EMC of cellular phones and electronic equipment

Snežana Lj. Stefanovski and Antonije R. Đorđević

Content – **In this paper, we consider the influence of electromagnetic field of cellular phones and base stations on the operation of electronic and electrical equipment. Minimal distances from these transmitters where the electric field does not exceed 1, 3 and 10 V/m are established. The response of an audio amplifier to interference from cellular phones is also analysed.**

Keywords – **cellular phones, electromagnetic compatibility.**

I. Introduction

SINCE the cellular phones entered our environment, we have mostly considered the influence of base stations and cellular phones on human health. Unwarrantably, the unwanted action of these devices on other electronic and electrical equipment in their vicinity has been neglected. The permitted level of the electric field for people is 27.45 V/m according to the standard JUS N.N0.205 (from 30 MHz to 300 GHz), whereas the electronic equipment is expected to be immune only to considerably lower electric fields. This discrepancy of field levels calls for closer attention and analysis.

The idea of this paper is to establish minimal distances from antennas of base stations and from cellular phones where the intensity of the electric field is sufficiently small so that disturbances in the operation of electronic equipment are not expected.

In Section II, data about requirements set by electromagnetic compatibility (EMC) standards are quoted. In Section III, as an example of unwanted action of cellular phones, the operation of an audio amplifier is analysed under the influence of strong electromagnetic field. Section IV contains the analysis of base-station antennas and calculation of minimal distances where the EMC requirements for electronic devices are satisfied. In Section V, similar analysis is carried out for cellular phones. Conclusions of the analysis and recommendations for further work are given in Section VI.

II. Electromagnetic compatibility

In terms of electromagnetic compatibility (EMC), the ability of devices to operate without disturbing each other is considered. Electromagnetic interference (EMI) is the appearance of interference in the operation of a device under the influence of unwanted voltages and currents or electric and magnetic fields. Analogue audio and video circuits are particularly susceptible to disturbances, because even relatively weak unwanted signals from the environment produce in loudspeakers, that is, on the screen, disturbances which are uncomfortable for the user.

Today, there are various standards and regulations that define necessary immunity levels of devices to electromagnetic disturbances [1]. IEC (International Electrotechnical Commission) standards for EMC are published within the plan IEC 61000. The basic standards include: IEC 61000-4: Section 3 (Radiated radio frequency field), equivalent to EN 61000-4-3, which sets the required immunity levels to the electric field of 1, 3 or 10 V/m, depending of the purpose of the device. IEC committee CISPR (International Special Committee on Radio Interference) is concerned with limits and measurements of interference characteristics of potentially disturbing sources.

CENELEC (European Committee for Electrotechnical Standardization) and ETSI (European Telecommunications Standards Institute) use IEC/CISPR data as the foundation of standard concepts. The generic standards, which refer to immunity, also include EN 50082 (part 1, part 2). EN 50082 part 1 (Generic immunity standard, part 1: residential, commercial and light industrial environment) sets the immunity level to the electric field of 3 V/m within the range of 80-1000 MHz and it is equivalent to IEC 61000-6-1. EN 50082 part 2 (Generic immunity standard, part 2: industrial environment) sets the immunity level to the electric field of 10 V/m within the range of 80-1000 MHz, except in the ranges 87-108 MHz, 174-230 MHz and 470-790 MHz, where the level is 3 V/m. It is replaced by EN 61000-6-2 (Electromagnetic compatibility, Generic standards, Immunity standard for industrial environments). Product standard applicable to immunity of radio receivers and associated equipment is EN 55020 (Immunity from radio interference of broadcast receivers and associated equipment). It comprises radio and TV receivers and associated equipment the purpose of which is to be connected directly to them or to generate or reproduce audio or visual information. It sets the immunity level to the pulse RF field of 3 V/m at 900 MHz.

In our country, there are plans for generic standards which refer to immunity. Those are: SRPS EN 61000-6-1, 2007 (Electromagnetic compatibility, Part 6-1: Generic standards-Immunity in residential, commercial and light industrial environment), identical to EN 61000-6-1: 2007,

S. Lj. Stefanovski and A. R. Đorđević, University of Belgrade, School of Electrical Engineering, Serbia (telephone: +381 11 3218329; fax: +381 11 3248681; e-mail: edjordja@etf.bg.ac.yu).

and SRPS EN 61000-6-2, 2007 (Electromagnetic compatibility, Part 6-2: Generic standards-Immunity in industrial environments), identical to EN 61000-6-2: 2005. They set the same immunity levels as the above-mentioned standards.

