The field strength measurement and SAR experience related to human exposure in 110 MHz to 40 GHz

J. Klima, R. Ščehovič

Department of Physics, Faculty of Natural Sciences, University of Mathias Bel, Tajovského 74, 974 01 Banská Bystrica, klima@fpv.umb.sk

PTT Research Institute Banská Bystrica, Zvolenská 975 90 Banská Bystrica, rscehovic@vus.sk

Abstract: *The actual discussions about exposure to electromagnetic fields mainly consider the radiation in lower microwave frequency bands originating from mobile cellular base station and mobile phones. As these base station are often connected to the core network via microwave links at higher microwave frequencies, their environmental influences has to be considered, too. This paper therefore investigates the characteristics radiation of lower (110 MHz to 2 GHz) and higher (2 GHz to 40 GHz) frequency bands and in terms of regulatory and legal aspects and looking at the physical and technological boundary conditions.*

Keywords: SAR, mobile phones, radiation

1. Introduction

Conditions concerning protection of the general public against exposure to electromagnetic fields have widely been investigated by the ICNIRP (International Commission on Non-ionizing Radiation Protection). Their recommendations form the basis for the European Council Recommendation 1999/519/ EC defining the limits of the electric and magnetic fields, the SAR (Specific Energy Absorption Rate), and power flux density. This European Recommendation has been converted into national law for most European nation. These laws set the limits, which can guarantee – according to the actual knowledge – the best protection of the general public.

The basic document from the point of view of resources of electromagnetic fields in Slovak Republic is European norm EN 50383 Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz – 40 GHz) [1]. There are defined basic terms and quantities needed for calculations and measurements in this norm.

Measurements are performed according to valid Proclamation No. 271/2004 of the Ministry of Health of Slovak Republic [2]. It must be made a measurement of all sources of radiation after their installation, or after a change in their configuration (antennas exchange or giving more sectors, adding of antennae, power rising) according to this proclamation. The measurement is made directly in vicinity of source of irradiation and it have to be made by the person authorial by the chief hygienist of Slovak Republic for that function

2. Subject and Methods

Guidelines and recommended limits on human exposure to radio waves give basic restriction in terms of SAR or power flux density and also reference levels in terms of field strength in absence of the body. *SAR* is defined as the time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of given mass density (ρ):

$$SAR = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}W}{\mathrm{d}m}\right) = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}W}{\rho \mathrm{d}V}\right)$$

and it is expressed in units of watt per kilogram (W/kg). *SAR* can be calculated also by:

$$SAR = \frac{\sigma E_i^2}{\rho}, \text{ or } SAR = c_i \left.\frac{\mathrm{d}T}{\mathrm{d}t}\right|_{(time=0)}$$

Where E_i is rms value of the electric field strength in the tissue in V/m, σ is conductivity of body tissue in S/m, ρ is density of body tissue in kg/m^3, c_i is heat capacity of body tissue in J/kg K, $\frac{\mathrm{d}T}{\mathrm{d}t}$ is time derivative of temperature in body tissue in K/s.

The authors were concentrating upon the electromagnetic field measurement as the other method recommended in [1]. The measurement procedures that may be used to assess, at point of investigation, the electromagnetic field components (E and H and therefore the power density) radiated by antennas. The field measurements can be obtained either by surface or volume scanning. The methods used are to measure directly or indirectly the E – field or H – field, deduce the field distribution for a given input power and frequency. *Method to perform surface scanning* could be, but are not limited to, far-field, compact range, and planar, cylindrical or spherical near-field as long as the methodology is accurately defined and the uncertainty are fulfilled. *Volume scanning method* is directly measurements of electric and magnetic fields made at sufficient points on investigation in a volume surrounding the equipment under test (EUT) to establish the compliance boundary.

2.1 Methods of electromagnetic fields level measurement

2.1.1 The method of EMF level measurement around equipment under test - EUT

The amplitude of electromagnetic field strength (EMF) is measured in this method in spherical surrounding of radiating equipment at points of investigation. That can be assigned the compliance boundary around appraisal equipment (compliance boundary is zone around equipment where are overload limit of human exposure). For performing of this measurement it is necessary to have special equipment, which enables moving of probe from and to equipment. All positions of probe are read and saved. The test site includes EUT – equipment under test fixed on no conducted base which can be turned in azimuth (range 0 - 360º) and in elevation (range -90º – 90). Furthermore the test site include testing equipment (probe or antenna) which is fixed on positional equipment, which enable positioning of testing equipment in different distances from tested equipment. The all positions are read by computer (see picture) during the measurement on each position of EUT.

