RESPONSE OF DIFFERENT TYPES OF LIGHTNING DETECTION SENSORS TO TOWER STRIKES IN AUSTRIA

G.Diendorfer[1], W.Schulz[1], M.Mair[2]
[1]OVE-ALDIS
[2]Techn. Univ. Vienna

1. INTRODUCTION

Lightning strikes to the instrumented Gaisberg tower are often detected by different types of sensors (IMPACT, IMPACT ESP, LPATS III, LPATS IV) that are installed in Central Europe as part of the EUCLID network. In this paper we present some preliminary results of an analysis of the response of the different sensor types to lightning discharges to the radio tower. During the period 01/2000 to 07/2002 we have successfully located 426 strokes to the tower with amplitudes in the range from -2 kA to -35 kA. For some of the strokes with higher peak currents reports from more than 30 sensors are available. The field propagation path from the tower site to the different sensors is mainly over flat terrain to the north and over mountains area to the south. This arrangement allows evaluating the effects of attenuation to the peak fields measured by the individual sensors.

2. STROKE DETECTION EFFICIENCY

To estimate the stroke DE we have summarized in Table 1 the number of strokes measured at the tower and located by the LLS as a function of minimum peak current. IDONE et al. (1998) observed a steadily drop of likelihood of detection with decreasing peak current. In our study a stroke DE of 97% is observed for strokes to the Gaisberg tower with peak amplitudes greater than 10 kA. Stroke DE reduces to 69% when all stokes with peak current amplitudes above 2 kA are included. We have to note, that in this analysis we do not distinguish between different types of stokes. The dataset includes current pulses superimposed on the initial continuing current (ICC) as well as current pulses following a time period of almost no current flow in the lightning channel. Some of the ICC current pulses do exceed the 2 kA limit but do not exhibit any fast rising front portion and therefore there is a small chance to detect those pulses from remotely measured fields.

Table 1: Stroke Detection Efficiency

Peak current measured at the tower	Number of strokes to the tower	Number of strokes detected by ALDIS	Stroke DE
> 10 kA	229	221	97%
> 8 kA	294	275	94%
> 6 kA	389	349	90%
> 4 kA	508	413	81%
-2 kA	614	426	69%

3. SENSORS PARTICIPATING IN THE LOCATION OF STROKES TO THE TOWER

Direct lightning current measurements started at the Gaisberg tower in 1998. Experimental setup at the Gaisberg tower and the Austrian lightning location system ALDIS is described in detail in DIENDORFER et al., 2000 and DIENDORFER et al., 1998, respectively. The lightning current is continuously digitized over a period of about 0,8 seconds. GPS time stamping of the current recording allows a precise correlation of the individual lightning current pulses and the stroke detection messages reported by the individual lightning location sensors installed in Austria and neighbouring European countries. In Table 2 some data of the sensors participating most frequently in the location of strokes to the tower are summarized. The closest sensor #1 at a distance of 31,5 km sent 334 sensor messages correlating with tower strikes. Obviously a wide range of sensitivity of the different sensor types exists. In a distance ranging up to about 300 km mainly IMPACT 141T type sensors are located and contribute well to the stroke locations.

It is interesting to note, that the LPATS IV sensor #64: Roermond in the Netherlands participated in a high number of stroke detections (143), although this sensor is at a distance of about 640 km. A comparable high detection efficiency over a large distance range is also observed for some other LPATS IV sensors in the regularly done performance evaluation of the EUCLID network.

