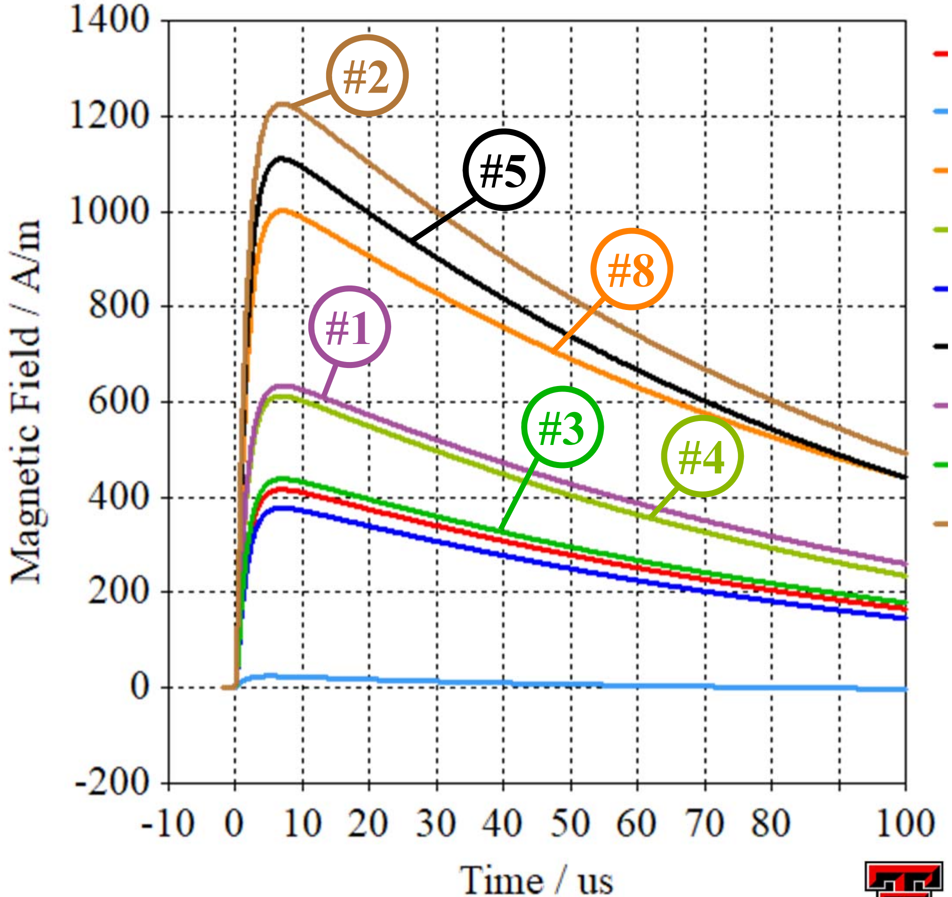
SZC1 New Figure
Shaw, Zachary C, 11/15/2021

Roof-Corner Strike, H-field

- Roof-Corner strikes yield the highest interior H-fields, but not necessarily E-fields





