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COST P18: The Physics of Lightning Flash and Its Effects

Vertical and Horizontal Components of the Electric Field Associated with Lightning Strikes to the Gaisberg Tower

A. Mosaddeghi, A. Mimouni, F. Rachidi, M. Rubinstein,
G. Diendorfer, H. Pichler, D. Pavanello

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

heig-vd
Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud

ALDIS

Outline

- Introduction
- Experimental Setup
- Experimental Data
- Simulation Results and Comparison with Data
- Discussion and Conclusion

Introduction (1/2)

- There is an inherent difficulty in measuring the horizontal electric field component of lightning because of the overshadowing effect of the vertical electric field component.
- Indeed, for observation points located on the ground or a few meters above the ground, the vertical electric field magnitude is much larger than that of the horizontal component (typically two orders of magnitude).
- This is the main reason why data for this component are very rare.

Introduction (2/2)

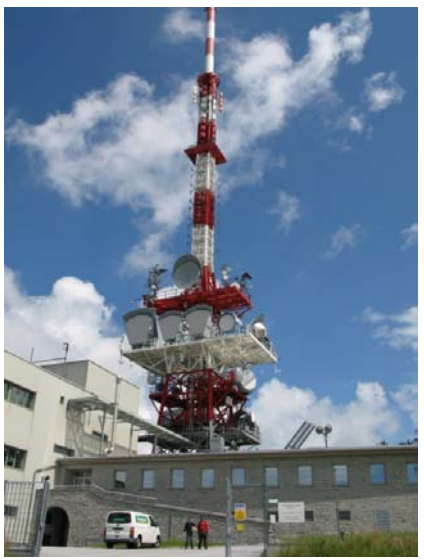
- To the best of the authors' knowledge, only two sets of experimental data are available in the literature.
- In 1988, Thomson et al. presented results of simultaneously measured vertical and horizontal electric fields associated with distant lightning (distance ranging from 7 to 43 km).
- More recently, in 2008, Barbosa et al. presented results for the horizontal electric field at 50 m from artificially-initiated lightning strikes in Brazil. The data of Barbosa et al., however, do not include the vertical component of the electric field.

Aim of the Paper

- We present simultaneous measurements of vertical and horizontal electric field components associated with lightning strikes to the 100-m tall Gaisberg tower. The fields are measured at about 20 m from the tower.
- At such a close distance and for lightning strikes to tall structures, the two components become comparable in magnitude, as shown by simulations and verified by the obtained experimental data.

Gaisberg Tower Data

The Gaisberg tower is a 100-m tall radio tower located 1287 m above sea level on the top of a mountain 5 km east of the city of Salzburg.



From 1.09.2007 to 31.12.2008

164 Flashes,
1599 Strokes

54/164
no return
strokes !

111/164
return
strokes

1280/1599
α-pulses

297/1599
β-pulses

Gaisberg Tower Data

ALDIS-EPFL, Recorded Fields in 2007-2008

	Flashes/ Strokes	Recorded Data				
From 1.09.2007 to 10.11.2007	11 / 74	I (tower)	Hφ (20m)	Ez (22m)	Ez (170m)	
From 11.11.2007 to 31.06.2008	2 / 10	I (tower)	Hφ (20m)	Er (22m)	Ez (170m)	
From 01.07.2008 to 01.08.2008	2 / 5	I (tower)	Er (20m)	Ez (22m)	Ez (170m)	Ez (108km)

Experimental Setup

- Near EM Field Measurement (R=22m, 20m)

• E-field sensor (TSN 245-E32, Thomson CSF, 1 kHz – 130 MHz)
• H-field sensor (TSN 245-H30, Thomson CSF, 4 kHz – 130 MHz)
• 100-MS/s, 8-bit digitizer
• Two channels with 1 MB memory per channel
• Computer controller equipped with a GPS receiver for time stamping
• 200-μs long strokes per lightning flash
• 40-MHz low pass filter

Experimental Setup

- Electric Field Measurement (R=170m)

• Bandwidth: ~300 Hz – 1 MHz
• Optical converter (Isobe 5500, Bandwidth 0 Hz – 25 MHz)
• Total bandwidth of 0 Hz to 3.2 MHz
• 5 MS/s
• 12 bit resolution
• Timestamp with GPS-clock (accuracy 500 ns)
• Recording time 5 seconds with two seconds pre-trigger time

