Surge Current Distributions in Base Station of Mobile Communication System

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Abstract: The paper presents selected results of on-site measurements of surge currents in a typical base station for mobile communication. The station consists of a communication tower and a small container with electronic equipment. The aim of these investigations was to determine surge current distributions in conducting parts of the tower structure and the equipotential bonding configurations during simulated lightning stroke into the top of the communication tower. Effects of different surge current shapes as well as grounding conditions have been taken into account.

Keywords: Surge Current Distribution, Lightning Protection, Global System for Mobile Communication

Introduction

Specific construction features of radio communication stations (i.e. usage of high communication towers) and their topographical location (mostly at an open area or at hills) are the reasons, that such objects are one of the preferential points for direct lightning strikes. In most cases, serious lightning failures in radio communication stations are caused by direct lightning stroke either to a power line near the station or to a communication tower or mast.

In case of stroke into a tower effects are twofold. Large currents flow through conducting parts of a whole structure and an associated grounding system and create high voltage differences between conductive elements. These voltage differences cause a serious danger, particularly for equipment connected to the grounding system. Some parts of lightning current may flow directly through cabling systems into radio-transmission equipment. Secondly, the lightning current creates strong electromagnetic pulses, which induce large overvoltages and overcurrents in wires of electric and electronic systems. Therefore, ensuring proper paths of sufficiently low impedance [5] for surge currents is an essential point for lightning protection and safety work in radio communication stations.

During the investigations, a direct lightning stroke into the tower was simulated by means of an external surge generator with one terminal connected to the top of the tower and the other terminal to four points around the station. The aim of these measurements was to provide knowledge for surge current distributions in various parts in the station taking into account also soil conditions.

Base station of mobile communication system

According to many standards and recommendations on lightning protection, there are mainly two types of bonding configurations for telecommunication stations [1, 2, 3, 4] to be considered. A mesh bonding configuration consists of ring conductors along inside perimeter of a building (on each floor) and several vertical down conductors outside; linking these ring conductors and a ring earth electrode of the building together. The second configuration is a star configuration, where all the telecommunication system components are isolated, sharing one single point connection to an earthing system through main earthing terminal. In freestanding base stations for mobile communication, such as considered in this case, generally the star bonding configuration is applied.

Measurement test set-up

During the investigations, one terminal of the test surge generator was connected nearly to the top of the tower (about 45m above ground) by means of an antenna grounding conductor (see Fig. 2). This conductor is insulated and normally connected to the antennas and to the earthing system as well as to the tower structure at the top and bottom. For the test purposes, this conductor was discon-
nected from the earthing system and the tower structure at the bot-
tom and was connected to one terminal of the surge generator.

![Antenna grounding down conductor](image)

Figure 2. Connecting the surge generator to the tower

Four separate return conductors (insulated copper – 10mm²) of the
same length were used to connect the other terminal of the surge
generator to four points around the station. Two scenarios were
considered for connecting the return conductors to the station:

1. the return conductors were connected to the station fence at
four points, where the fence was connected to the earthing sys-
tem (like in Fig. 4);

2. the return conductors were connected to four steel rods (75cm
long, 1cm diameter) driven into the ground in some distance
behind the station fence (like in Fig. 7).

The measurements for scenario (1), in which the current distribu-
tions in the soil were not taken into account, were performed in
order to provide a comparison for scenario (2) and to help ensuring
a possibly equal distribution of currents in the soil.

This measurement test set-up represents only an approximation for
simulation of direct lightning stroke to antenna or to tower. Par-
ticularly, when induced effects with surges of fast front times need be
investigated, influence of the test circuit might be significant. The
test set-up however, can be considered to be sufficient to determine
the general paths for surge currents in various parts of the station
and it is useful for further verifications with numerical models
where the influence of the test circuit can be easily determined.

Two different waveforms of the test current surge with approxi-
mately double-exponential shape were used:

- 8/50µs with amplitude of 83.7A – for scenario (1);
- 1.2/50µs with amplitude of 22.5A – for scenario (2).

The measurements were performed by means of wideband impulse
current probes and the data were registered by an oscilloscope con-
ected to a notebook. The overall bandwidth was 100MHz. Fig. 3
shows the measurement equipment. It should be pointed out that
during the measurements the station was fully equipped and in
operation.

For the purposes of further numerical modelling, the soil resistivity
was also measured. It amounted to about 1600Ωm.

**Measurement results for scenario (1)**

The measurements were performed outside and inside the container
in three stages. In the first stage, surge currents in the generator
conductors and in the tower legs (at the bottom of the tower) were
measured. The second stage contained measurements of currents in
the equipotential bonding configuration at a location where the
communication cables from the tower enter the container. Finally,
the last stage comprised measurements of currents in the equipo-
tential bonding system inside the container.

The measurement results for scenario (1) and for surge current
approximately 8/50µs with amplitude of 83.7A are schematically
indicated in Fig. 4. The results are valid for peak values of surge
currents in the generator conductors and the tower legs. Some re-
sults for scenario (1) for different current shape were previously
published [6].

