Frequency Selective Method for Measurement and Estimation of Electromagnetic Emissions

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Abstract – **In this paperamethod for measurement and integral estimation of electromagnetic emissions(EME) in VHF and UHF is presented.The approach is to divide the evaluated frequency range of sub-bands and the measurement to be performed with the maximum frequency resolution. The objective is to increase the accuracy and traceability of the measurements and respective assessments.The method issuitable for on-site (ad hoc) estimations and takes into consideration the internationally standardized EME measurement requirements.Results of measurements are presented and analysed.**

*Keywords:***Electromagnetic Emission, electromagnetic compatibility, VHF, UHF, RF measurement,**

I. Introduction

The development of communication technologies during the last decades and especially of mobile communications (GSM, GPRS, UMTS, TETRA, Wi-Fi, WiMAX, and expected LTE) lead to a significant increase of the electromagnetic emissions (EME) from telecommunication sources.Electromagnetic emissions find application in many other spheres of human life, such as medicine, industrial technologies, etc., which also contribute to the overall increase of the electromagnetic background level. This maintains the interest to this topic not only from a scientific point of view, but also because of the sensitivity of the society concerning the influence of electromagnetic emissionsover human health and especially the ones from the base stations of the mobile networks.

The problems of electromagnetic compatibility (EMC) and the admissible levels of the Electromagnetic Fields (EMF) generated from different types of communication systems is permanently a topic of research and analysis. World-wide there are legal regulations and standards defining the maximum admissible levels of EME for the different frequency ranges.According to these regulations, in the process of putting into operation, commissioning, maintenance and monitoring oftelecommunication systems radiating in the radio spectrum, measurement and control of the EME is required, so that the radiation from such systems does not exceed the maximumadmissible levels.

Monitoring is one of the basic ways for control of the levels of EME from different sources in an area or region. It can be done using two basic approaches;first, by the installation of stationary sensors, orsecond, as periodic “ad hoc” measurements, andstoring in a data base and analyzing the results for the levels of the EME.

The first way gives the opportunity of performing constant monitoring and analysis of the results in predefined points, but requires significant financial resources and time for the development and building up the networkof sensors. The second is based upon periodical measurements and analysis of the electromagnetic field and its variations in predefined “hot spots”, which are of special attention and/or social interest, as for example hospitals, kindergartens, schools, universities etc.This approach allows higher accuracy of the measurements, requires less financial and time resources, but does not give the possibility of a long time continuous monitoring of the electromagnetic field and its variations at a specific point. Such measurements are performed with the help of specialized measuring equipment and for the analysis of the electromagnetic field and the estimation of its long term expected variations are applied statistical approaches. The measurements could be performed either with equipment, giving an integral estimation of the electromagnetic radiation, or with the help of a frequency selective equipment, which gives the possibility of estimating the contribution of each of the telecommunication technologies to the total level of EME in a given point or area.

In this paper a method for the measurement and estimation of EME, with the help of a frequency selective type of equipment is considered. The method is in conformance with European and national legislations for the maximum admissible levels of exposure of the population to EME in populated areas and working conditions. The specifics of the telecommunication applications emitting in the different frequency ranges are taken into consideration, as well as the resolutionof the measurement equipment. In order to increase the measurement accuracy, in the case of integral estimation of EME, a segmentation of the frequency range into sub-rangesit is proposed. The measurements must be performed with the highest frequency resolution of the equipment. Such a methodology is applicable in the VHF and UHF ranges, with are basically used by telecommunication technologies today.

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II. Measurement and Estimation Methodology

The proposed method is in conformance with the maximum allowable levels of the intensity of the electrical fields and power density of the electromagnetic fields (EMF) in populated areasand working conditionswhich are defined in European and national legislations [1,2,3,4].According to the principles of superposition the intensity of the fields from different sources in the VHF range are summed geometrically for obtaining an integral estimation of the intensity of the field in the range. In the UHF range, it could be assumed that the sources are uncorrelated, thus the resulting energy flux could be obtained as an algebraic sum of the fluxes from all of the separate sources [5,6].

