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Measurements of Surge Currents and Potentials in a Radio Base Station for Estimation of Lightning Threat

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Introduction

Effective protection of objects and their contents against direct lightning strikes requires estimation of lightning threat. For this purpose various experimental and numerical methods have been used [1]. However, due to complex nature of the phenomena none of these methods is fully capable to perform the task, which hence can be studied only partly.

One of the methods used to study lightning effects on structures and systems consists of a simulation of lightning strike by injecting a surge current from the generator attached to the structure [2–4]. The most serious technical limitations of this method are lower peak values and different waveforms of surge currents attainable in practice with regard to the natural lightning phenomena and influence of the surge generator simulation circuit [1].

The method was used in the presented work in order to estimate the performance of a base station subjected to surge current flows. The knowledge gained as a result of this investigation will be the basis for analysis of the performance of the station affected by natural lightning using different methods [5, 6], e.g. numerical.

This approach was used so far by the authors [5, 7]. However, basically only surge currents at various elements of bonding system and construction were measured. Presently, to complete the information about the station properties, potentials with respect to remote ground have been measured as well. Such methodology has been tested so far in a large telecommunication centre [8].

Some example results of the on-site measurements in the considered base station have been presented in [9]. In this work the complementary results are presented.

Methodology

The measurements were carried out in a typical freestanding radio cellular base station with a 50 m high communication tower and a small container nearby. On the station site outdoor equipment was also located. This equipment was standing on a metallic platform beside the tower. The overall view and of the base station and its main elements are presented at the photographs in Fig. 1 and 2.

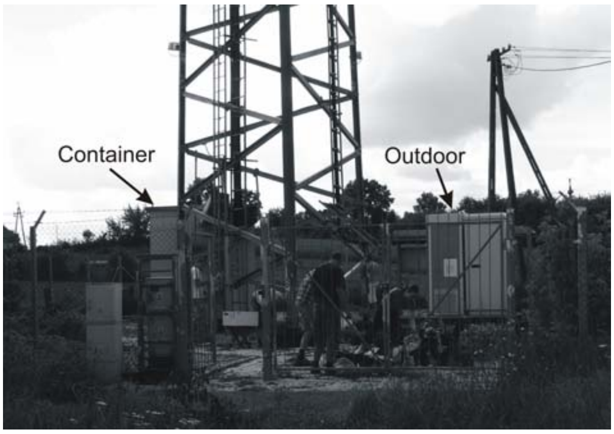


Fig. 1. Overall view of the radio base station

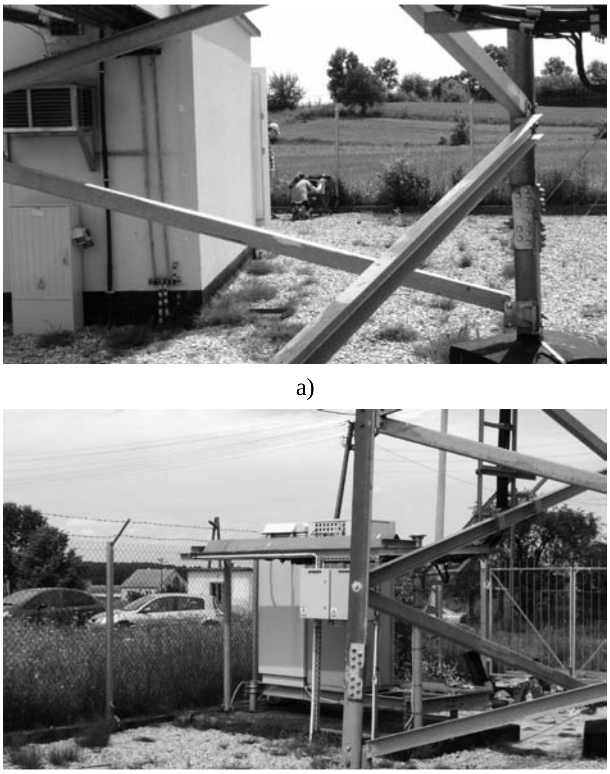
Surge currents were generated with UCS 500-M surge generator, which is capable to produce:

- surge voltage: from 250 V to 6600 V peak value and 1.2/50 μs waveform at the open circuit;
- surge current: from 125 A to 3300 A peak value and 8/20 μs waveform at the short circuit.

