Fair-weather Atmospheric Electric Field Measurements at the Gaisberg Mountain in Austria

Helin Zhou[1], **Gerhard Diendorfer**[2], **Rajeev Thottappillil**[1], **and Hannes Pichler**[2]

[1]Division of Electromagnetic Engineering, School of Electrical Engineering
Royal Institute of Technology (KTH), Stockholm, Sweden
[2]Department of ALDIS (Austrian Lightning Detection & Information System)
Austrian Electrotechnical Association (OVE), Vienna, Austria

Abstract— A field mill (FM) has been permanently operated at a distance of about 170 m from the Gaisberg Tower (GBT) in Austria since several years. The electric field measurements suffer from field enhancement due to its location on a 4-m tall metal platform near the tower which itself is located on a 1280 meter high mountain. A special measuring campaign was conducted to determine the fair-weather atmospheric electric field at the Gaisberg Mountain on June 24th, 2010. The main objectives of this campaign were to calibrate the field mill in order to infer the relation between the electric fields at the tower tip and the ground level measured by the field mill under thunderstorm conditions. Besides the permanent field mill near the tower, two Campbell Scientific CS100 electric field meters were used during this campaign, and distances between each other were determined by using the Global Positioning System (GPS). Overall we determined an enhancement factor of 2.75 due to the mountain itself with reference to the mountains surrounding terrain. A field enhancement factor of 7.81 was obtained for the permanently installed field mill at the measurement platform next to the GBT with reference to the undisturbed electric field at the mountain top close to the platform at ground level. The electric field near the tower (distances about the tower height of 100 m) was smaller than the field measured at larger distance from the Tower. This observation was possibly caused by a shadowing effect of the tower.

1. INTRODUCTION

The amplitude of fair-weather atmospheric electric field is usually of the order of one to two hundred Volts per meter [1, 2]. It can be measured by a field mill on flat ground. If the field mill is mounted above the ground or installed at elevated objects, it will suffer from field enhancement. On the other hand, if the field mill is located close to tall objects (i.e., buildings, big trees, towers), the field mill reading will be lower due to the shadowing effect of these objects. Electric field enhancement factors at the top of buildings with different heights for lightning radiated fields are reported in the range of 1.5 to 2.3 compared with the measurements at ground level [3–6]. Next to the Gaisberg Tower (GBT) in Austria, a field mill (FM) is permanently operated since several years. The main purpose of those electric field measurements is to determine the background electric field that exists right at the time when upward lightning is triggered by the 100 m high tower. This radio tower on the mountain triggers about 60 upward initiated lightning flashes per year and is instrumented in order to measure the lightning current waveforms [7]. Knowledge of the background electric field at the mountain top will allow the estimation of the local electric field at the tower top by using a finite element model of the tower structure.

The FM is mounted on a 4-m tall metal platform at a distance of about 170 m from the GBT and hence the electric field measurements suffer from field enhancement. In order to get an approximate correction factor, simultaneous measurements are necessary. Besides the permanent field mill, a reference field mill is needed.

In this paper, we report the results of measured atmospheric electric fields under fair weather conditions at the Gaisberg Mountain in Austria. The enhancement factors due to the mountain itself and the elevated metal platform are investigated. Also the shadowing effect of the 100-m radio tower on the fair-weather electric field is presented.

2. INSTRUMENTATION

Two CS100 electric field meters manufactured by Campbell Scientific Inc. are employed for the simultaneous measurements. Unlike the traditional continuously rotating field mills, this type of electric field meter uses a reciprocating shutter, which reduces significantly power consumption. This feature makes it possible to operate the field mills powered by batteries and move them around easily. Each CS100 has been already calibrated in the factory when it is mounted at 2 m height tripod mast. An embedded CR1000M data-logger is used to record the data.

On the other hand, the permanently installed field mill was manufactured by Previstorm Inc. and is mounted on the 4-m tall metal platform at a distance of 170 m from the GBT. This field mill is in operation for several years. In order to synchronize the data measured by the mobile electric field meter, during the field campaign, the sampling rate of the permanent field mill was set to 1 Hz, the same sampling rate as used for the other two field mills.

3. MEASUREMENTS AND RESULTS

On June 24th, 2010, a field campaign was conducted in order to measure the fair-weather atmospheric electric field at the Gaisberg Mountain. During this campaign two mobile Campbell Scientific CS100 electric field meters and one permanent field mill were employed at different locations and distances between each other were determined by using the Global Positioning System (GPS).