III. AUDIO AMPLIFIER UNDER INFLUENCE OF STRONG ELECTROMAGNETIC FIELD

A cellular phone broadcasts in packages with a lapse of 4.615 ms, i.e., 217 packages per second. The package duration is 577 μs and it is followed by a seven times longer pause. In the GSM range (890-960 MHz), the maximum average power that the cellular phone broadcasts during a package transfer is 2 W, and the maximum average power during the entire lapse amounts to 0.25 W. The cellular phone operates at the maximum power in the phase of connection establishing, during handover or when communicating with a distant base station. Once the connection is established, and if the quality of the connection is good, the cellular phone decreases the broadcasting power up to 1000 times.

The strong signal from the cellular phone penetrates into the low-frequency (audio) part of the radio receiver and drives the audio amplifier into nonlinear regime, which results in the appearance of the characteristic disturbance in loudspeakers.

As an illustration for the influence of the RF disturbance on the operation of an analogue audio amplifier, an amplifier was chosen, the schematic of which is shown in Fig. 1 [2,3]. The output stage of the amplifier operates in class AB. The amplifier is analysed using program PSpice [4].

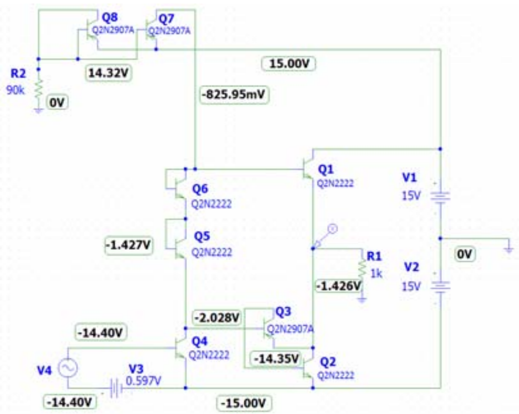


Fig. 1. The circuit of the analogue audio amplifier.

First, a sinusoidal signal with amplitude of 10 mV and frequency of 1 kHz was brought to the input of the circuit. In this case, the amplifier operated in linear regime.

When a sinusoidal signal of 1 GHz, which represents the influence of the cellular phone, is brought to the input of the amplifier, it is sufficient that the amplitude of this signal is 100 mV to drive the amplifier into the nonlinear regime, primarily due to the signal demodulation at transistor Q4. In that case, the bias point moves, so that the output signal of the amplifier looks as shown in Fig. 2. If the signal is turned off after 7 μs, the amplifier will need substantially longer time to return to the linear regime of operation. That can be seen in Fig. 3, where it is depicted how the bias point returns to its original position.

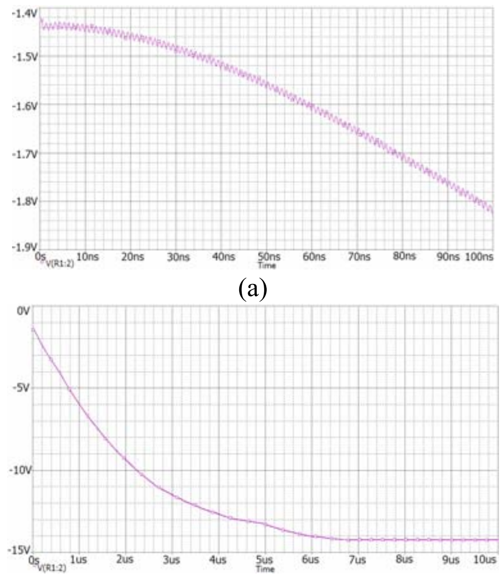


Fig. 2. Output signal of the audio amplifier caused by sinusoidal signal of 1 GHz: (a) during the first 100 ns, (b) during the first 10 μs.

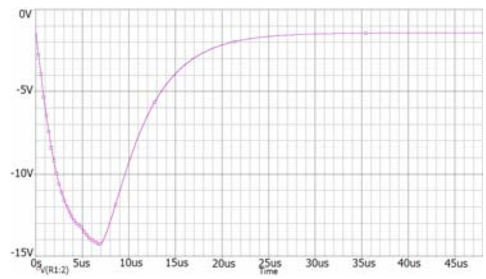


Fig. 3. Output signal of the audio amplifier after turning off the sinusoidal signal of 1 GHz.

However, due to the entry to the nonlinear regime and the exit from it, the output voltage of the audio amplifier swings, which causes the characteristic sound in the loudspeakers.