Table 2. Sensors Participating Most Frequently In The Location Of Strokes To The Tower

Sensor Nr.	Country: Sitename	Sensor Type	Distance [km]	Number of Correlated Sensor Messages
1	A: Hitzging	141T	31,5	334
4	A:Niederoeblarn	141T	76,6	324
2	A:Schwaz	IMPACT ES	115,7	283
18	D:Muenchen	SeriesIII	117,8	308
5	A:Noetsch	141T	141,7	139
8	A:Dobersberg	IMPACT (ESP)*	204,3	207
7	A:Bad Voeslau	141T	235,8	93
6	A:Fuerstenfeld	141T	239,0	71
3	A:Hohenems	141T	260,7	53
13	D:Bayreuth	SeriesIV	264,4	299
21	D:Wuerzburg	SeriesIV	319,1	230
41	CZ:Mohelnice	SeriesIV	356,5	169
22	Karlsruhe	IMPACT ES	377,4	248
77	D:Erfurt	IMPACT ES	388,3	180
19	D:Freiburg	SeriesIV	393,6	221
25	D:Goerlitz	IMPACT ES	395,5	124
17	D:Kassel	SeriesIII	465,5	83
16	D:Braunschweig	SeriesIV	527,4	85
40	F:Metz	SeriesIII	529,4	68
64	NL:Roermond	SeriesIV	638,9	143
67	NL:DenHaag	SeriesIV	776,0	95
62	NL:Kollum	SeriesIV	783,4	71
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**NOTE: Sensor #8 was upgraded from a 141T to IMPACT ESP in 2001*

4. PEAK CURRENT ESTIMATES

Peak current estimates provided by the lightning location system are the average values taken from all sensors that contributed to the locating of the discharge. Although this average value is in good agreement with the measured peak current as shown in Fig.1, the peak current estimates provided by individual sensors are much more variable than the average. Main reasons for this variability are assumed to be the propagation effects and imperfect gain correction.

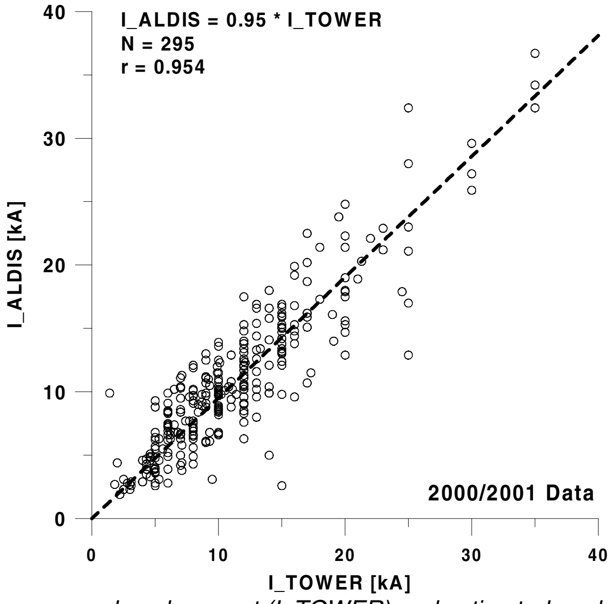

Fig. 1: Correlation between measured peak current (I_TOWER) and estimated peak current provided by the Austrian LLS ALDIS

NOTE: Absolute values of negative stroke peak currents are plotted

In Fig. 2 to Fig.13 for a selection of sensors we have plotted the ratio I_TOWER/I_DF (measured peak current I_TOWER divided by the individual sensor peak current I_DF). Ideally this ratio should be close to 1. A ratio of I_TOWER/I_DF < 1.0 means, that the peak current inferred from the sensor reported peak field is higher than the actually measured stroke current.

Comparison of Fig.2 and Fig.3 demonstrates the effect of field attenuation due to wave propagation over mountainous area. For sensor #1, where field propagation is mainly over flat area and over a distance of D=31,5 km, for a majority of correlated strokes the ratio I_TOWER/I_DF is in the range of 0,5 to 1,0. Therefore the peak current inferred from the signal report of sensor #1 typically overestimates the directly measured peak current. Contrary to sensor #1, the wave propagation path to sensor #2 at a distance of 115,6 km is mainly over high mountains. The calculated ratios are all greater than 1 and in a range up to 4 and above.

It is interesting to note, that all the shown LPATS type sensors (Fig.10, Fig.11 and Fig.12) have a tendency to overestimate the peak current, even at large distances.

