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COST P18: The Physics of Lightning Flash and Its Effects

Electromagnetic Fields At Very Close Range to Gaisberg

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Outline

- Introduction
- Experimental Setup
 - Gaisberg Tower
 - Near Electromagnetic Field Measurement
 - Distant Electric Field Measurement
 - Current Measurement
- Experimental Data
- Discussion and Conclusion

Introduction

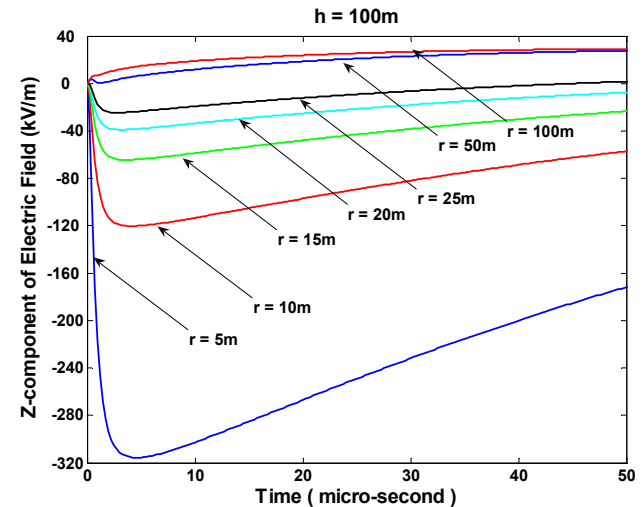
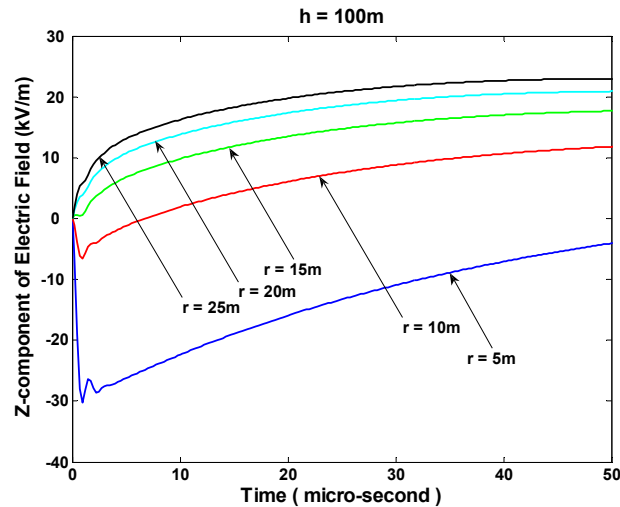
- Based on theoretical modeling and experimental observations, it is a well established fact that the presence of a tower may result in **a substantial increase** (a factor of 3 or so) of the electric and magnetic field peaks and their derivatives for observation points located **at distances exceeding the height of the tower**.
(e.g. [*Baba and Rakov, 2005; Bermudez, et al., 2005; Rachidi, et al., 2001*])
- Interestingly, the effect of the tower **at distances of about the height or the tower or less** could result in **a significant decrease** of the electric field
(e.g. [*Baba and Rakov, 2005; Miyazaki and Ishii, 2004; Pavanello, et al., 2004*]).

Close-by EM Environment

- Recent theoretical studies suggest that **the electric field** generated by a lightning return stroke to a tall structure **can change polarity** at very close distance range, typically at distances of about one tenth the height or so of the struck object.
- The simulation results based on engineering models and Antenna Theory (AT) model show this inversion of polarity can occur when the **reflection coefficient** at the base of the tower is about 0.8 or lower.

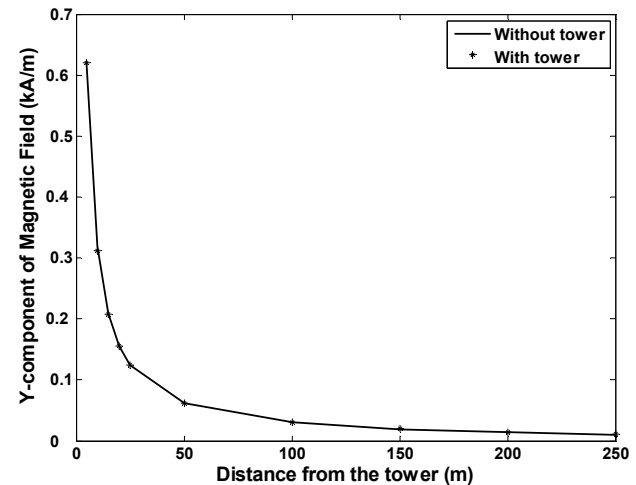
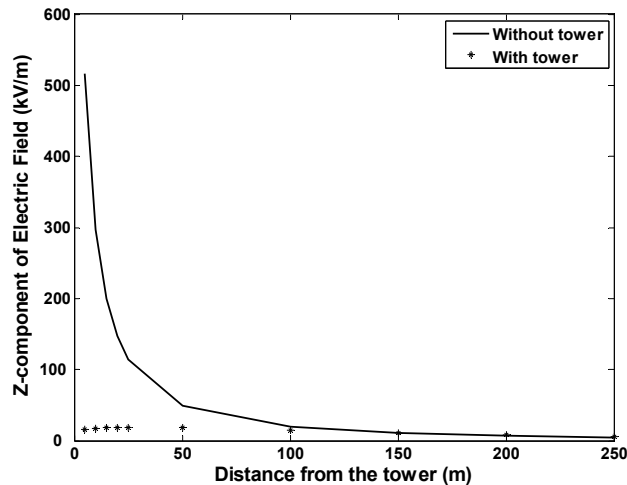
Close-by EM Environment

