COMPUTATIONAL PROBLEMS OF ELECTRICAL ENGINEERING

Vol. 3, No. 2, 2013

NEAR FIELD EMF METROLOGY DEVELOPMENT

Pawel Bienkowski[1], Vitaliy Nichoha[2], Hubert Trzaska[1]

[1]Technical University of Wroclaw, Wroclaw, Poland,
pawel.bienkowski@pwr.wroc.pl, hubert.trzaska@pwr.wroc.pl
[2]Lviv Polytechnic National University, Lviv, Ukraine,
nich@org.lviv.net

Abstract. The paper discusses problems related to the near field EMF measurements for labor safety and environment protection purposes in comparison with the far field measurements.

Keywords: EMF measurements, labor safety, environment protection, EMF quantifying.

1. Introduction

Electromagnetic field (EMF) metrology is of concern in the wide area of indoor and outdoor applications. The former is related mainly to propagation studies, radio interference (RFI), antenna measurements, etc, while the latter includes susceptibility of living and nonliving matter studies, measurements related to the labor safety and environment protection and in variety of laboratory investigations and experiments. The outdoor measurements are usually performed in the far field, in conditions of a plane wave (TEM wave). It allows the use, in the metrology, of an arbitrary antenna playing the role of a measuring antenna (EMF sensor). Although there are several important factors that limit accuracy of the measurements (especially reflections and multipath propagation); however it does not change the general idea of these measurements but only requires a care during the measurements in order to find possible sources of uncertainty and try to eliminate (limit) them. An advantage here is good knowledge represented by a measuring team. Without regard to this, the measurements uncertainty at the levels below ± 1 dB is unachievable [1].

Apart from the others the first problem connected with the near field measurements is the personnel performing them. Often these are the people having a very little (limited) experience in electromagnetics and, as a result, they are unable to analyze conditions in which the measurements are performed and introduce necessary corrections or measures to achieve the greatest possible (maximal, possible) accuracy.

In order to present conditions of the near field measurements, they are compared with those of the far field in Table 1.

On the ground of the basic considerations, the paper presents practical solutions proposed by the authors and applied to metrological practice. The solutions show specificity of the near field EMF measurements and the measures necessary to minimize measuring errors.

Table 1

EMF measurements in the far- and in the near field

parameter	near field	far field
measured EMF component	E, H & S	E or H, and S on microwaves
other magnitudes measurement	I, T, (SA, SAR) "HESTIA"	unnecessary
spatial components	3	1 or 2
polarization	quasi-ellipsoidal spherical wave	linear or elliptical plane wave
environment	complex, multi-path propagation & interference	usually simple
frequency spectrum	wide, often unknown, many fringes	usually single frequency
antennas	small, omnidirectional	resonant, directional
temporal & spatial EMF alternations	significant	usually negligible
uncertainty	3, 6 or more dB	around 1 dB
temperature sensitivity	significant	unessential
susceptibility	significant	ommitable
influence of surroundings	significant	usually ommitable
procedures	complex	simple
agreement with theory	reasonable	good
measured levels	V/m, kV/m	mV/m, μV/m, dBμV/m

2. Metrological concepts for the far- and near field

Considering differences in the approach to the far- and near field, we should define where the fields are.

The boundary of the near field R is usually assumed as:

$$R \geq \frac{2D^2}{l}, \tag{1}$$

where: D is the maximal size of the radiation source and λ is the wavelength.

With no regard to it, the authors suggest a definition of their own: the near field is everywhere, where the measurements are performed. Although the boundary given by formula (1), in some sense, is in agreement with intuition locating the near field at distances of several ells from a source, with no regard to it, especially in the case of long-wave antennas or high gain antennas, it may be pretty several hundred of yards, far away of a source. Due to propagation phenomena, there may appear EMF of a structure and properties similar to those in the near field. It implies necessary caution during any EMF measurement and it has created an inspiration for the authors to define the boundary [2].

Concepts of widely applied solutions of EMF meters for both fields are presented in Fig.1.