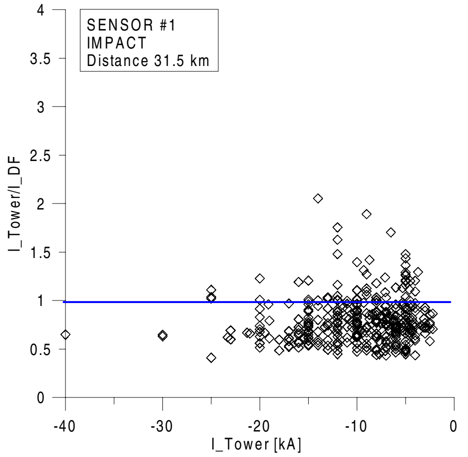

Fig. 2: Ratio I_TOWER/I_DF for sensor #1

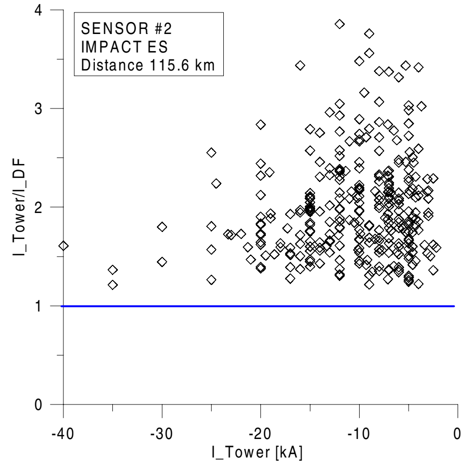

Fig. 3: Ratio I_TOWER/I_DF for sensor #2

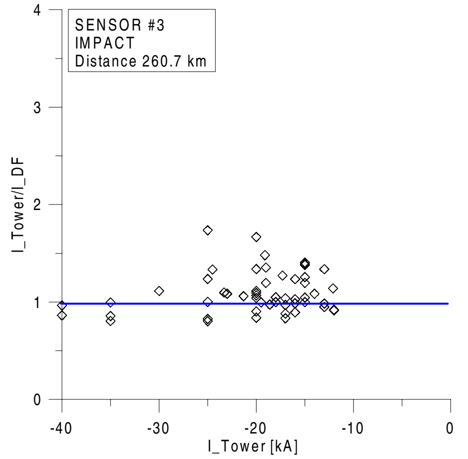

Fig. 4: Ratio I_TOWER/I_DF for sensor #3

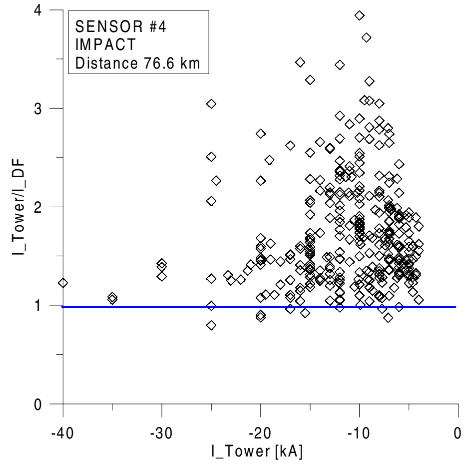

Fig. 5: Ratio I_TOWER/I_DF for sensor #4

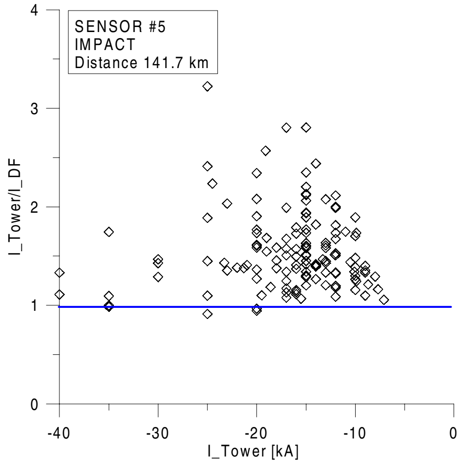

Fig. 6: Ratio I_TOWER/I_DF for sensor #5

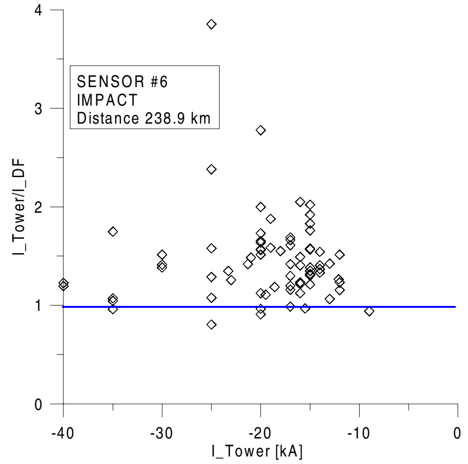

Fig. 7: Ratio I_TOWER/I_DF for sensor #6

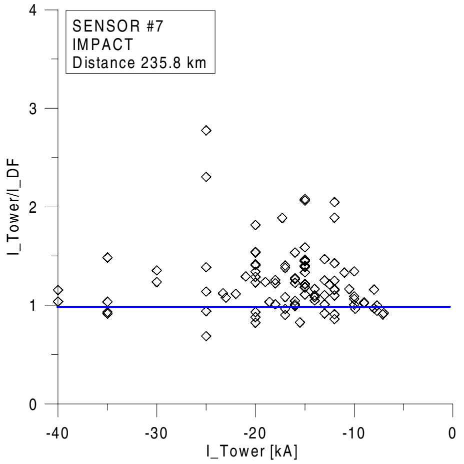