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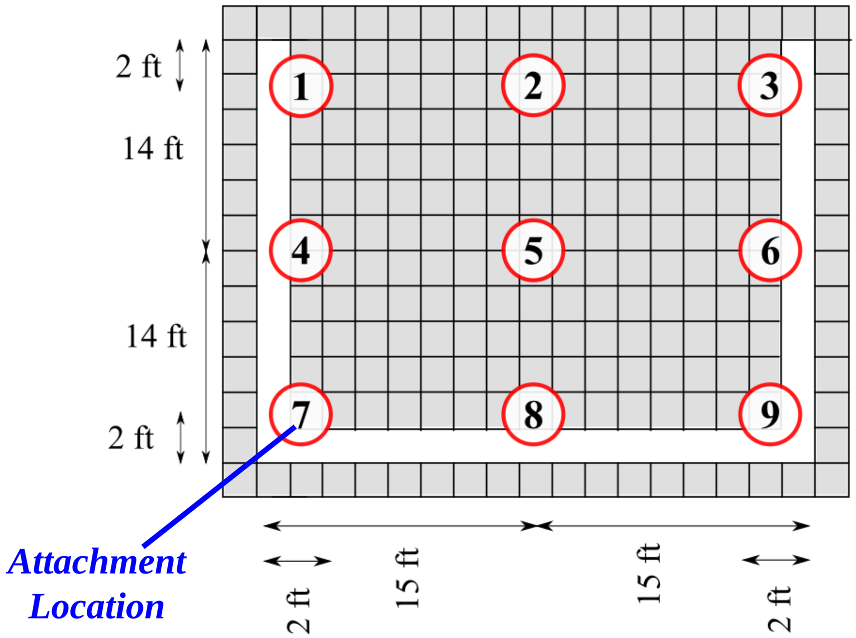
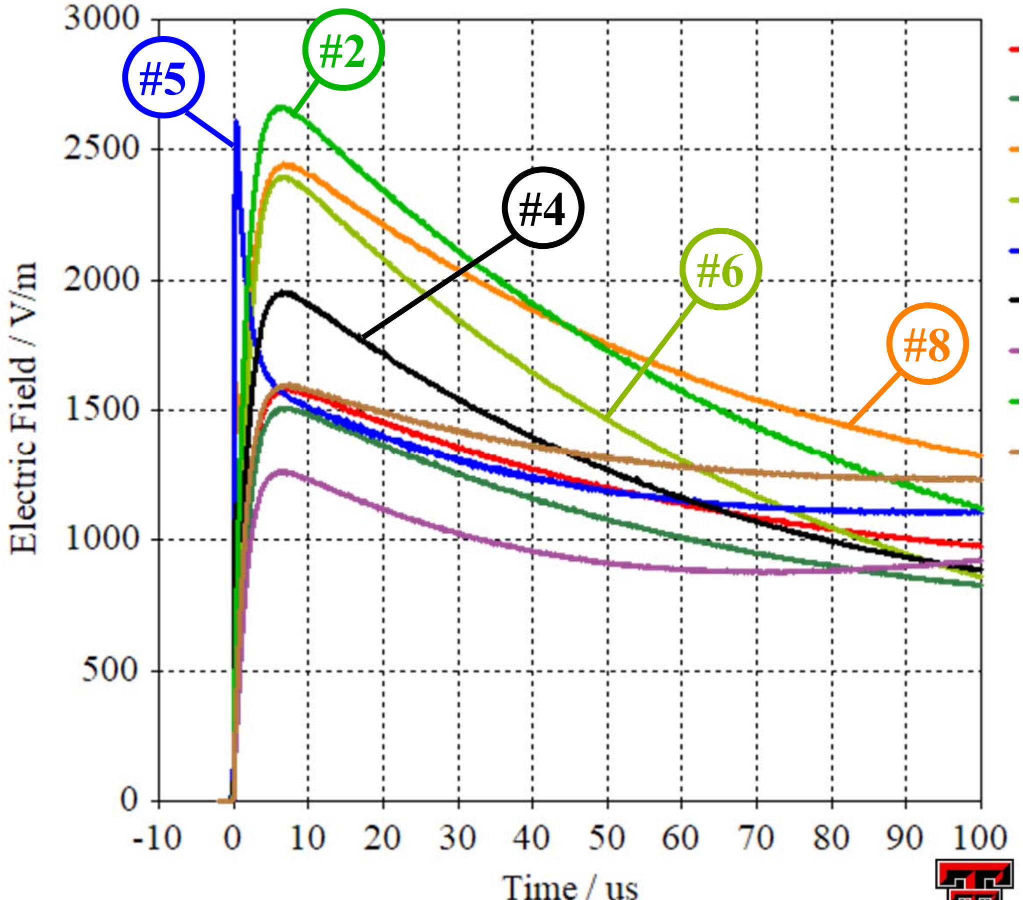
Roof-Corner Strike, E-field

- Roof-Corner strikes yield the highest interior H-fields, but not necessarily E-fields





Slide 7

SZC4 do we know why #5 does not follow the other waveforms? Interesting.