Experimental Setup

- Current Measurement

Shunt resistance installed at the top of tower

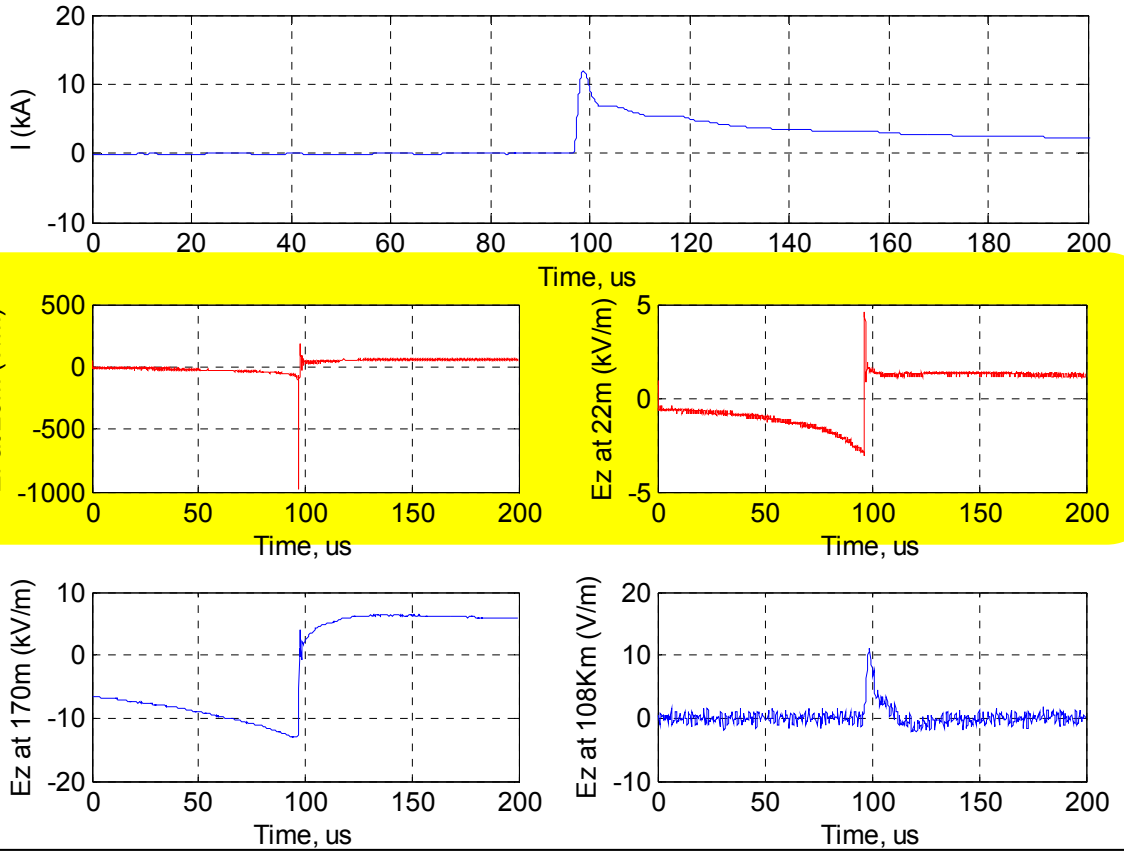
• 25mΩ shunt resistance
• Total bandwidth of 0 Hz to 3.2 MHz
•Two channels with a measuring range of ±2 kA and ± 40 kA
• Fiber optic links (Isobe 3000, bandwidth 0 Hz – 15 MHz)
• Two channel 20 MS/s, 8-bit digitizer
• Recording time 800 ms with 15 ms pre-trigger