Fig. 8: Ratio I_TOWER/I_DF for sensor #7

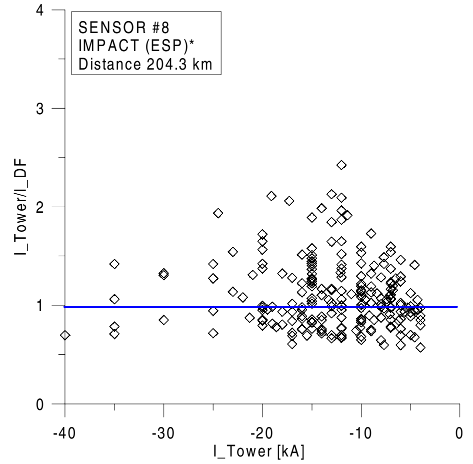

Fig. 9: Ratio I_TOWER/I_DF for sensor #8

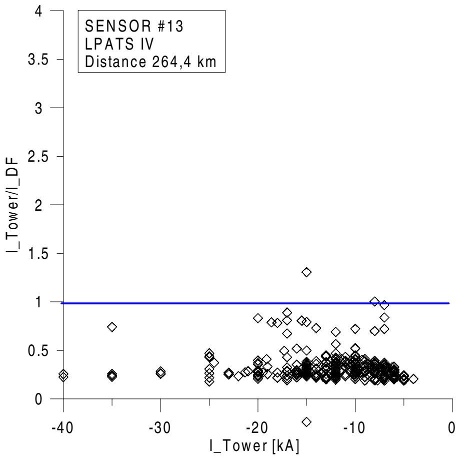

Fig. 10: Ratio I_TOWER/I_DF for sensor #13

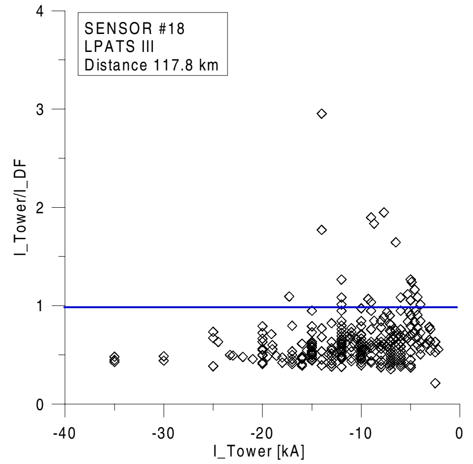

Fig. 11: Ratio I_TOWER/I_DF for sensor #18

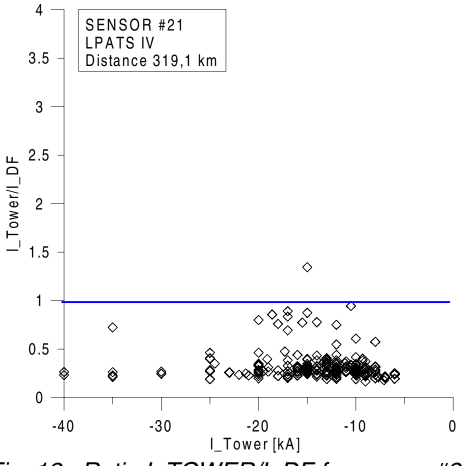

Fig. 12: Ratio I_TOWER/I_DF for sensor #21

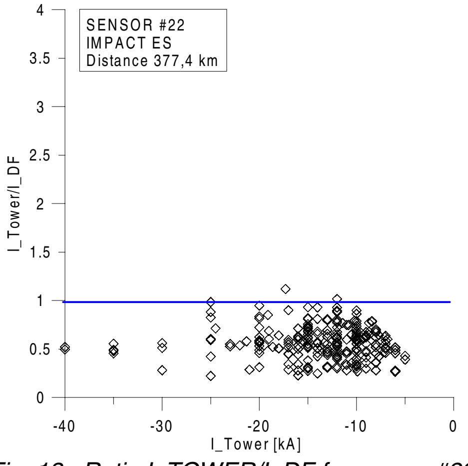

Fig. 13: Ratio I_TOWER/I_DF for sensor #22

5. ANGLE MEASUREMENT BY IMPACT SENSORS

For strokes to the tower at a fixed position a particular sensor should report the same angle of field incidence all the time. In Fig.14 and Fig.15 we have plotted the histograms of the angles reported by sensor #1 and sensor #2, respectively. For the nearby sensor #1 we determined a mean of 169,07° with a standard deviation of 0,8°, which is in the range of expected values for the standard deviation. For the more distant sensor #2 with field propagation over the mountains, the estimated standard deviation of 3,1° is much larger than for sensor #1.