During the experiment the surge generator was located on isolated wooden table on the ground near the tower.

The HV (high voltage) terminal of the generator was attached via a long insulated wire to the equipotential bonding bar at the tower top. It should be mentioned here that this bonding bar is normally connected to the tower construction and, using a separate long conductor, to the earthing terminal at the tower base, which is grounded near the tower inspection ladder.

The other (COM) terminal of the surge generator was connected, using 4 long insulated return wires, to 4 auxiliary vertical ground electrodes buried at some distance (10-20 m) behind the station fence (Fig. 3).



a)

b)

Fig. 2. View of the container (a) and the outdoor equipment (b) of the radio base station

The surge current produced by the generator flowed from the generator HV terminal to the tower top, then, through the tower construction, the LPS (Lightning Protection System), the equipotential bonding system and the earthed cable installations to the grounding system. Next, the current was distributed in the soil structure and collected by the auxiliary electrodes. Finally, it was directed back to the surge generator (COM terminal) via the return wires.

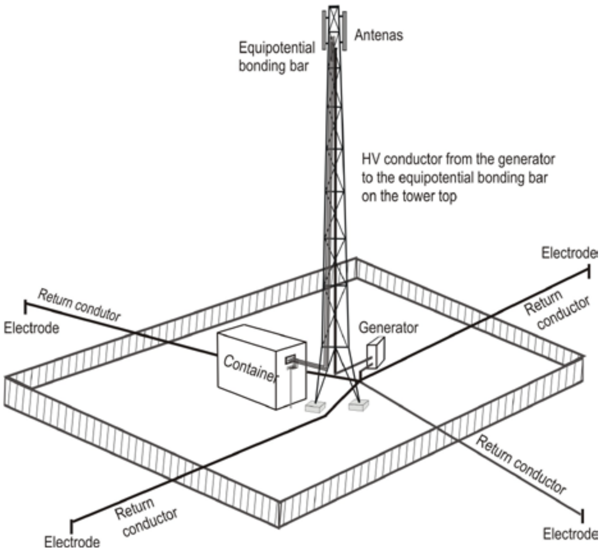


Fig. 3. Plan of the generator arrangement during the measurements in a radio base station [9]

The measurements of potentials with respect to remote ground required an additional artificial auxiliary ground located appropriately far from the station. This auxiliary ground was provided in a few hundred meters distance from the station. It was realized using 4 vertical electrodes inscribed in 1 x 1 m square. The electrodes were buried at 0.5 m depth and linked together above the earth surface.

Surge currents and potentials with respect to the auxiliary ground at various places in the equipotential bonding system, construction and cable installations outside and inside the container were measured. The following measuring equipment was used:

- a clamp-on current probe of 20 MHz bandwidth and 500 A range (peak);
- a high voltage probe of 100 MHz bandwidth and 4000 V range.

The measured currents and voltages were registered using digital oscilloscopes, which have the possibilities of saving the data on a hard drive or a floppy disc.

During the measurements, the surge generator as well as the measuring equipment was supplied from a separated power supply system based on a petrol generator. The surge generator was supplied from the petrol generator directly and the measuring equipment - through an isolating transformer.

Some example of measurement process is presented at the photograph in Fig. 4.