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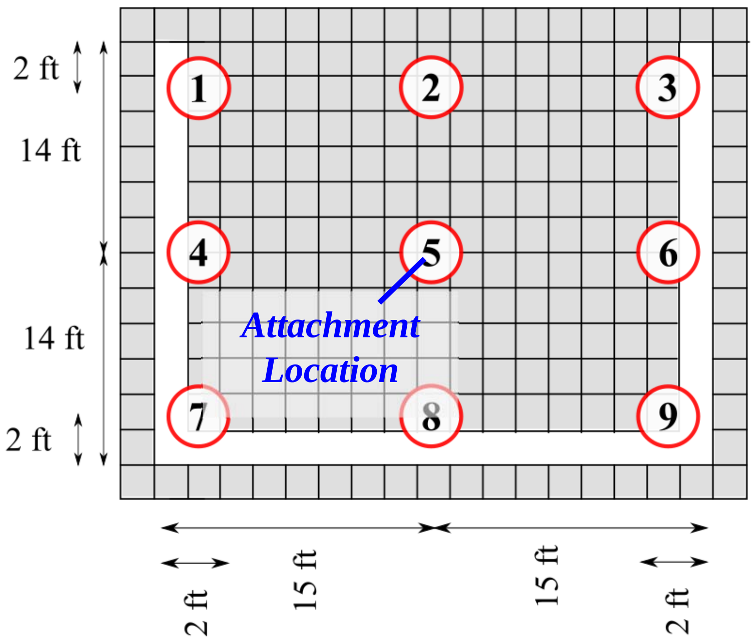
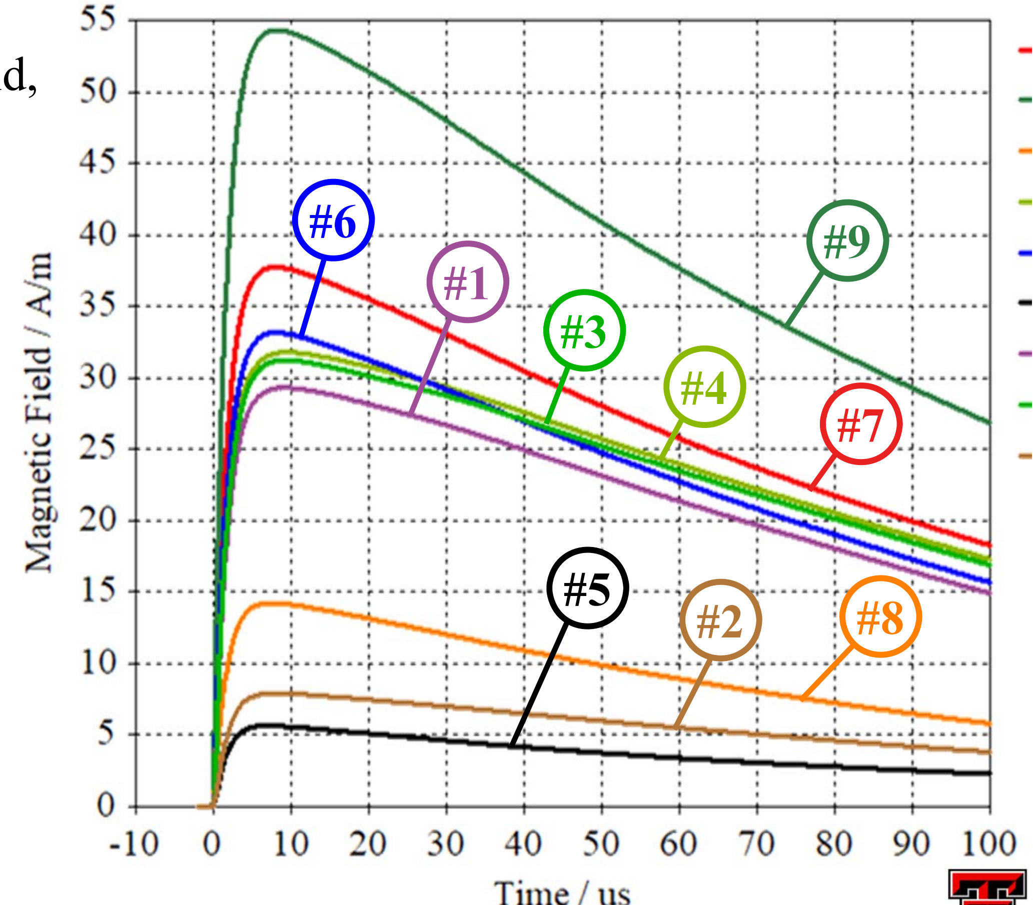
SZC3