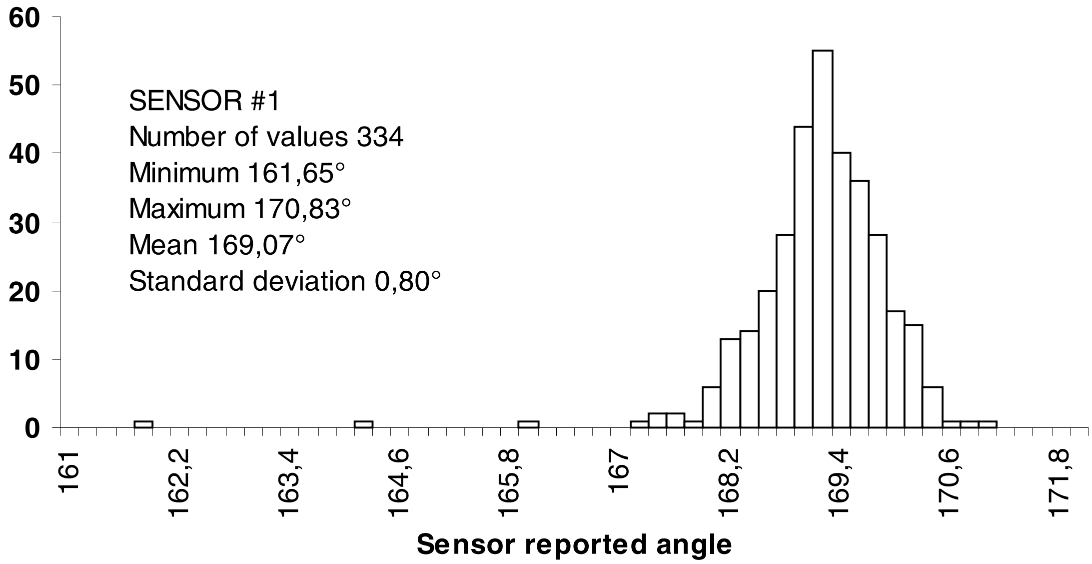

Fig.14: Histogram of reported angles by sensor #1 (D=31,5 km)

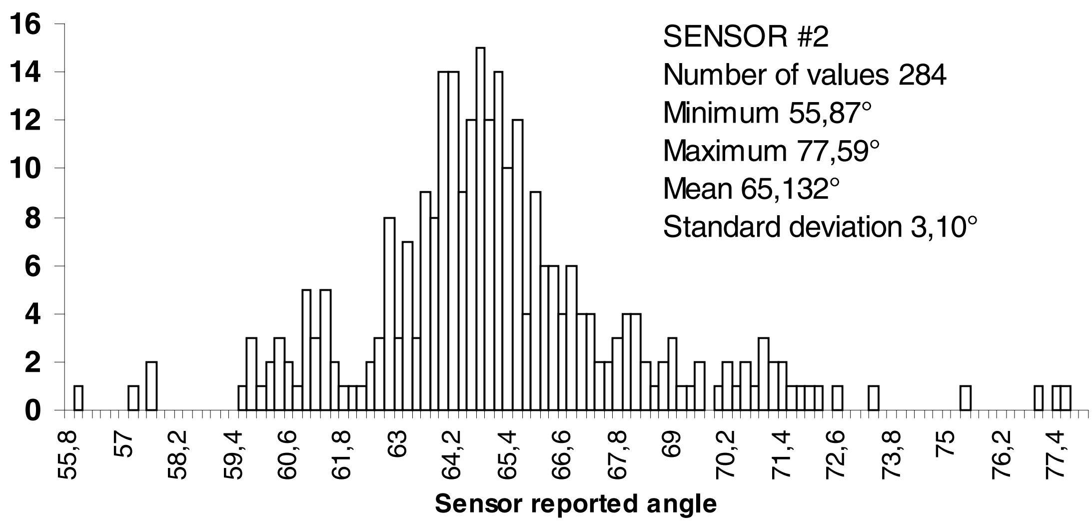

Fig.15: Histogram of reported angles by sensor #2 (D=115,6 km)

6. DISCUSSION AND CONCLUSION

Using the frequently occurring strokes to the Gaisberg tower as a ground truth reference it is possible to evaluate the response of the different sensor types in terms of location accuracy, detection efficiency and peak current estimation. In this preliminary study we could show, that the performance of individual sensors either of the same type or of a different type (LPATS or IMPACT) is quite different. Field attenuation due to propagation as well as sensor technology are assumed to be the two major parameters that determine the actual sensor performance.

LPATS IV sensors seem to have a higher sensitivity in detecting strokes to the tower than the IMPACT 141T sensors installed in Austria. IMPACT 141T sensors at distances of about 250 km (#6, #7 and #3) participated in detection of less than 100 strokes, whereas LPATS IV and IMPACT ES sensors at distances of about 700 km show a similar detection efficiency.

Although the peak current estimate of the LLS as a medium value of all reporting sensors is close to the measured peak currents, the individual sensor currents show a large variability. This explains the large differences in a direct comparison of individual stroke amplitudes.

Evaluation of the angle reports of sensor #2 (Schwaz) revealed a standard deviation of more than 3°. At the moment it is unclear whether this high standard deviation is the result of local noise at the sensor site or it is a result of wave propagation over the poor conducting mountainous area.

7. ACKNOWLEDGEMENTS

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