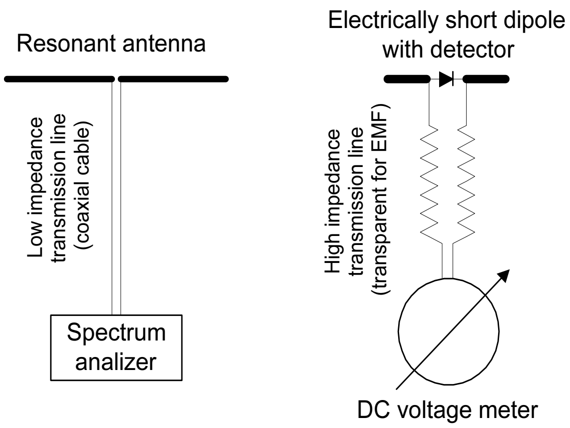

Fig. 1. EMF meter for the far field (left) and for the near field (right).

In the far field case, an antenna (usually resonant, often directional) is connected to an indicator (microvoltmeter, spectrum analyzer) via a matched cable. There are several exceptions from the idea, especially while low frequency fields are of concern, for instance, a whip antenna or loop antenna for E-field measurement, however, it does not change radically the presented concept. In the case of the near field measurements, a small size antenna, loaded by a detector, is connected to an indicator via a transparent line which is “invisible” to a measured field and does not affect the field. Also here any modifications and solutions are possible and acceptable; however, one parameter must remind unchanged, i.e the sizes of the antenna.

The issue of the antennas size is well discussed in the literature [2]. We would like only to remind the two most important factors limiting the size:

* Contrary to the far field, where, with acceptable simplification, we may assume the presence of a TEM wave (although such a wave, in free propagation, does not exist); in the case of the near field this is a spherical wave of three spatial components and remarkable curvature. The curvature causes measurement of an averaged (at the antenna) field and leads to an error of the measurement which is a function of the antenna sizes, distance to a source and its type.

* A small antenna is characterized by its input reactance. The reactance is affected by couplings between the antenna and material media close to it. A role, played here by surrounding, is similar to the above.

We may add here that the both errors may be assumed as negligible at distances exceeding sizes of an applied antenna. In order to neglect an influence of the phenomena on the meters, available on the market, a probe is often covered by a dielectric material of an appropriate diameter.

The last question: what size of an antenna is here acceptable? There is no univocal answer to the question. The size is to be selected for specific requirements of the measurement. Sometimes it must be as small as possible, for instance in EMF measurements close to a printed board or a microchip. In the case of measurements related to environment protection, it may be larger. The enlargement of the antenna’s size may be sometimes necessary to get required sensitivity and to limit instability and other undesirable effects while working with maximal sensitivity.

3. Selected solutions

In order to present specificity of the near field measurements, the authors propose several solutions that illustrate practical applications of the theoretical considerations.

* Selective meters

One of the oldest designs of the authors were selective EMF meters designated mainly to EMF measurements in transmitting centers for labor protection purposes. They are presented in Fig. 2.

Fig. 2. A selective H-field meter (left) and E-field meter (right).

In the solutions, no transparent separation between the antenna and indicator exists. In the H-field meter, the inductance of electrostatically screened loop takes a part of the resonant circuit. The separate antennas are applied to specific frequency ranges. The circuit is loaded by a detector and an analog indicator. In the case of the E-field meter, a symmetric dipole antenna (behind the meter) is coupled with a resonant circuit, switched for specific frequency ranges. Both antennas allow a single spatial component of the field to be measured. However, a possibility to turn the antenna and turning the meter on the tripod makes it possible to measure three field components.

The construction of the meters is, in some sense, "panzer". It well illustrates the problems the authors had with screening and limitation a role of the field penetration into the meter via other ways than the meters antenna. It is a place to call attention that the problem is still not satisfactorily solved in many meters available on the marked.

* Integrated wideband meters

Wideband meters are the alternative to the selective meters preferred by sanitary and inspection services.

As a rule, a frequency response of a wideband meter should be flat within a frequency range. In the case of the E-field meter, it requires loading the measuring antenna by a high resistance detector (amplifier) while in the case of the H-field meter, an increasing, with frequency, effective high of the antenna must be compensated by a low pass filter connected between the antenna and loading it detector (amplifier). Such an approach is widely applied to different types of meters and probes available on the market.

The authors' proposals of the integrated E- and H-field meters are presented in Fig. 3.

Fig. 3. An integrated wideband E-field meter (left) and H-field meter (right).