Roof-Center Strike, H-field

- Roof-Center strikes yield a higher E-field, but much lower H-field





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SZC3 Might recommend changing scale if there is time. At first glance this looks like this produces higher magnetic field
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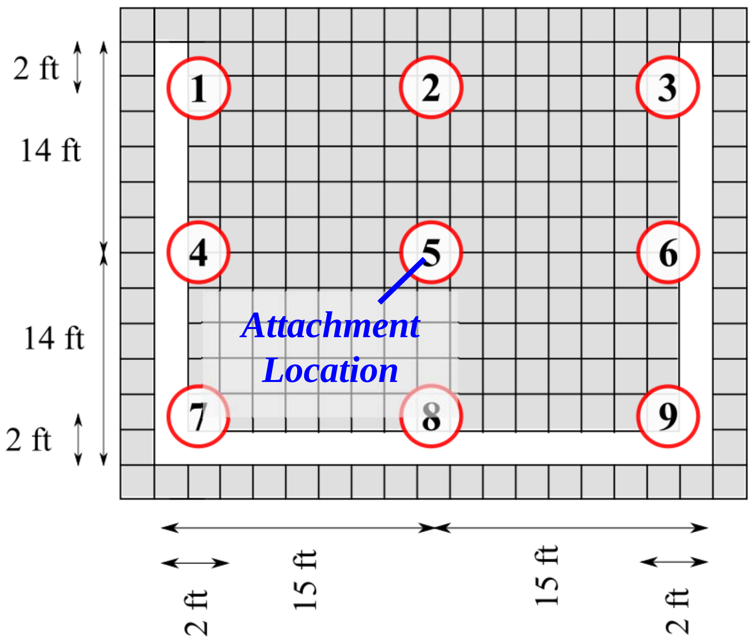
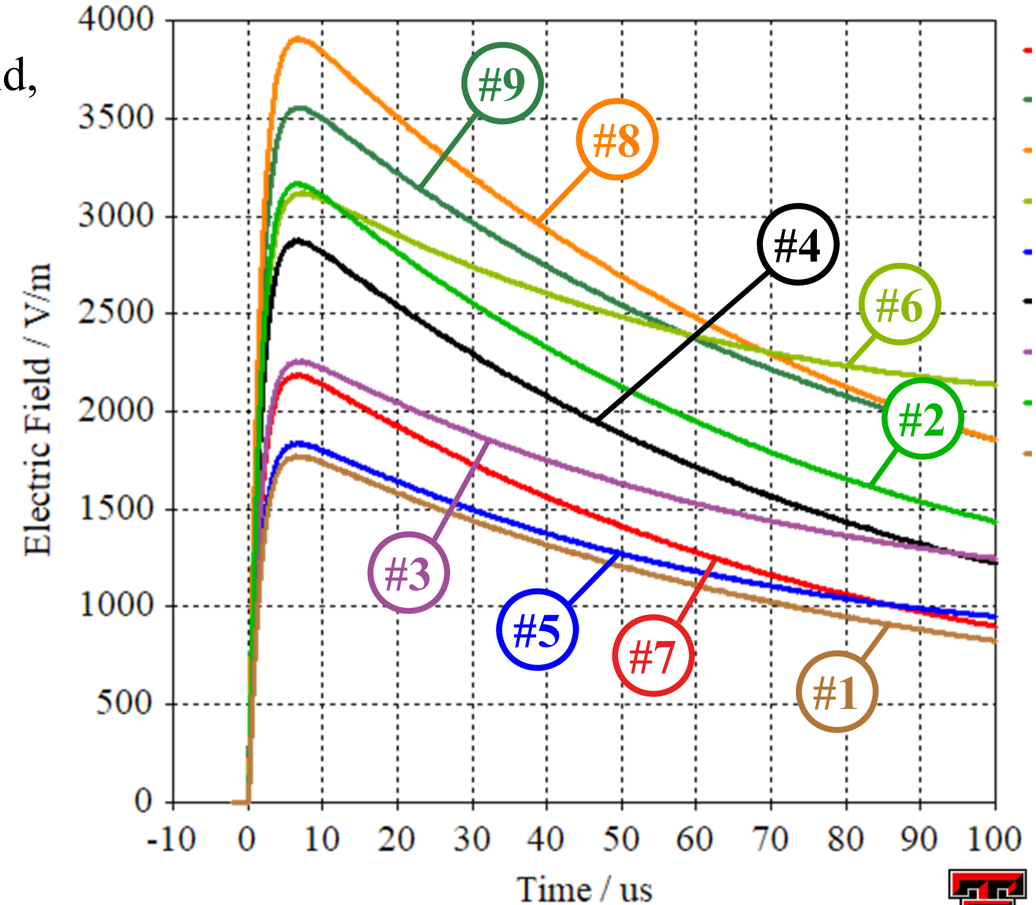
SZC5

Roof-Center Strike, E-field

- Roof-Center strikes yield a higher E-field, but much lower H-field





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SZC5 No figures here follow what #5 did on corner strike. Interesting.