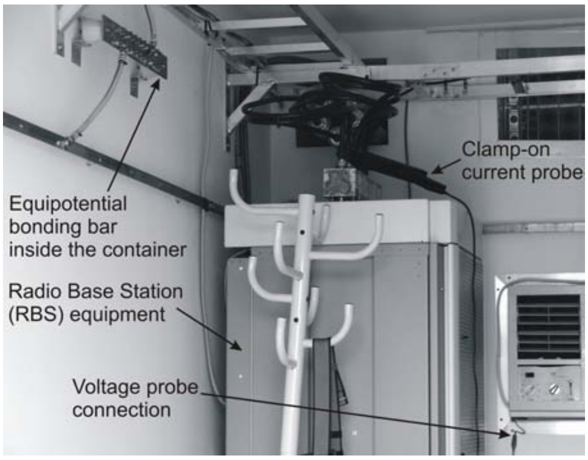


Fig. 4. Measurements of surge current in the antenna cable and potential of the air-conditioning unit

The measurements were not performed simultaneously in all the considered locations but successively for different surges produced by the generator. However, each particular surge current and voltage produced at the generator terminals in every successive case was measured and proved to be the same.

Results

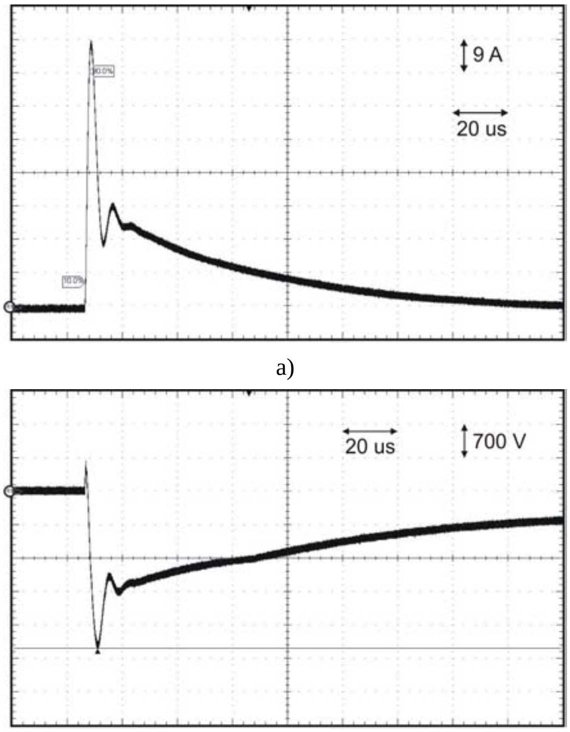
Currents and potentials with respect to the auxiliary ground at various locations at the station were registered during the experiment. These locations comprised:

- The HV and 4 return conductors of the generator;
- Ground conductors of particular installation and construction elements, i.e. the conductors which link these elements directly with buried earth electrodes;
- Earthing conductors of particular station equipment and

cable systems, i.e. the conductors which link these elements to the earthing terminals;

- Bonding conductors of particular construction elements i.e. the conductors which link these elements with the equipotential bonding system.

The total surge current produced by the generator and the potential of the generator HV terminal with respect to the auxiliary ground are presented in Fig. 5 [9].



a)

b)

Fig. 5. Waveforms of the total surge current (a) and the potential of the generator HV terminal (b)

The charge voltage of the generator storage capacitor was set to 5 kV. The peak values of the corresponding total surge current and the generator HV potential are 72 A and 3.3 kV respectively (Fig. 5).

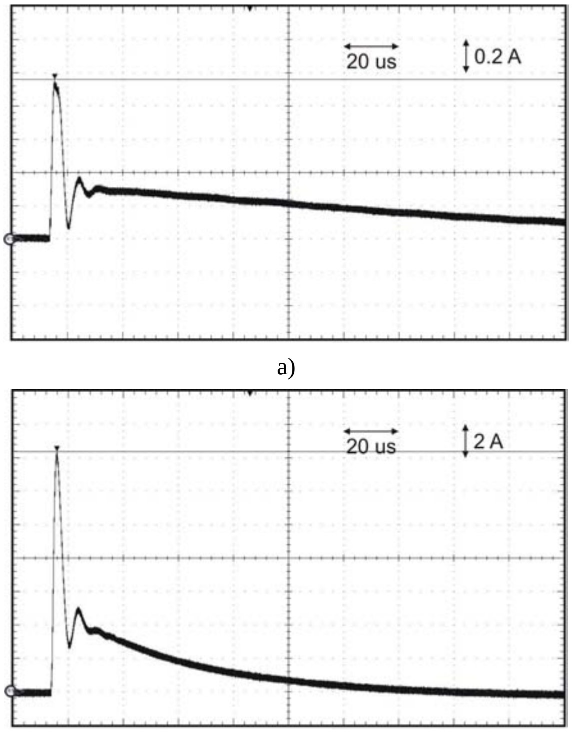
The characteristic feature of the total surge current and potential presented in Fig. 5 is that the potential has a waveform very similar to the current waveform.