![Figure 4. Test circuit layout and peak values of measured surge
currents for scenario (1)](image)

The resultant sum of currents from the generator return conductors
shows some inconformity with regard to the entire current injected
into the tower which might be due to capacitive coupling in the
surge generator. This however, influences only the peak values of
the surge currents not the general current distribution around the
station, which is of major importance for these studies.

It is seen from the Fig. 4 that the obtained current distributions are,
in general very unequal. In particular, the current that is drained off
to the earthing system by one leg of the tower is from 11 to 26% of
the total current from the generator return conductors. The entire
current from the three tower legs amounts to about 52% of the total
current. The rest of this current flows through the middle support-
ing leg and the grounding down conductors at the entry to the con-
tainer and from inside of the container (see Fig. 5 and 6).

![Figure 5. Peak values of measured surge currents in equipoten-
tial bonding configuration at the entry to the container](image)
Figure 6. Peak values of measured surge currents in equipotential bonding configuration in the container

Fig. 5 shows the surge current distribution in the equipotential bonding configuration at the entry of the communication cables to the container. The current drained off to the earthing system in this place is much lower than that in individual tower legs, but is still significant. From Fig. 6 it is seen that the total current that flows to the earthing electrode from the container (9.5A) is comparable to the currents in individual tower legs. This current is a sum of currents resulting mainly from earthing conductors of the exchange equipment and the equipotential bonding strap. A relatively large value of peak current from the power supply corresponds with the time moment several tens of µs after the main impulse and might result from supplying conditions of the base station due to particular grounding conditions of the base station and the transformer station in some distance away.

Measurement results for scenario (2)

In case of scenario (2), the current returned to the generator through the ground. In this case the current surge with faster front time was applied – 1.2/50µs and amplitude of 22.5A.

As for scenario (1), in the first stage the general surge current distribution in the station was determined. The test circuit layout for scenario (2) together with the measurement results is shown in Fig. 7. The indicated results represent peak values of surge currents in the generator conductors and in the tower legs measured at the bottom of the tower.

The capacitive coupling in the surge generator is larger due to faster front time of the current. In comparison with scenario (1), a more equal current distribution between the tower legs was achieved. The currents in individual tower legs are from 13 to 15% of the total current from the generator return conductors. The entire current drained off to the ground by the three tower legs is however relatively small (only 43% of the total current). This means that more current flows through other paths (the middle supporting leg and the grounding down conductors). The time domain surge currents in the generator return conductors and in the three tower legs measured at the bottom of the tower are presented in Fig. 8.

To prevent parts of lightning current from flowing into the container through the communication cables shields or armouring, a good grounding of these shields or armouring at the entry to the container is necessary. Some results of measurements in the bonding configuration at the entry to the container are shown in Fig. 9. As it was indicated above, there were six antenna cables entering the container. The figure presents the peak value of the current in the earthing conductor for only one antenna cable (0.34A). It should be noted that the total current drained off to the earthing system in this place (1.37A) is relatively large with respect to the currents in individual tower legs.

Fig. 10 presents an example of the time domain surge current in antenna cable earthing conductor. The character of the current that flows into the ground from the earthing terminal is similar.
A summary of measurement results in the equipotential bonding system of the container is shown in Fig. 11. As for scenario (1), large currents have been obtained in earthing conductors of the exchange equipment and equipotential bonding strap (7 and 5% of the total current from the generator return conductors respectively). The entire current that flows to the ground from the earthing terminal is as large as the current in individual tower leg.

During the measurements of surge currents in bonding configurations very different shapes of currents have been obtained. See for example the currents in earthing conductors of the exchange equipment, the equipotential bonding strap (Fig. 12) and the power supply (Fig. 13). The shapes, that reach their maximum values at different time moments, might be due to flows of currents and current wave reflections in the supplying transformer station at some distance away from the base station (regarding particular grounding conditions of the base station and the transformer station).

The entire current that flows to the ground from the main earthing terminal of the container is of a double exponential shape. Fig. 14 presents the comparison of the measured time domain surge current in the grounding conductor from the main earthing terminal in the container and the current obtained by the sum of the digital data recorded in all the earthing conductors that are connected to this earthing terminal. Both the curves show very good agreement.

**Conclusions**

Surge currents in conductive elements of a typical base station for mobile communication system have been measured for two different scenarios. In scenario (1), the generator return conductors were connected to the station fence and in scenario (2) they were connected to four steel rods driven into the ground in some distance behind the station fence.

In general, the currents drained off to the ground by every individual tower legs were relatively small, especially for scenario (2) – about 14% of the total current. Also the currents distribution among the three legs was much equal for this scenario.

The entire current from the container measured in the grounding conductor of the main earthing terminal for scenario (2) was significant and nearly as large as in every individual tower leg. This current was a sum of currents resulting mainly from earthing conductors of the exchange equipment and the equipotential bonding strap.

The entire current from the three tower legs and the two grounding conductors of the container was lower for scenario (2). That might mean that more current flew through other paths, probably the middle supporting leg of the tower.

**References**


**Biographical notes**

Renata Markowska received the M.Sc. degree in Electronics Engineering from Białystok Technical University in 1997. Since 1998 she has been with Białystok Technical University. She is working in the area of electromagnetic compatibility, particularly lightning protection in radio communication and industrial objects.