The proposed methodology is applicable for an integral estimation of the EME emissions in the VHFandUHFranges, generated by radio andalso other sources. It supposes the measurements to be done with a frequency selective type of equipment in thefar field zone of the transmitting antennas.

A. Measurements in theVHFrange

The measurements of the levels ofEME emissions in this range are performed in the integral estimation mode of the measurement equipment. The measurement is performed applying the smallest possible Resolution Bandwidth (RBW) of the equipment, but in any case it should be at least 300kHz. The time of the measurement is not less than 6 minutes. In this frequency range the major sources are the VHF-FM radio stations and TV transmitters. These technologies use a bandwidthwhich is higher or commensurable to the one used in the measurement, whichguarantees enough accuracy. This range is used also by narrowband radio stations for special services which are transmitting in the ranges of 50MHzand 160MHz, but their emitted powers are significantly lower than those of the above transmitters. Moreover, their emissions usually are not constantor they are sporadic, taking into account the type of their users. In the measurements, the frequencies for which there are maximums of the field intensity and theirabsolute values are considered.

B. Measurements in the UHF range

This range is used for a number of telecommunication technologies, including the ones from the mobile networks, which have the major contributions to the increase of the total level of the electromagnetic field. The bandwidth of the radio channels, used for the different applications varies significantly,from 200 kHzforGSM, up to 5 MHzforUMTSand8 MHz for analogue TV broadcasting. This requires the separation of this frequency range into sub-ranges, in order to increase the accuracy of the measurement, because usually the frequency selective equipment does not allow small RBW when measuring the whole frequency range. We suggest the division of sub-ranges to be performed according to the frequency intervals given in Table I.

For the determination of the RBWfor each sub-range the specifics of the basicoperating technologies are taken into consideration. Some of them are recommended in the respective documents, as for example is the case withGSM-900,GSM-1800, UMTS[1,8,9,10]. The measurement of each sub-range is performed using the integral estimation mode of the equipment and lasts not less than 6 minutes. For each sub-range the measurements are done for at least two frequencies, witha maximum of the energy flux. This is necessary in order to analyze the sources, which have biggest contribution in the resulting integral values of the energy flux.

TABLE I

No.	Frequency	RBW_{max}	Basic Technologies
1.	300 – 880 MHz	200kHz	Analog TV, DVB-T, TETRA
2.	880-960 MHz	50kHz	GSM-900
3.	960 – 1710 MHz	300kHz	Military
4.	1710 – 1880 MHz	50kHz	GSM-1800
5.	1880 – 2400 MHz	200kHz	UMTS
6.	2400 – 3000 MHz	200kHz	Wi-Fi

C. Integral estimation of the level of electromagnetic fields

The integral estimation of the total influence of all of the sources from the ranges in Table I is done using the following relation:

$$\frac{E_{VHF}^2}{E_{\max VHF}^2} + \frac{S_{\Sigma UHF}}{S_{\max UHF}} \le 1, \qquad (1)$$

where $E_{\max VHF}$[V/m]and $S_{\max UHF}$ [μW/cm^2] are the maximum admissible values of the EME for the frequency ranges according to the national regulations and standards.In order to determine the sum of the power density in the UHF range, the following relation is used:

$$S_{\Sigma UHF} = \sum_{i=1}^{6} S_i \;, \qquad (2)$$

where$S_i$are the measured values of the energy fluxfor each of the sub-ranges according to Table I.

When people are working in the vicinity of radio emitting equipment, the maximum permissible time for staying in a given area is determined by the formula [4]:

$$T_{\max} = \frac{W_{S\max}}{S_{\Sigma}}, \qquad (3)$$

wherethe value of $W_{S\max}$[μW.h/cm^2] is alsostandardized and is dependent on the type of the antenna system.$S_\Sigma$is calculated using the equation,

$$S_{\Sigma} = \frac{E_{VHF}^2}{120\pi} + S_{\Sigma UHF} \;. \qquad (4)$$

III. Measurement Results

The proposed method is tested in the measurement and estimation of the level of the EME emissions in more than 20 points of a densely populated city area. The measurements are performed with a frequency selective equipment. For comparison, integral measurement results in one of the points in the whole frequency UHF rangewith the minimum possible RBW of 1 MHz (without division into sub-ranges), are presented in Table II.