Typical Data Set

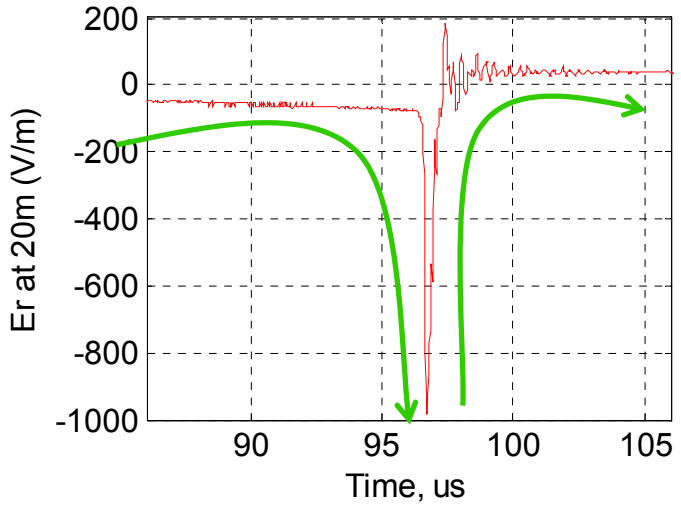
Flash,
2008-07-20, 15:07:17
Stroke 2/3

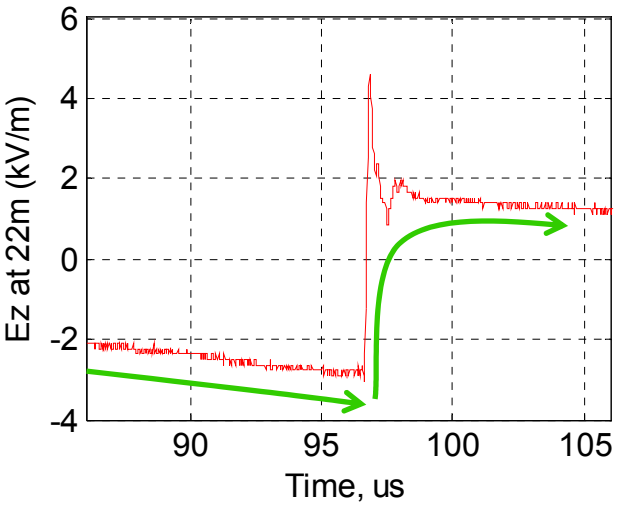
Recoded Data:

I (tower)
Er at r = 20m
Ez at r = 22m
Ez ar r = 170m
Ez at r = 108Km



Typical Data Set: Expanded Time Scale





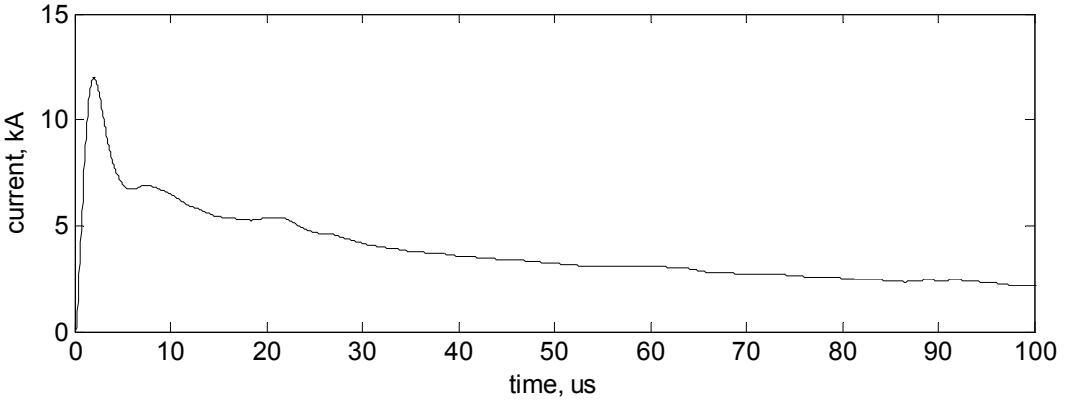
Modeling Approaches

- Two Modeling approaches have been adopted in this study for the field computation:

1. Engineering Models + FDTD

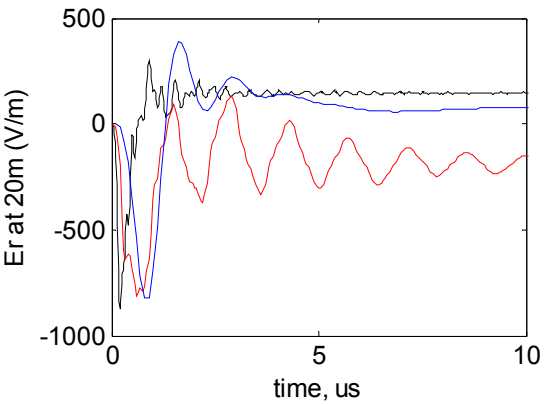
2. Antenna Theory Model using NEC-4 for the field computation (Method of Moments)