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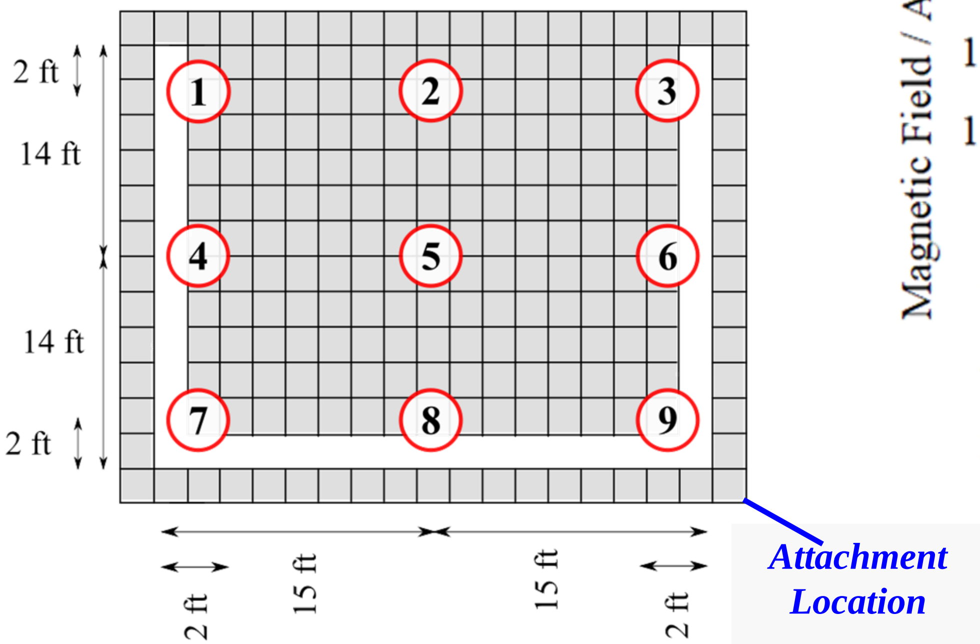
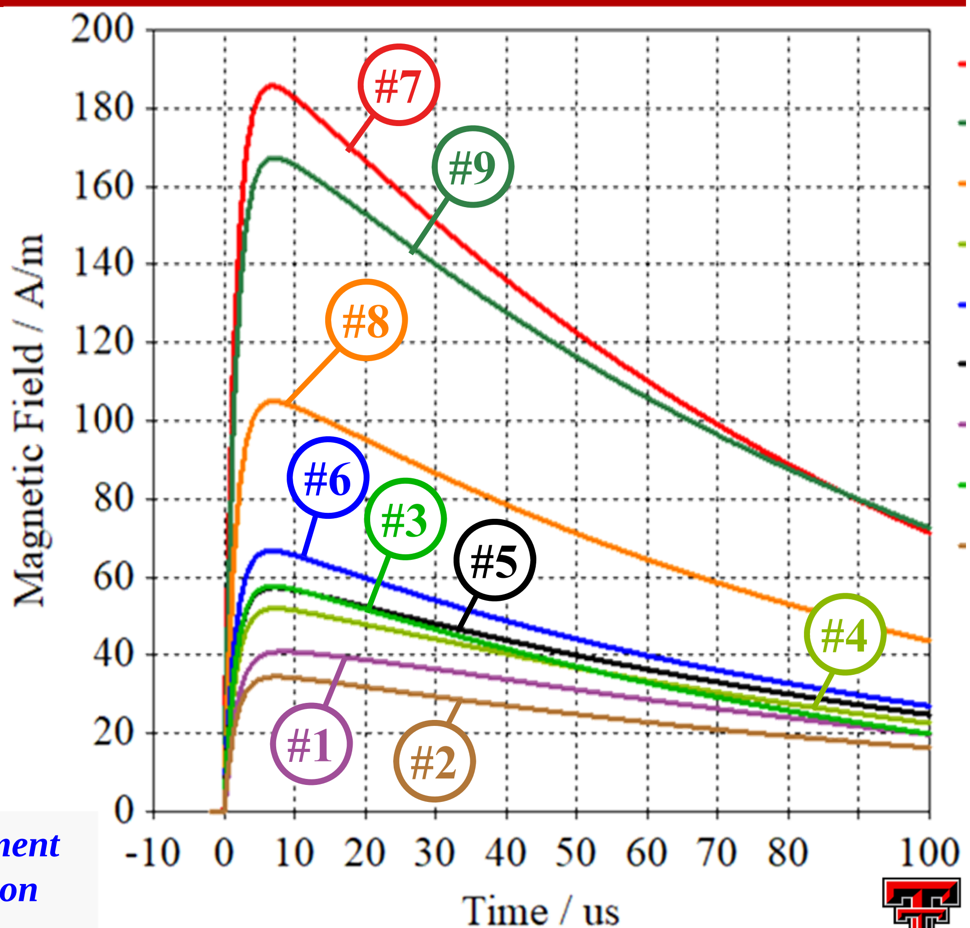
Wall-Corner Strike, H-field

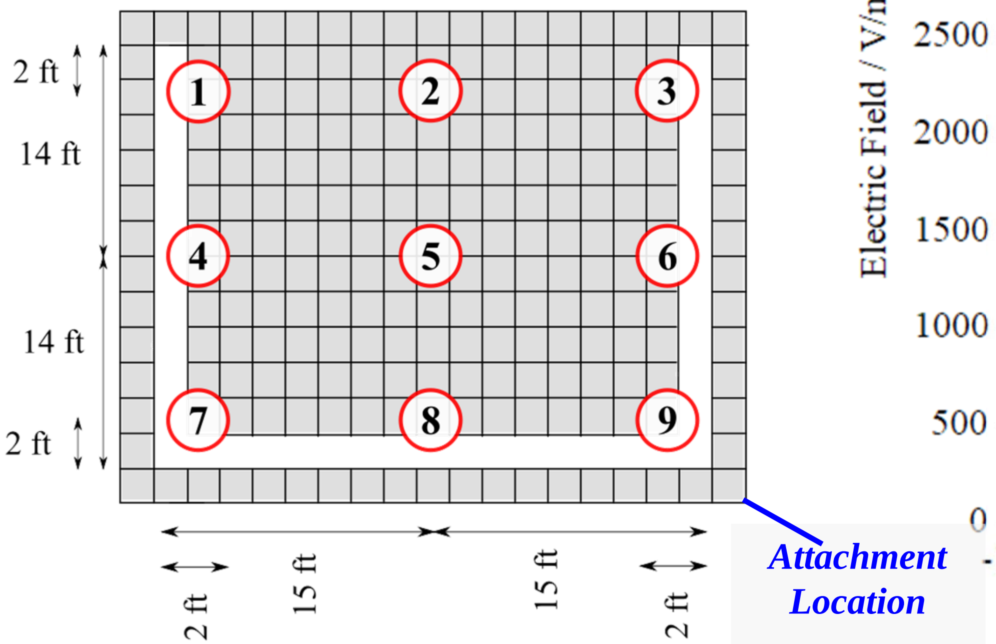
- Wall-Corner Strike yield moderate H-fields and higher E-fields