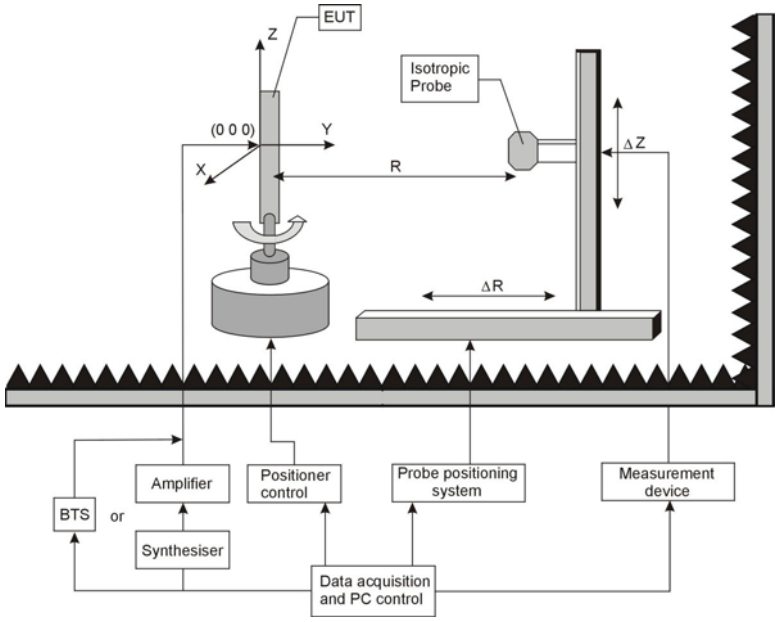

Fig. 1 Block diagram of the EMF level measurement around EUT

The probe is moving in direction from and to EUT with maximum step λ/72. In each position the probe measures level of EMF intuit. The final result of measurement is spatial arrangement of compliance boundary. The probe shall be constructed so to minimize its influence to electromagnetic field around EUT. It is possible to use directional antenna – horn, instead of isotropic probe, mainly for measurement in frequency range over 1 GHz. The positional equipment for EUT has to be constructed from non conducted material, not to have influence on electromagnetic field.

2.1.2 The local SAR measurement

The local SAR measurement is performed on fathom model, which simulate the human body or his part exposure by EMF radiated from antenna. The test report is used for compliance boundary assessment which depends on local SAR limits. This measurement meted is applicable only under these conditions:

1) Distance between fathom and radiating surface of antenna has to be lower the 40 cm.
2) Dimensions of radiated structure shall be lower than 60 cm x 30 cm
3) Operating frequency of EUT shall be in the range 800 – 3 000 MHz.

In another part of this allowance are involved result of real measurement performed according clause 2.1.1.

2.2 Method of measurement and assessment of field strength and SAR

The measurement of electromagnetic field strength in the place where is possible inhabitance presence In case of base stations with antennas placed on the mast the measurement is performed near the mast base stations in main lobe direction. If the places with long time inhabitance presence are in this direction in the distance up to 100m it is necessary to perform measurement in these places.

The measurement of electromagnetic field strength made from all surrounding EMF sources. The relevant source is that whose submission is higher than 1% from submission of the strongest EMF source. The measurement is needs to perform mainly on the places where other important sources, which can have affect on the total EMF strength, are situated. The places like this are mainly telecommunication towers, with TV or FM transmitters, TV converters or radio relays transmitters. Measurement is performed by selective receiver – spectrum analyzer together with calibrated antennas in all measured frequency band. Measured band covers all operation frequency bands all relevant surrounding EMF sources. For assignation the relevant sources is possible to use the list of local EMF sources which are situated on the tower or close to it. Another way how to define relevant sources is list of all TV and FM transmitter published on the Telecommunication office web side. Other possibilities are not officially available that why it is necessary to perform measure – scan of frequency band 10 MHz to 3 GHz. In higher frequency bands operate only radio relay systems which use antennas with very narrow radiation patterns (up to 4° for 3 dB loss) that why this sources are relevant only in places very near up to 10 m directly in front of antennas and this case will be registered by visual inspection. Where the base stations are placed on a roof of block of flats or where the place with long time inhabitance presence is in the immediate vicinity of base station the assessment is more difficult.

3. Results of the practical measurements

According possibility of human EMF exposure the radio equipments can be divided in to two groups. One group includes radio equipments with omni directional or sector radiation antenna diagram (base station GSM, UMTS, NMT and PMR). The second group includes radio equipments with narrow radiation antenna diagram (radio relay transmitters, satellite transmitters). The actually measured values around base station with antennas placed on the masts is up to 0,1 % from maximum accessible value for general public. Higher levels of EMF strength under roof is mainly in that cases when antennas are mounted directly on the roof not on the higher mast but nor this level are not higher than 10 % of maximum permissible level. As the access on the roof have only worker which are assigned for this job it is not possibility of exceeding limits of human exposure for general public. In this cases the measurement are performed mainly on the roof under or in front of antennas and on highest floor. The actually measured values in the places with long time inhabitance presence is lover than 0,1 % of maximum permissible level. More detailed results will be presented at the lecture of conference. Some results are showed in the table.

Table 1: Results of measurement from different places with GSM antennas

Place of measurement	**Frequency range**	**Measured value**	**limits**
Base of tower mast	935 – 960 MHz	0,05 – 0,1 V/m	42 V/m
Roof of house with anten. on the mast (3-5 m height)	1800 – 1880 MHz and 935 – 960 MHz	1 – 4 V/m	63 and 42 V/m
Roof of house with anten. on the mast (1-2 m height)	1800 – 1880 MHz and 935 – 960 MHz	4 -10 V/m	63 and 42 V/m
Top floor under roof antennas	1800 – 1880 MHz and 935 – 960 MHz	0,4 – 0,8 V	63 and 42 V/m
Roof of opposite house	1800 – 1880 MHz and 935 – 960 MHz	1 – 5 V/m	63 and 42 V/m

4. Conclusions

It can be seen from the presented short outline a very wide spectrum of problems concerning to methods of measurement, their technical realization, as well as their concrete values. It must be made a great deal of sophisticated method of measurements for find out the harmless effect of EMF to human body and for find out reliable values of EMF surrounding for general public.

References

[1] EN 50383 Basic standard for the calculation and measurement of electromagnetic field strength and SAR ralated to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz – 40 GHz)
[2] Ministry of Health Notification No. 271/2004. Vyhláška Ministerstva zdravotníctva SR č. 271/2004
[3] ECC recommendation 02/04 *Measuring non ionising electromagnetic radiation* (9 kHz – 300 GHz)
[4] ICNIR Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields up to 300 GHz
[5] Pr EN 50 400 Basic standard for calculation and measurement of electromagnetic fields related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz – 40 GHz), when put into service.