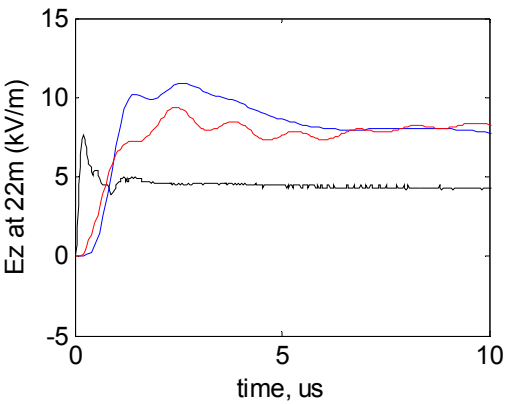
Comparison (return-stroke phase)



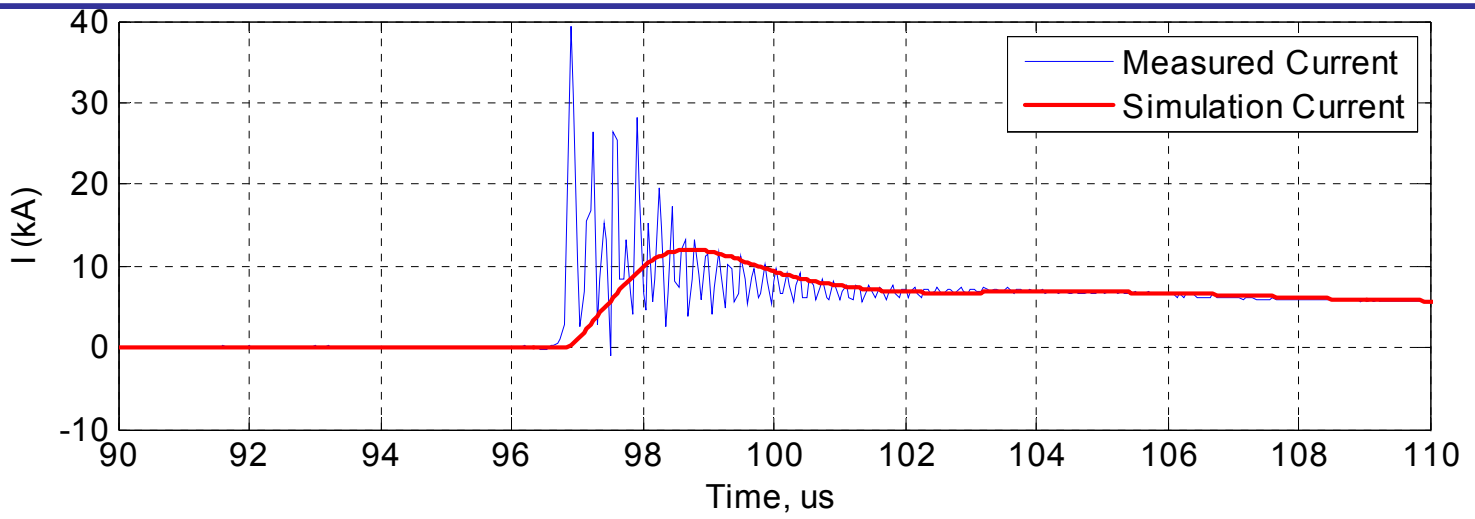
Black: Measurement
Blue: Engineering-FDTD
Red: AT-MoM

Perfect ground





Measured Current



- The Gaisberg Tower current data was filtered using a
- There is evidence, however, that the high frequency fine structure of the current is a true feature and not a result of induced noise signals (Diendorfer et al., 2009).

Conclusion (1/2)

- Horizontal and vertical E-Field waveforms associated to lightning strikes to the Gaisberg Tower have been simultaneously obtained.
- Both components are characterized by asymmetrical V-shape waveforms.
- The vertical electric field change at 22 m appears to be significantly smaller than similar measurements obtained using triggered lightning (Crawford et al 2001).
- This is presumably due to the shadowing effect of the tower which results in a significant decrease of the electric field at distances of about the height of the tower or less.

Conclusion (2/2)

- Simulation results obtained using Antenna Theory and Engineering models are compared with experimental data.
- The differences between theoretical predictions and experimental data can be partly due to the filtering of the incident lightning current and the uncertainty in the ground parameters.