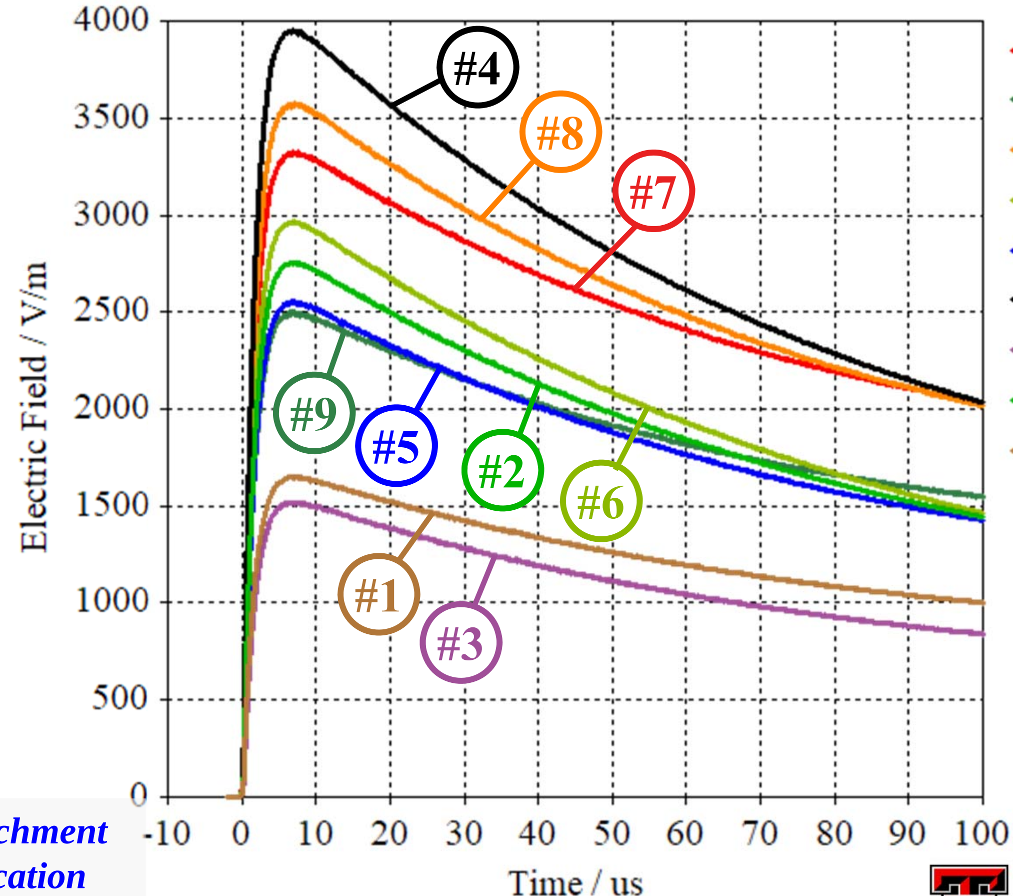




Wall-Corner Strike, E-field

- Wall-Corner Strike yield moderate H-fields and higher E-fields





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Summary of Full-Scale Computational Results

- Calculated E-field and H-field magnitudes are generally consistent with published literature for conventional structures*
- Roof strikes, near the discontinuity induce significantly higher H-fields, while E-fields less dependence on the strike location