In the E-field meter, its antenna is a part of screening, while in the H-field meter, a loop antenna is connected to the rear wall of the meter. Both of them are placed at a dielectric handle and are designated mainly for measurements at the power line frequency and its harmonics.

* Universal wideband EMF meter

A concept of a universal wideband EMF meter is similar to that shown in Fig.1. A measurement procedure, using such a meter, is shown in Fig. 4. The upper photo demonstrates measurements with a meter in which a probe is connected directly to an indicator while the lower one shows a solution in which both components are connected by a cable.

Fig. 4. EMF measurements using an universal EMF meter.

An arbitrary probe is connected to an indicator (monitor). The probe includes an appropriate antenna (dipole or loop), filters shaping the frequency response and a detector. Output voltage of the system, in majority of E-field probes, is connected to an output of the probe through a transparent line. Then the probe may be connected with the indicator by a screened cable or may be connected directly to the casing of the indicator. The probes are prepared for specific frequency ranges, for required sensitivity and with different directional patterns.

The presence of transparent lines, separating a probe and a device (operator`s hand) may be seen in Fig. 4. The transparent lines are immersed inside of tubes made of dielectric material. The solution may make some problems, especially at the lowest frequencies, due to their charging with static charges.

* Directional pattern

In the above presented selective and wideband meters, a single antenna (dipole or loop) was applied. As a result, such a meter allows measurement of a single spatial EMF component. Such a solution has several advantages, for instance, it allows a source of radiation to be found. There may be a problem related to (It may be of concern in) quantifying measurements as a source of radiation is often unknown *a priori*. Although the solution allows the resultant field to be found by the way of separate EMF components measurement and the result to be calculated, however, such a procedure is troublesome and may lead to mistakes. Thus, by inspecting the services, for quantifying purposes, omnidirectional probes are preferred. The examples of such probes, proposed and completed by the authors are shown in Fig. 5.

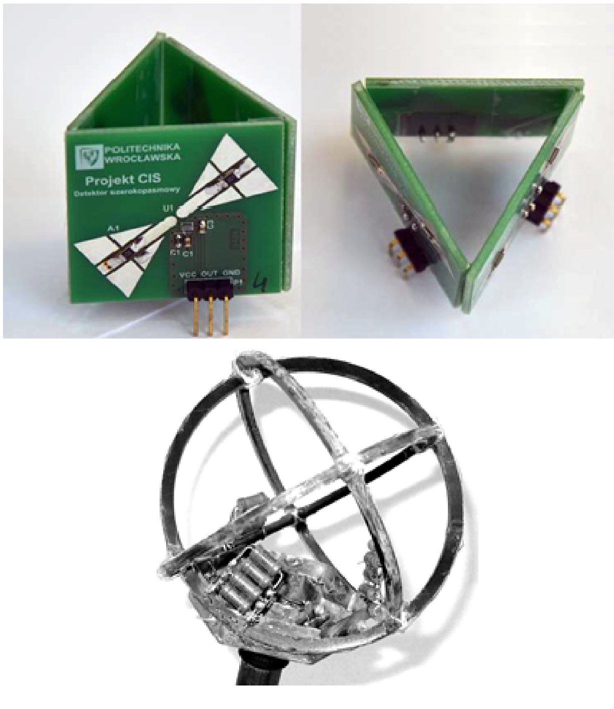

Fig. 5. Spherical E-field (above) and H-field probe (below).

* Low frequency H-field sensor

In the H-field probe, shown in Fig. 5, the loops are placed coaxially. Such a solution is possible in probes for higher frequencies. For lower frequencies and required sensitivity, it would require multiturn loops of quite large diameter and weight. In order to limit sizes and the weight, a solution with ferrite rods was proposed. However, it the case, a coaxial placement of the three loops is impossible and they have to be placed at a distance on three mutually perpendicular axes as shown in Fig.6. The loops are loaded by amplifiers of shaped frequency response and then to an indicator that allows separate H-field components measurement or resultant H-field.

It may be noticed that the E-field probe, shown in Fig, 5, because of construction problems, has three separate sensors placed mutually skewed in three walls of the prism.