IV. FIELD OF BASE STATION

Using a model of a base-station antenna, the field produced by the antenna is computed. Hence, zones are established where the electric field does not exceed limits set by the standards, i.e., 1, 3 and 10 V/m. We analysed the antenna 739 623 of German manufacturer "Kathrein" [5]. The antenna has dual polarization (±45°). It can operate in frequency range of 806-960 MHz. However, we consider only the operation of the GSM system, so that we observed the range of 890-960 MHz. Within this range, the antenna gain is 17 dBi, and the half-power width of the main lobe is 65° in the horizontal plane and 9.5° in the vertical plane. The dimensions of the antenna are 1936/262/116 mm (height, width and depth).

In this paper, we used program WIPL-D [6] to make a model of this antenna (Fig. 4). The operating frequency is selected to be 947.5 MHz, which is the downlink central frequency. The model contains two arrays of vertical dipoles, the number of which is chosen based on an educated guess, since the actual construction details of the antenna are not known. The dipoles are placed in front of a conducting plane, whose dimensions correspond to the dimensions of antenna. The dipoles are fed by voltage generators of identical electromotive force of 10.68 V. Hence, the power radiated by the antenna amounts to 16 W. The field produced by the antenna is analysed based on the evaluation of the far field and the near field. For comparison, program RADCALC supplied by "Kathrein" is used.

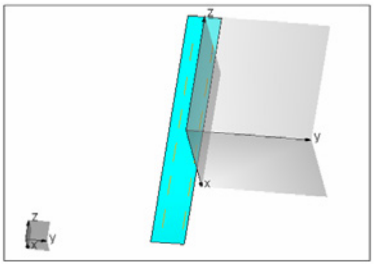


Fig. 4. Model of antenna 739 623 in program WIPL-D.

The three-dimensional radiation pattern of the antenna is shown in Fig. 5, and the radiation patterns in planes $\phi = 0°$ and $\theta = 0°$ are shown in Fig. 6.

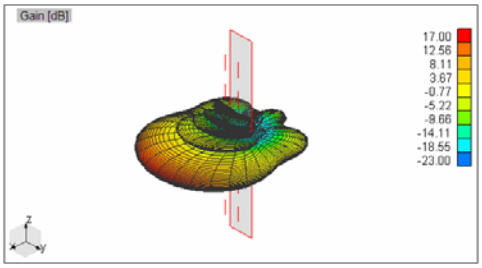
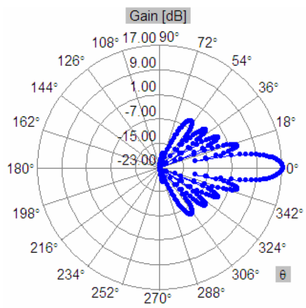
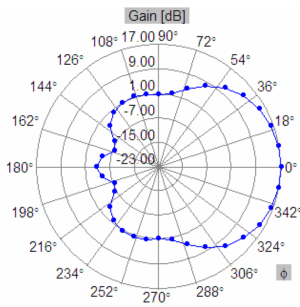


Fig. 5. Radiation pattern of antenna 739 623.



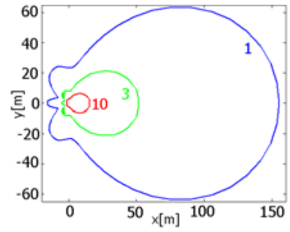
(a)



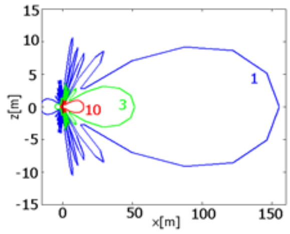
(b)

Fig. 6. Radiation pattern of antenna 739 623 in plane (a) $\phi = 0°$ and (b) $\theta = 0°$.

In figs. 7-9, boundaries of zones are shown in which the intensity of the electric field exceeds 1, 3 and 10 V/m, respectively, in the xOy and xOz plane. In each graphic representation of zones, obtained using program Matlab [7], the boundaries are plotted using blue, green and red lines, respectively, and the antenna location is marked by a black point.

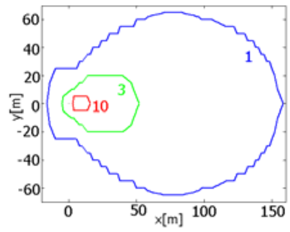


(a)

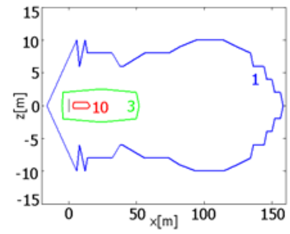


(b)

Fig. 7. Zone boundaries obtained by program WIPL-D using far-field calculation in (a) xOy and (b) xOz plane.