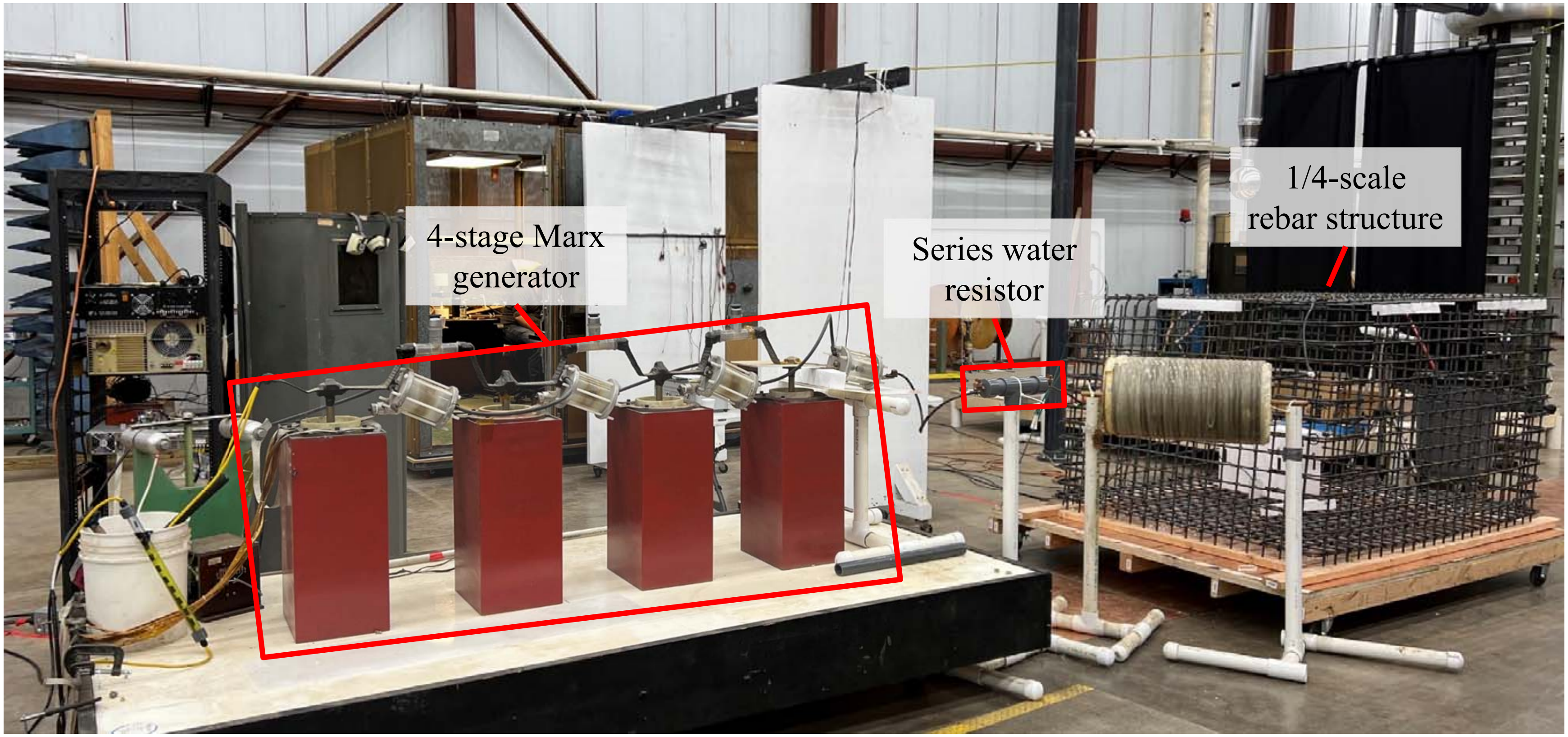
Table: Maximum field values observed for the 3x3 matrix of field probes, 3' above the foundation surface

	Peak H-field	**Peak E-field**
Roof-Corner Strike	1200 A/m	2600 V/m
Roof-Center Strike	54 A/m	3900 V/m
Wall-Corner Strike	185 A/m	4000 V/m