The currents and potentials registered at the ground conductors of particular tower legs are presented in Fig. 6 and 7.

The results presented in Fig. 6 suggest that the surge current waveform might be different depending on the measurement location. However the difference is seen at the back of the impulses, not at their front.

On the other hand, the waveforms of surge potentials, apart from the generator HV terminal (Fig. 5 b), are similar to one another. They have a form of damped oscillations of around 120-140 kHz frequency, what is related to the front of the surge current impulse.

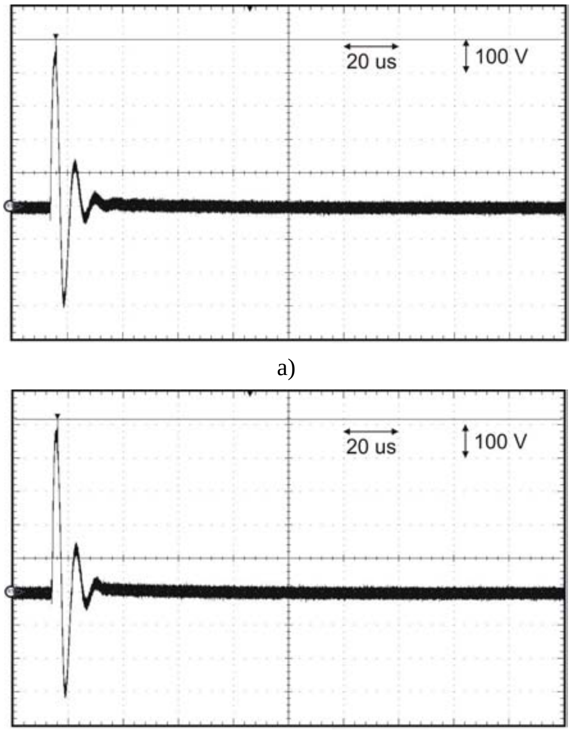
These waveforms are limited to the time range specific to the front oscillations in the surge current waveforms. The reason is that the measurements were carried out at earthed conductors or construction elements and so the distance from the measurement place to the auxiliary ground across the soil structure was too small to produce a significant voltage drop for relatively low frequency components. Hence, the potential waveforms show only components of higher frequencies.



a)

b)

Fig. 6. Surge currents registered in the ground conductors of tower legs no: a) 1; b) 3; farther from the outdoor platform



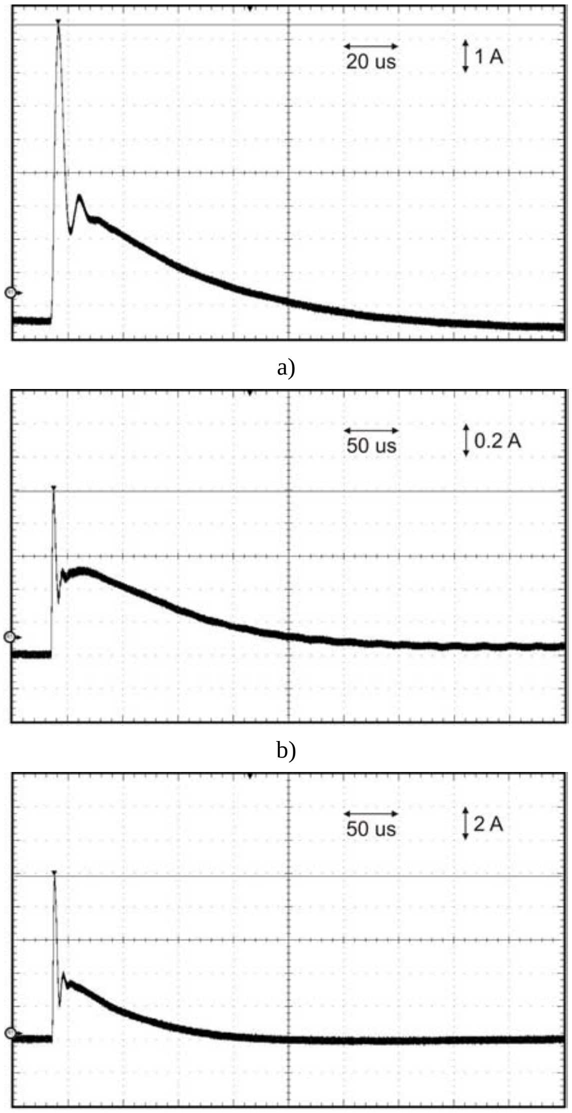
a)