Electric field at different distances from the 100-m tall struck tower located on lossy ground (Antenna Theory Models – NEC4)



Close-by EM Environment

Electric and magnetic field peaks at different distances in the presence and absence of the 100-m struck tower (perfect ground considered)



———— strike to ground
- - - - - strike to a 100-m tall tower

Aim of this presentation

- Obtain experimental data on electric and magnetic fields at very close range to a tower struck by lightning.
- Currents and electromagnetic fields were recorded at two close distances for several lightning flashes to the Gaisberg Tower which occurred during the fall 2007.
- Electric field changes were measured at distances of 22 m and 170 m from the tower base and the magnetic field was measured at a distance of 20 m.
- Simultaneously, the lightning return stroke current was measured using a sensor located near the top of the tower.

Outline

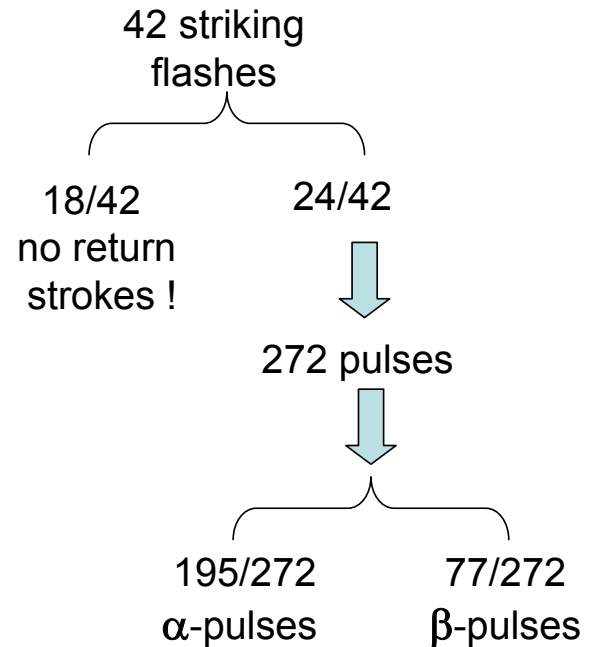
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Gaisberg Tower

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 4.09.2007 to 10.11.2007



Experimental Setup

- Near EM Field Measurement ($R_1=22\text{m}$, $R_2=20\text{m}$)



- E-field sensor (TSN 245-E31, Thomson CSF, 1 kHz – 130 MHz)
- H-field sensor (TSN 245-H31, Thomson CSF, 4 kHz – 130 MHz)
- 100-MS/s, 8-bit digitizer
- Two channels with 1-MB memory per channel
- Computer controller
- up-to-20 strokes, 200- μs long each, per lightning flash
- 40-MHz low-pass filter

Experimental Setup

- Distant Electric Field Measurement (R=170m)



- Bandwidth: ~300 Hz – 1 MHz
- Optical converter (Isobe 5500, Bandwidth 0 Hz – 25 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