Firstly, one CS110 Electric Field Meter was deployed and operated at a site of the surrounding area of the Gaisberg Mountain (786 m above sea level). After an initial test to verify that both CS110 field meters provided the same result when they were placed at the same location, the second CS110 was taken to measure the electric field simultaneously at sites of different altitudes along the way up to the top of the Gaisberg Mountain. Due to the mountain itself increasing field enhancement with increasing altitudes of the measuring sites were found. In Figure 1, we present as an example the simultaneously measured field from the reference site at the surrounding terrain and field at the top of the Gaisberg Mountain (site was at a distance of 249 m from the GBT). An arithmetic mean of 66 V/m at the surrounding terrain and 181 V/m at the top of the Gaisberg Mountain is obtained, respectively, corresponding to an enhancement factor of 2.75 due to the mountain itself.

In order to determine the enhancement factor for the field mill mounted on the 4-m tall metal platform at a distance of 170 m from the GBT, we deployed a CS100 electric field meter at a distance of 185 m nearby to the metal platform but at ground level. Simultaneous measurement results are shown in Figure 2. An electric field arithmetic mean value of 181 V/m at the ground level and 1406 V/m at the 4-m tall metal platform is obtained, corresponding to an enhancement factor of 7.81 due to the 4-m tall metal platform.

Similar to the measurements along the way up to the mountain top, at the local area of the Gaisberg mountain top, one CS110 was deployed at a distance of 249 m, assuming this was far enough from the 100 m high GBT to have negligible effect of the metal tower on the fair weather electric field. The second CS110 was used to measure simultaneously the electric field at different distances from the tower and ranging up to about the height (100 m) of the tower. Figures 3, 4 and 5 show the simultaneously measured data obtained from the two identical CS110 electric field meters. The mean ratios of the field values measured at 111 m, 85 m and 50 m to the reference values measured at 249 m from the GBT are 0.65, 0.73 and 0.71, respectively. We can see that

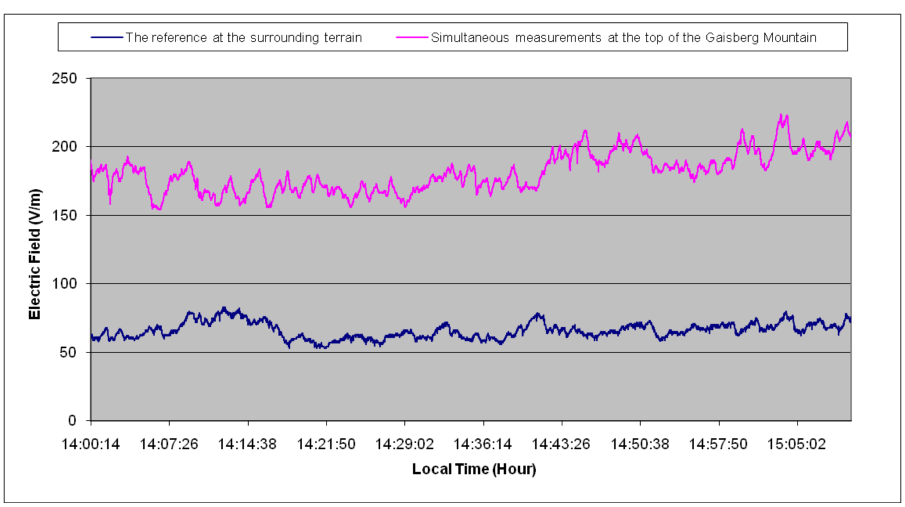

Figure 1: Simultaneously measured fields at the surrounding terrain and at the top of Gaisberg Mountain.

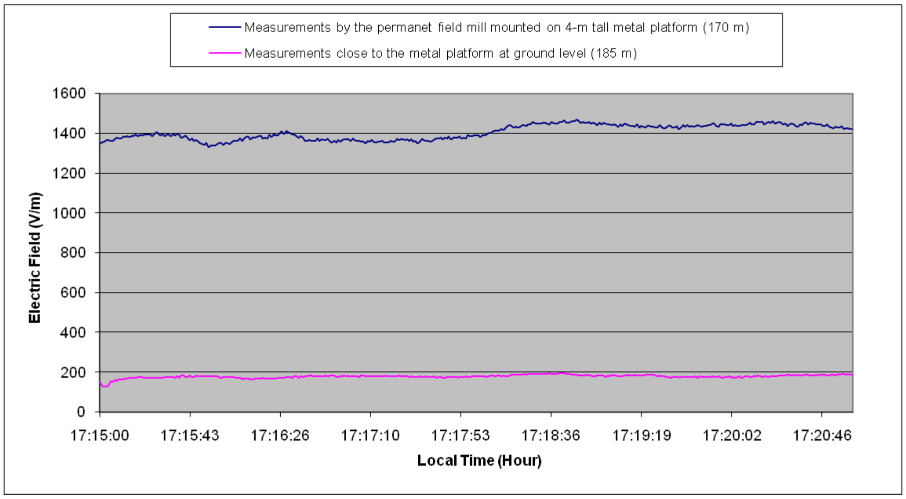

Figure 2: Simultaneously measured fields at the 4-m tall metal platform and at ground level.