b)

Fig. 7. Potentials of the ground conductors of the tower legs no 1 (a) and no 3 (b), farther from the outdoor platform

Some more examples of the surge currents registered outside and inside the container are presented in Fig. 8,

Fig. 9 and Fig. 10. Since the waveforms of all the potentials registered at the earthed conductors or construction elements were similar to the presented in Fig. 7, they are omitted here.



a)

b)

c)

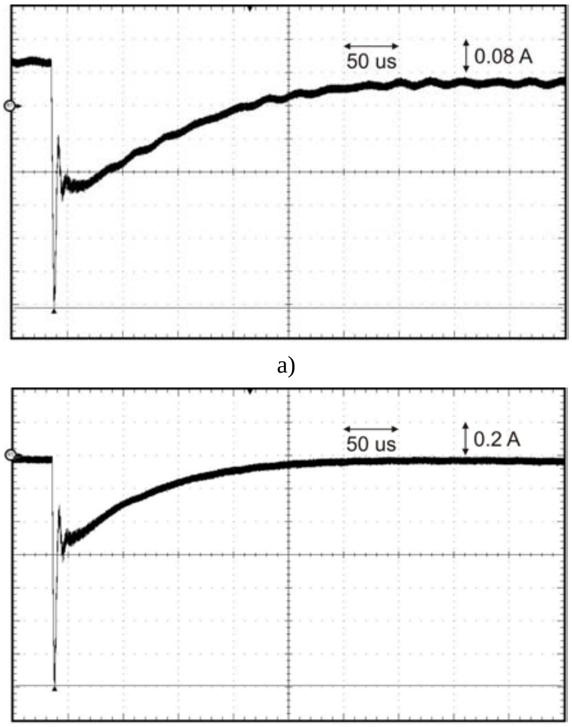
Fig. 8. Surge currents that flowed in the ground conductors of: a) the outdoor equipment; b) the comprehensive earthing terminal below the antenna cable passage to the container (conductor No. 1 out of 2); c) the main earthing terminal

Some of the currents registered inside the container or at the cable passage to the container have oscillations of about 30 kHz frequency (Fig. 9 a, Fig. 10), which is the result of normal operation of the station equipment.

The summary of the peak values of the registered currents and potentials are presented in Tables 1 and 2 respectively [9]. Some of the peak currents presented in Table 1 is negative, indicating that the current was diverted with regard to the direction indicated in the description of the measurement place [10-12].

The peak values of currents observed in ground conductors that link the station construction and installation elements directly to earth electrodes are around 1-20 % of the total surge current.