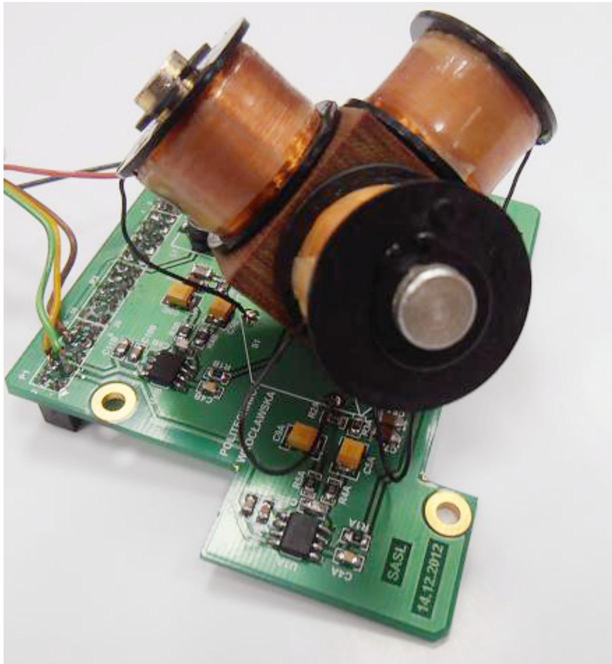

Fig. 6. An example of LF H-field probe.

4. Conclusion

As it could be seen from the presentation, both in the far field EMF measurements, and in the near field ones, a device that “pick-ups” the field is an antenna. Apart from large directional antennas, these are dipoles for E-field measurements and loops for H-field measurements. The main difference is in the sizes of the antennas. In the case of the near field, they should be as small as possible. The sizes here are usually a compromise between the sizes limitation and required sensitivity of the device.

As a result of more complex measuring procedures, in the near field measurements, there are more complex devices necessary for the measurements. Some specific solutions proposed by the authors illustrate attempts to the measurements optimization and increase in their accuracy.

Apart from the technical problems, there exists a specific problem concerning measuring teams. Far field measurements made for the purposes of propagation studies, EMC investigations, etc. are performed by the people experts in electromagnetics. Quantifying the measurements for evaluation of the hazard in terms of labor or for general public protection purposes are often performed by the people educated in biology, chemistry, and nonionizing radiation, etc. It often results in faults and mistakes. The best illustration of them are, for instance, presented in "scientific" papers or symposia presentations results of indoor EMF measurements using log-periodic, or similar directional antennas, E-field measurements with the use of commercially available meters with loop antennas (correct in the far field case), etc.

References

[1] E. Grudzinski and H. Trzaska, *EMF standards and exposure systems*. SciTech Publ. Inc., 2013.

[2] P. Bienkowski and H. Trzaska, *EM Measurements in the near-field*. SciTech Publ. Inc., 2012.

[3] V. Nichoha, I. Gontar, and P. Dub, "Three-component Wide-band Low-frequency Magnetic Antenna for Diagnostics of Magnetic Fields in Outboard Space," in *Proc. 5th Int. Conf. TELSIKS'2001*, vol. 2, pp. 657-660, Nis, Yugoslavia, 19-21 Sept. 2001.

РОЗВИТОК МЕТРОЛОГІЇ ЕЛЕКТРОМАГНІТНОГО ПОЛЯ В ЗОНІ ІНДУКЦІЇ

Павел Бєнковські, Віталій Нічога, Губерт Тшаска

У статті обговорено проблеми, пов'язані з вимірюванням електромагнітного поля в зоні індукції з метою охорони праці та захисту довкілля порівняно з вимірюваннями у дальній зоні.

Pawel Bienkowski – DSc., Ph.D., professor, born in Wroclaw (Poland) in 1968. Head of the Electromagnetic Environment Protection Lab at the Chair of Telecommunications and Teleinformatics of the Technical University of Wroclaw. Author of over 150 publications, presentations and patents.

Vitaliy Nichoha – Ph. D., DSc., Professor, born in 1938, holds a post of the Professor at the Department of Radio Electronic Devices and Systems of the Institute of Telecommunications, Radio electronics and Electronic Technique of Lviv Polytechnic National University, Ukraine; the author and co-author of more than 330 scientific works.

Hubert Trzaska, DSc, Professor, born in 1939. He holds a post of the Professor of the Wroclaw Technical University and the manager of the Electromagnetic Environment Protection Department at the Institute of Telecommunication, Teleinfor-matics and Acoustics.