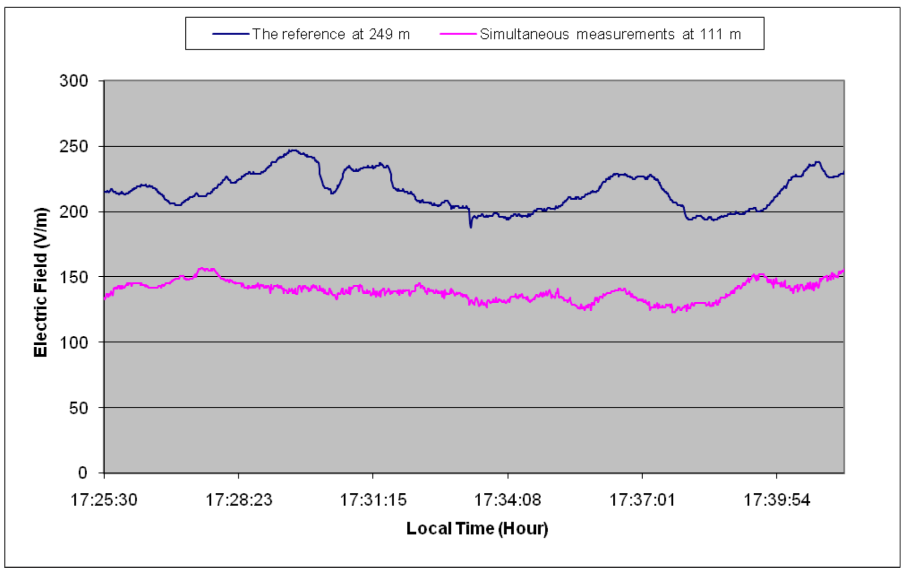

Figure 3: Simultaneously measured fields at distances of 249 m and 111 m from the GBT.

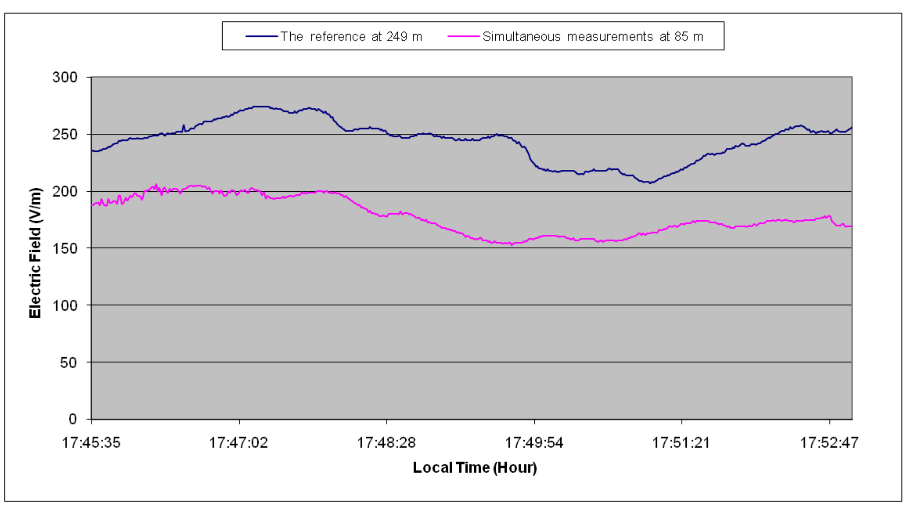

Figure 4: Simultaneously measured fields at distances of 249 m and 85 m from the GBT.