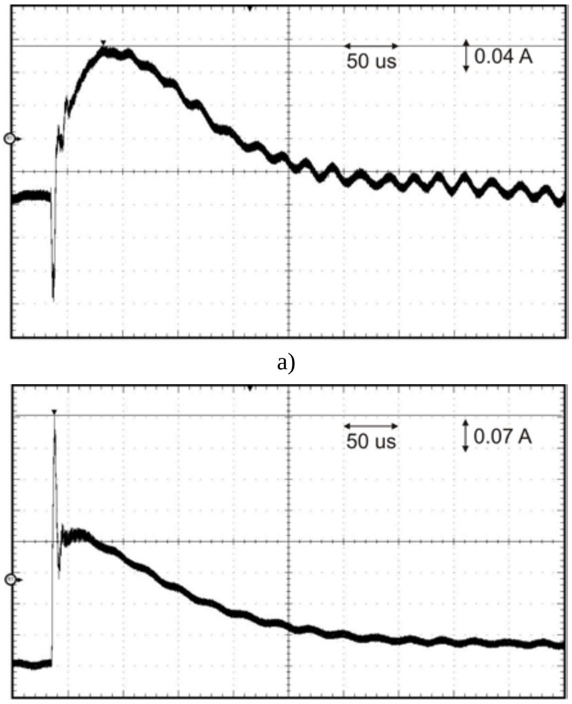
The currents flowing in bonding or earthing conductors outside and inside the container are up to 4 % and 0.8 % of the total surge current respectively.



a)

b)

Fig. 9. Surge currents that flowed at the antenna cable passage to the container in: a) the bonding conductor from the bonding bar inside the container to the antenna cable earthing terminal; b) the earthing conductor of the antenna cable No. 1



a)

b)

Fig. 10. Surge currents that flowed inside the container in the bonding conductors: a) from the cable ladder to the bonding ring (connection 1 out of 4); b) from the equipotential bonding bar inside the container (Fig. 4) to the bonding ring

Table 1. Peak values of measured currents [9]

Measurement place / conductor	Current (A)
Surge generator	
Generator HV conductor (total surge current)	72.1
Generator return conductor no 1	13.7
Generator return conductor no 2	18.5
Generator return conductor no 3	17.8
Generator return conductor no 4	26.4
Outside the container – around the tower	
Ground conductors of the tower leg no 1 (connections of tower leg to ring earth electrodes)	0.96
Ground conductors of the tower leg no 2	3.3
Ground conductors of the tower leg no 3	14.3
Ground conductor of the tower inspection ladder	3.8
Outside the container – near the outdoor equipment	
Ground conductor of the outdoor equipment	8.8
Ground conductor of the outdoor cable ladder	7.4
Outside the container – near the external antenna cable earthing terminal at the cable passage to the container	
Ground conductor no 1 of the comprehensive earthing terminal below the antenna cable passage	1.0
Ground conductor no 2 of the comprehensive earthing terminal below the antenna cable passage	0.77
Bonding conductor of the container reinforcement connected to the comprehensive earthing terminal	3.1
Earthing conductor of the antenna cable no 1	–1.4
Earthing conductor of the antenna cable no 2	–0.7
Bonding conductor that connects the antenna cable ladder to the antenna cable earthing terminal	2.2
Outside the container – near the door to the container, on the wall opposite to the antenna cable passage	
Bonding conductor of the door embrasure	–2.8
Ground conductor of the main earthing terminal	9.8
Inside the container	
Earthing conductor of the Radio Base Station (RBS) equipment	0.37
Equipotential bonding ring connection to the main earthing terminal	0.1/–0.3
Earthing conductor of the radio-line equipment connected to the bonding ring	0.4
Bonding conductors of the cable ladder to the bonding ring	from –0.1 to –0.49
Antenna cable no 1 to the RBS equipment chassis	–0.13
Bonding conductor from the equipotential bonding bar inside the container to the bonding ring	0.56
Grounding connection of the station fence	0.27

The peak values of potentials of those construction or installation elements, which are located inside the container or outside but at the side opposite to the tower (near the main earthing terminal), are around a few percent higher than those located at the other places.