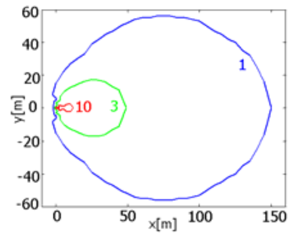


(a)

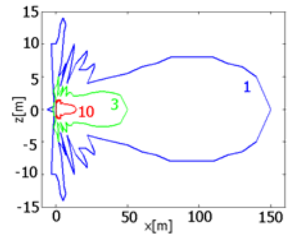


(b)

Fig. 8. Zone boundaries obtained by program WIPL-D using near-field calculation in (a) xOy and (b) xOz plane.



(a)



(b)

Fig. 9. Zone boundaries obtained by program RADCALC in (a) xOy and (b) xOz plane.

From the presented results, it can be seen that there are certain, but not drastic, deviations among the obtained zone boundaries, using the calculation of the far field and the near field in program WIPL-D and using the program RADCALC.

The most dangerous is the direction along the positive part of the x axis, since this direction corresponds to the radiation maximum. Hence, the distance of the zone boundary from the antenna is largest in this direction.

V. The Field of the Cellular Phone

To evaluate the electric-field intensity of cellular phones, a model of a cellular phone is made in program WIPL-D. We consider the situation when the phone transmits in the GSM uplink range (at 900 MHz), at its maximum power (2 W). The antenna is modelled by a quarter-wave monopole connected to a conducting plate (which models the body of the phone) and fed by voltage generator of electromotive force of 15.54 V, which amounts to the radiated power of 2 W. The model of the cellular phone is shown in Fig. 10. Using this model, the radiation pattern shown in Fig. 11 is obtained.

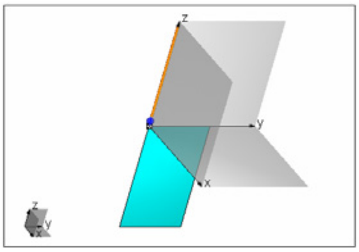


Fig. 10. Model of cellular phone in program WIPL-D.

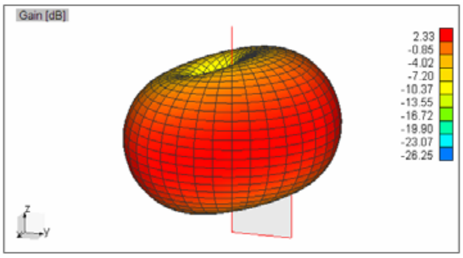


Fig. 11. Radiation pattern of cellular phone.

Based on the calculation of the far field, zone boundaries are established as presented in Fig. 12, in xOy plane.

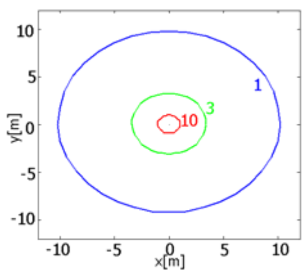


Fig. 12. Zone boundaries in xOy plane.

The influence of the cellular phone on an audio amplifier was established experimentally. Two models of cellular phones produced by “Sony Ericsson“ and “Nokia“ and a radio receiver “Gelka“ SK2000S were used. The radio receiver was tuned to operate as a cassette player, so that only its low-frequency amplifier was turned on. The cellular phone was in the phase of establishing the connection, when it broadcasts at the maximum power (2 W). The measurements have shown that disturbances in the radio receiver are induced up to a distance of 5.80 m (for both cellular phones). Compared with Fig. 12, this corresponds to the position between the zone boundaries for 1 V/m and 3 V/m.

Based on the results presented in Section III, the audio amplifier is brought into the nonlinear regime if a signal of 100 mV appears at its input. Let us assume that the audio amplifier is illuminated by an electric field of 1 V/m, generated by a cellular phone. The electromotive force of 100 mV can be induced in a square loop whose side is about 3.5 cm, which is the order of magnitude of typical trace lengths on standard printed-circuit boards.

VI. Conclusion

Based on the analysis of the field radiated by a base-station antenna and by a cellular phone, we assessed the boundaries of zones where the EMC requirements for radiated susceptibility are met. The obtained minimum distances of approximately a few tens of meters prove that, in many practical cases, the operation of electronic equipment can be disturbed by these transmitters. Often, the electronic devices are brought closer to the transmitters than these minimum distances, so that they are substantially exposed to the influence of the transmitters. In particular, due to the mobility of cellular phones, it seems that the appearance of the characteristic sound of disturbance in loudspeakers of audio equipment is practically unavoidable.

Therefore, in parallel with the development and the use of new technologies, methods for protection of electronic devices from potential disturbances should be developed. It is very important that standards and regulations rigorously set the necessary limits according to real situation in practice. Also, their enactment must not succumb to the influence of leading manufacturers.

References

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