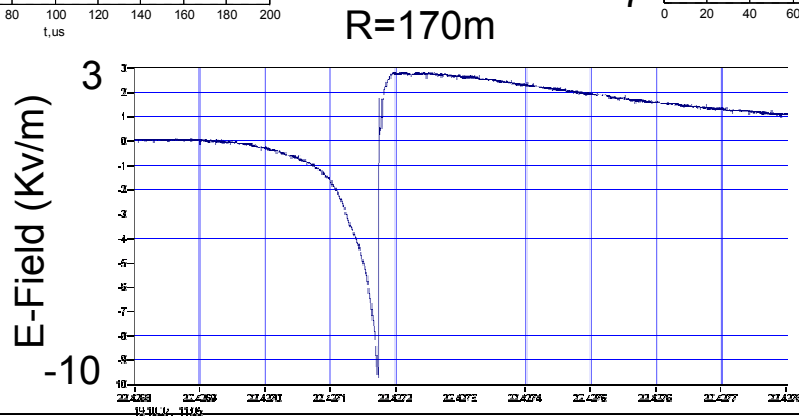
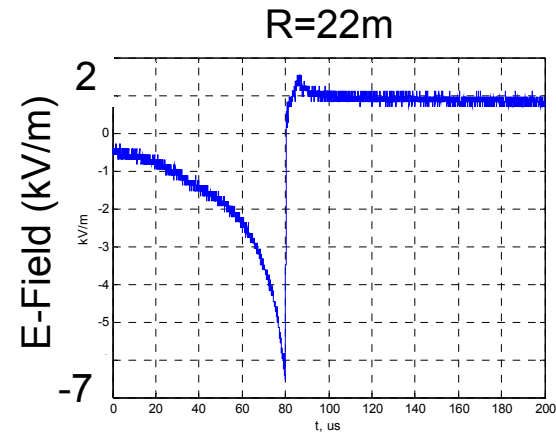
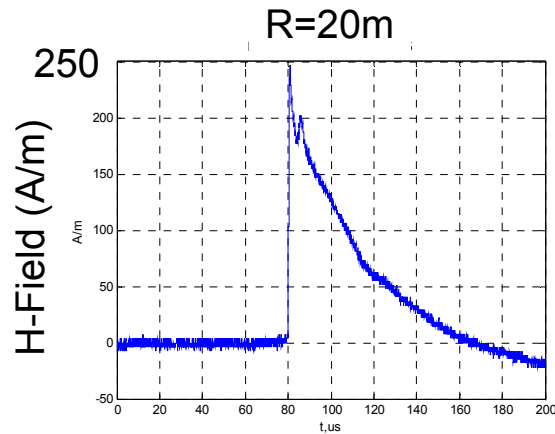
Rogowski Coil installed
at the top of tower

- 25-m Ω 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

Outline

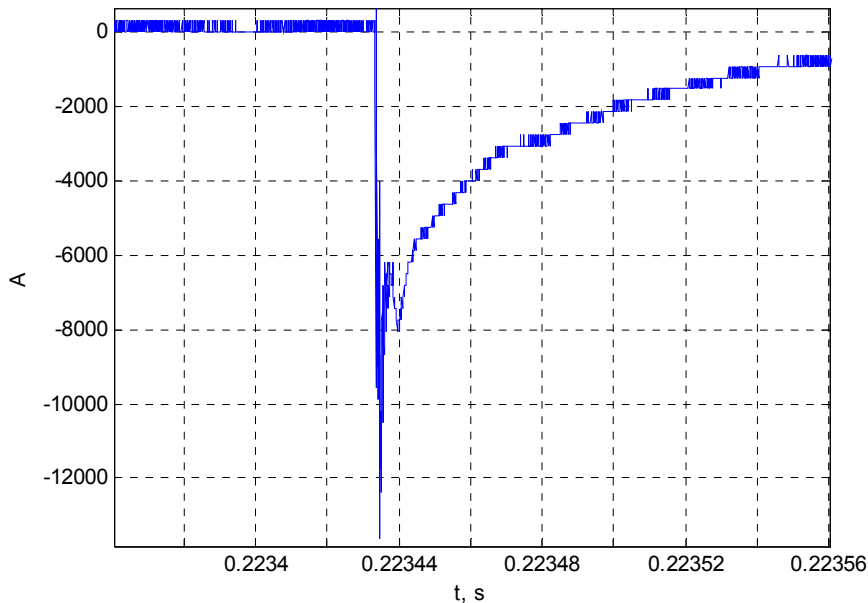
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A typical set of experimental data: EM Field



A typical set of experimental data: Current

First stroke of a 5-stroke



Lightning current corresponding
the flash occurred on
October 19, 2007
11:05:41 UTC

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Discussion and Conclusion

- The magnetic field appears to be a factor of about 2.5 larger than the value predicted by the Ampere's law.
- This enhancement could be due to several possible causes such as the proximity to the tower base and other close-by metallic structures, and also to the presence of a horizontal ground wire connected to the base of the tower.
- The return-stroke 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

Discussion and Conclusion

- The electric field change at 22 m is even smaller than that measured at 170 m. This can be partially due to the shadowing effect of the tower. Such effect was predicted by Antenna Theory models.
- No inversion of polarity of the electric field was observed. This is presumably due to the 'good grounding' of the tower.
- It is also important to consider that the electric field sensors located on the top of metallic structures could suffer local enhancements typically ranging from 1.5 to 2.5.

Thank You!