Table 2. Peak values of measured potentials with respect to the auxiliary ground [9]

Measurement place / conductor	Potential (V)
Surge generator	
Generator HV conductor	3300
Outside the container – around the tower	
Ground conductors of the tower leg no 1 (connections of tower leg to ring earth electrodes)	500
Ground conductors of the tower leg no 2	516
Ground conductors of the tower leg no 3	516
Ground conductor of the tower inspection ladder	512
Outside the container – near the outdoor equipment	
Ground conductor of the outdoor equipment	500
Ground conductor of the outdoor cable ladder	516
Outside the container – near the external antenna cable earthing terminal at the cable passage to the container	
Ground conductor no 1 of the comprehensive earthing terminal below the antenna cable passage	502
Ground conductor no 2 of the comprehensive earthing terminal below the antenna cable passage	496
Bonding conductor of the container reinforcement connected to the comprehensive earthing terminal	504
Earthing conductor of the antenna cable no 1	505
Earthing conductor of the antenna cable no 2	502
Bonding conductor that connects the antenna cable ladder to the antenna cable earthing terminal	496
Outside the container – near the door to the container, on the wall opposite to the antenna cable passage	
Bonding conductor of the door embrasure	520
Ground conductor of the main earthing terminal	516
Metallic stairs grating	517
Bonding ring around the station fence	533
Inside the container	
DC power plant chassis	520
Earthing terminal of the DC power plant	522
DC power plant chassis inside	513
Equipotential bonding ring connection to the main earthing terminal	516
Earthing conductor of the radio-line equipment connected to the bonding ring	532
Bonding conductors of the cable ladder to the bonding ring	521 - 542
Earthing conductor of the air-conditioner	525
Antenna cable no 1 to the RBS equipment chassis	520
Antenna cable no 2 to the RBS equipment chassis	532
Bonding conductor from the equipotential bonding bar inside the container to the bonding ring	530
Grounding connection of the station fence	520

Conclusions

The on-site method of simulation of direct lightning strike to typical radio base stations using a surge generator and simultaneous measurements of surge currents has been already tested by the authors [1, 5].

In the present work the methodology was developed with combined measurements of surge current flows and potentials with respect to remote ground. This allows for completing the information about the radio base station surge performance and, in consequence, for better accuracy of further analyses.

Concerning typical radio base stations, this methodology has been used in one base station only. The paper presents some examples of waveforms out of all the registered currents and potentials. The complementary results of the experiment are presented in [9].

The results obtained with the presented methodology will provide the basis for verification of numerical models used for calculations of lightning threat or for analysis of the performance of various lightning protection measures in cellular radio base stations.

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R. Markowska, J. Wiater, A. Sowa. Measurements of Surge Currents and Potentials in a Radio Base Station for Estimation of Lightning Threat // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 1(107). – P. 93–98.

The paper presents a methodology and example results of on-site measurements of surge current flows and potentials in a radio base station. The basic idea of the method is to simulate a lightning strike to the base station tower using a surge generator and to measure surge current flows and potentials with respect to remote ground at various elements of the station. The aim of the experiment was to provide complex information on the performance of a radio base station affected by surge currents. This information will be used in further theoretical analysis of lightning threat for testing and verification of numerical models and/or for analysis of various lightning protection measures. Ill. 10, bibl. 12, tabl. 2 (in English; abstracts in English and Lithuanian).

R. Markowska, J. Wiater, A. Sowa. Žaibo išlydžio sukurtų srovių ir įtampų matavimas ir vertinimas radijo ryšio stotyse // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 1(107). – P. 93–98.

Straipsnyje pateikta radijo ryšio stotyje žaibo išlydžio sukurtų srovių ir įtampų matavimo metodika ir praktiniai rezultatai. Pagrindinė pasiūlytos metodikos idėja yra matuoti, prie ryšio bokšto prijungto aukštosios įtampos generatoriaus, įvairiuose radijo ryšio stoties elementuose indukuotas įtampas ir sroves. Atlikto eksperimento tikslas – pateikti įvairiapusę informaciją apie elektromagnetinius vyksmus stoties įrangoje išlydžio metu. Eksperimente gauti rezultatai bus panaudoti tolesniuose teoriniuose tyrimuose, matematiniams modeliams tikrinti, apsaugos nuo viršįtampių tyrimuose. Il. 10, bibl. 12, lent. 2 (anglų kalba; santraukos anglų ir lietuvių k.).

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