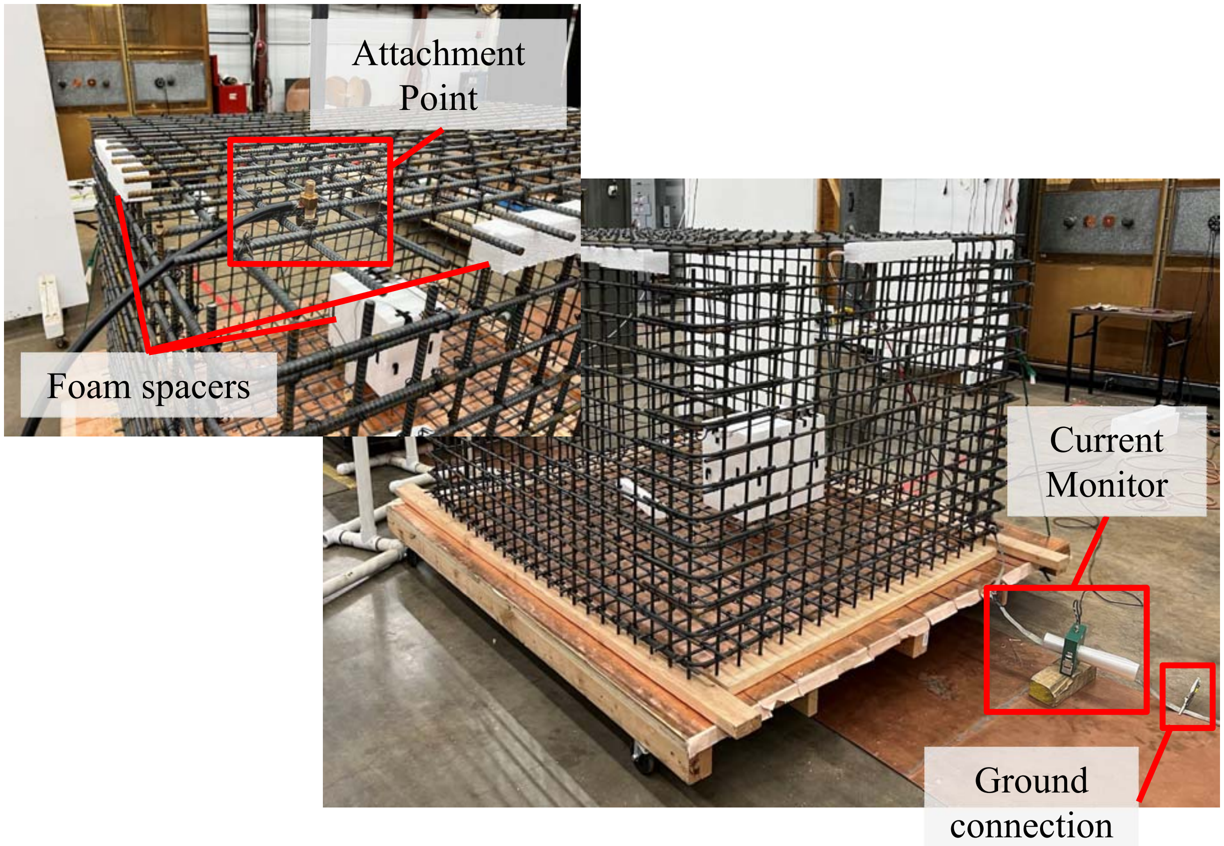
* I.A. Metwally, F.H. Hiedler, W.J. Zischank, "Magnetic Fields and Loop Voltages Inside Reduced and Full-Scale Structures Produced by Direct Lightning Strikes" IEEE Trans. Electromag. Compat. **48**, 414 (2006).

SZC7 Are there any conclusions/equations that can be drawn from this so far? Seems pretty empirical at the moment.
Shaw, Zachary C, 11/15/2021

Experimental Setup

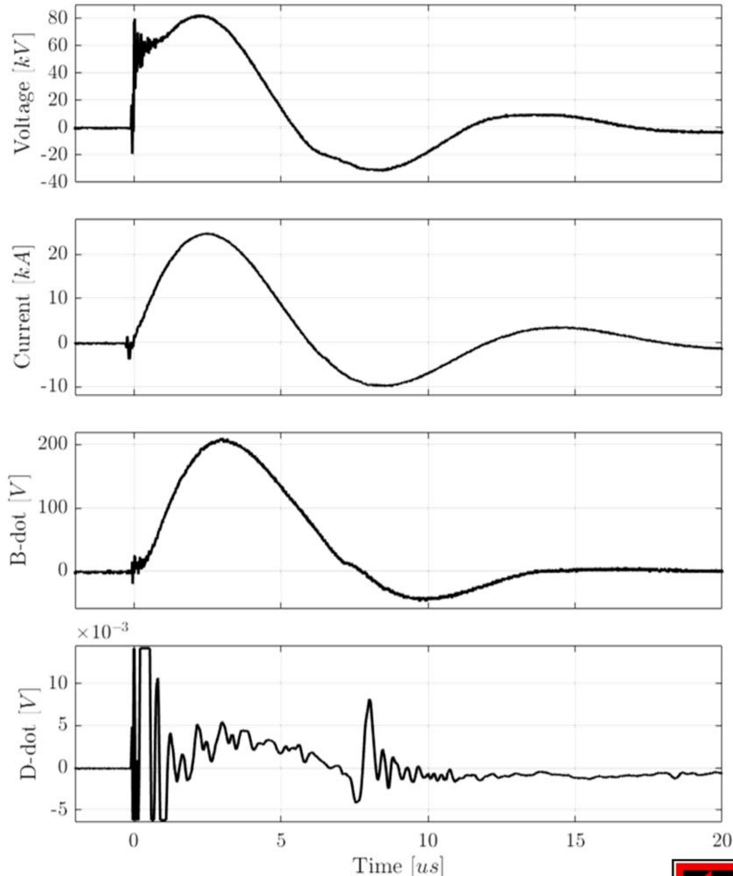


1/4-Scale Rebar Structure



First Experimental Shots

- Example shot for 30 kV marx charge voltage (~120 kV) output
- Currently collecting experimental data with varying current waveforms and strike locations
  - Voltage, Current, E-fields, B-fields



Conclusion & Future Plans

- Continue modeling effort to better understand induced fields
  - Varying attachment location, strike type (positive, negative, etc.), grounding details, etc.

- Revision of our Marx generator to provide 1/4-scale relevant peak current and pulse risetime
  - Measurement of interior magnetic and electric fields

- Reconciliation of experimental and computationally modeled fields
  - Improved confidence in computational model results