TABLE II

E_{VHF}, mV/m	$S_{300\text{-}880\ MHz}$, μW/cm²	$S_{880\text{-}960\ MHz}$, μW/cm²	$S_{960\text{-}1710\ MHz}$, μW/cm²	$S_{1710\text{-}1880\ MHz}$, μW/cm²	$S_{1880\text{-}2400\ MHz}$, μW/cm²	$S_{2400\text{-}3000\ MHz}$, μW/cm²	$S_{\Sigma UHF}$*, μW/cm²	$S_{\Sigma UHF}$**, μW/cm²
199	$5,89.10^{-3}$	0,0223	$1,33.10^{-3}$	0,0159	0,0315	$6,1.10^{-3}$	0,08302	0,0645

* $S_{\Sigma UHF}$ calculated from Eq. (2).
** $S_{\Sigma UHF}$ measured with RBW=1 MHz.

The results from Table IIshow, that the values calculated using equation (2) and the onesmeasured with the equipment (RBW=1MHz)have a difference of about28,8%. Similar is the result (approx. 30 %) for the rest of the measured points. This is due to the fact, that in the case of integral measurement in the whole UHF frequency range, when RBW=1MHz is fixed, many of the maximum values could be “skipped”. In this case the integral estimation of the level of the EME will be with lower accuracy, due to the fact that some of the telecommunication technologies (and especially GSM, which has the major contribution in the total level of the emissions – Fig.1) use more narrow-band frequency channels.

A chart of the relative contributions of the separate sub-ranges to the total overall level of the electromagnetic field based on the performed measurements and proposed method, of estimation, is presented in Fig.1. As it could be seen, the biggest relative contributions to the level of the EME in the UHF range have the technologies GSM-900 andGSM-1800. This is easy to explain, as the measured base stations are located in the city area and create bigger intensity of the field in the measurement points. The measurements show also, that the power density in the ranges 300-880 MHzand 960-1710 MHzis relatively constant, respectively 5-7nW/cm²and 1-2 nW/cm².

IV. Conclusion

In this paper a method for measurement and estimation of the electromagnetic emissions in the “far field zone” from transmitting antennas or sources of electromagnetic fields is proposed. Using a frequency selective equipment, the methodology is applicable for the integral estimation of the electromagnetic emissions in the VHF and UHF ranges, generated from radio and other sources. A division of the measured frequency range into sub-ranges is proposed andsuggested the measurements to be performed with the maximum frequency resolution of the measuring equipment. The goal is to increase the accuracy of the measurements and a more precise tracing of the estimations to be obtained.

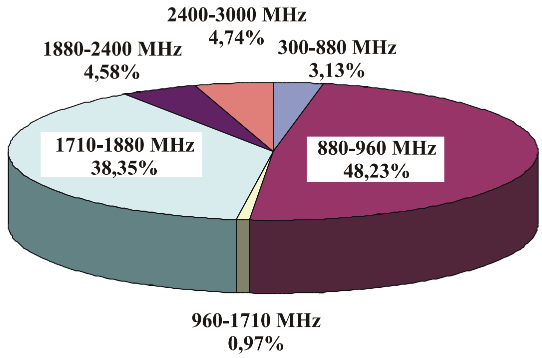

Figure 1. Relative contributions of the separate sub-bands in the UHFrange to the total level of EMF

The proposed method is approbated through the measurement and integral estimation of the EME in more than 20 points in a densely populated urban area. After summing up and analyzing the results, it is shown that:

1. The division into sub-ranges increases the accuracy of the integral estimation;
2. The biggest relative parts of the EME in the UHF range have the technologies GSM-900andGSM-1800, followed by UMTSandWi-Fi;
3. The power density in the ranges 300-860 MHzand 960-1710 MHzis relatively constant.

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