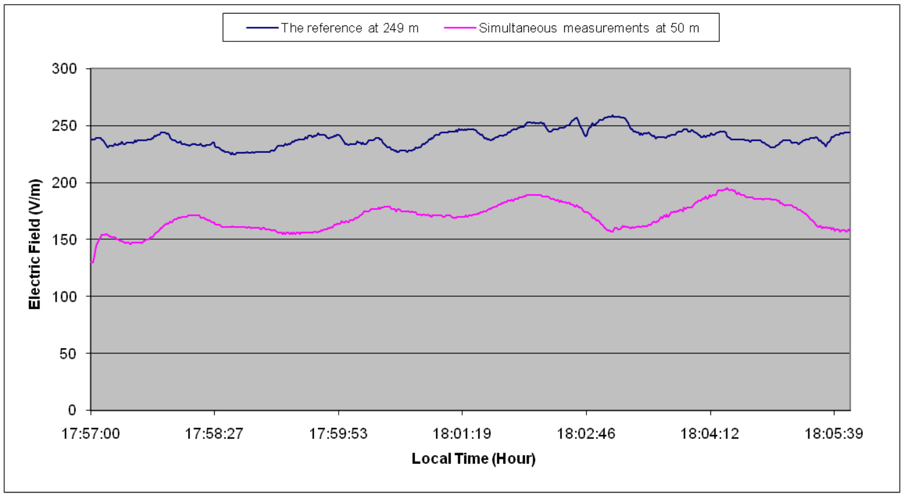

Figure 5: Simultaneously measured fields at distances of 249 m and 50 m from the GBT.

relatively smaller values were obtained at closer distance compared to the field measured at larger distance from the tower. This observation was possibly caused by a shadowing effect of the tower. The shadowing effect of the tower has also been observed in transient electric fields from lightning strikes to the GBT measured at very close distances [8].

4. CONCLUSION

In this paper, we present results of fair-weather electric field measurements during a campaign conducted at the Gaisberg Mountain in Austria at the end of June of 2010. By comparing the simultaneously measured electric fields from a reference field mill placed at the top of the mountain and the permanently installed field mill at the metal platform at a distance of about 170 m from the GBT, a field enhancement factor of 7.81 for the permanently installed field mill was determined. We also determined an enhancement factor of 2.75 due to the mountain itself with reference to the mountains surrounding terrain. A shadowing effect of the tower was observed when the electric field was measured at distances of up to about the tower height of 100 m compared to the reference field mill measured at a distance of 249 m from the tower.

ACKNOWLEDGMENT

The authors acknowledge the financial support received from the Swedish Research Council (VR Grant: 621-2005-5939), and the Swedish National Rail Administration (Banverket), Verbund (Contract 4500157745), the Austrian Science Fund (Project P17336-N07), Telekom Austria and Austrian Broadcasting Services (ORS). The authors also acknowledge the support of the European COST Action P-18 'Physics of Lightning Flash and its Effects'.

REFERENCES

1. Israelsson, S. and H. Tammet, "Variations of fair weather atmospheric electricity at Marsta Observatory, Sweden, 1993–1998," *J. Atmos. Sol. Terr. Phys.*, Vol. 63, No. 16, 1693–2003, 2001.
2. Guha, A., B. K. De, S. Gurubaran, S. S. De, and K. Jeeva, "First results of fair-weather atmospheric electricity measurements in northeast India," *J. Earth Syst. Sc.,* Vol. 119, No. 2, 221–228, 2010, Doi: 10.1007/s12040-010-0014-9.
3. Rubinstein, M., E. Montandon, and M. Ianoz, "Analysis of multi-station cloud lightning electric field pulses recorded with the swiss LPATS network," *Proceedings of 22nd International Conference on Lightning Protection*, Budapest, Hungary, 1994.
4. Bonyadi, R. S., R. Moini, S. H. H. Sadeghi, and A. Mahanfar, "The effects of tall buildings on the measurement of electromagnetic fields due to lightning return strokes," *Proceedings of 2001 IEEE EMC International Symposium*, Montreal, Canada, 2001.
5. Baba, Y. and V. A. Rakov, "Electromagnetic fields at the top of a tall building associated with nearby lightning return strokes," *IEEE Trans. Electromagn. Compat.*, Vol. 49, No. 3, 632–643, 2007.

6. Mosaddeghi, A., D. Pavanello, F. Rachidi, M. Rubinstein, and P. Zweiacker, "Effect of nearby buildings on electromagnetic fields from lightning," *Journal of Lightning Research,* Vol. 1, 52–60, 2009.
7. Diendorfer, G., H. Pichler, and M. Mair, "Some parameters of negative upward-initiated lightning to the gaisberg tower 2000–2007," *IEEE Trans. Electromagn. Compat.*, Vol. 51, No. 3, 443–452, 2009.
8. Mosaddeghi, A., A. Shoory, F. Rachidi, G. Diendorfer, H. Pichler, D. Pavanello, M. Rubinstein, P. Zweiacker, and M. Nyffeler, "Lightning electromagnetic fields at very close distances associated with lightning strikes to the Gaisberg tower," *J. Geophys. Res.*, Vol. 115, D17101, 2010, Doi: 10.1029/2009JD013754.