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Ján IVANKA*

TOLERANCE REQUIREMENTS FOR POSITIONING MECHANISM FOR MEASURING ON CYLINDRICAL AREA

TOLERANČNÍ POŽADAVKY PRO POLOHOVÝ MECHANIZMUS PRO MĚŘENÍ NA VÁLCOVÉ PLOŠE

Abstract

The paper presents a study of analysis of tolerance requirements for positioning mechanism for measuring on cylindrical surface with respect to precision of the positioning mechanism (azimuth/elevation) in the field of measuring of near and distant zones of electromagnetic fields of electro-technical devices in the aneochoic chamber.

Abstrakt

Článek prezentuje studii rozboru tolerančních požadavků pro polohový mechanizmus pro měření na válcové ploše s ohledem na přesnosti polohového mechanizmu (azimut/elevace) v oblasti měření blízké a vzdálené zóny elektromagnetických polí elektrotechnických zařízení v aneochoické komoře.

1 INTRODUCTION

Electromagnetic compatibility represents a science discipline dealing with the question of undesirable affecting of the function of various technical and biological systems through the action of electromagnetic field while individual system can have or need not have mutual functional relationship. For that reason, the new integrating discipline called ***electromagnetic compatibility (Elektromagnetische Verträglichkeit (EMV) in German, elektromagnitnaja sovmestimost' in Russian) with internationally recognized abbreviation EMC*** as a reflection of the necessary coexistence of electro-technical systems mutually as well as in relationship with respect to live organisms. Sometimes occurring Czech term "*elektromagnetická slučitelnost"* is not considered to be suitable by most of the Czech experts.

Measurements of electromagnetic interference are very wide and important field. It includes measurement methods and procedures for quantitative assessment of the selected parameters in particular at the interfaces of interference sources and receivers, namely in the field of both near and distant zone. Besides measurements, the field of testing of electromagnetic susceptibility of buildings using so called interference simulators has developed quickly recently. Testing is carried out not only on the finished equipment, but mainly also during its development.

The paper provides basic pieces of knowledge about measurements of the parameters of microwave aerials in the near zone. The objective of this paper is to provide an overview of advantages and disadvantages of the measurements in the near zone and a comparison of measurements in the near and distant zones. The study is determined in EMS and EMI fields in which quite different problems are solved – programs for numerical field calculation in the distant zone including probe correction, reverse projection and gain, software for displaying calculated values, programs for control of scanning equipment and measuring instruments, hardware and apparatuses for measuring including construction of scanning equipment.

*Ing., Department of Electrotechnics and Measurements, Faculty of Applied Informatics, Tomas Bata University in Zlín, Nad Stráněmi 4511, tel. (+420)576035247, e-mail: ivanka@fai.utb.cz

Reliable estimate of measurement errors is one the basic requirements for any measuring method; this applies in particular to the methods that use a high level of mathematical analysis such as measurements of areas in the near zone. Determination of limits of errors for any measuring system for a given combination aerial/probe/near zone may be difficult and time demanding task and mathematical complexity is the main reason of the difficultness. For that reason, attempts to bypass mathematical methods and to set the limits of errors for a general method of measuring using measurements for a certain aerial are made frequently. Results of measurements in the distant and near zones are compared when using this approach and the differences between these two methods are taken as a criterion of measurement errors in the near zone. Theoretical relationships that are important for making measurements more accurate (analysis of final dimensions of scanning for cylindrical scanning any analysis of accuracy of the scanning mechanism) are described in the paper. These relationships form a base for analysis of the tolerance requirements for positioning mechanism for measurements on the cylindrical surface with respect to the accuracy of the positioning mechanism (azimuth/elevation). The method of cylindrical scanning attracted probably the least interest in analysis of errors of all generally used scanning methods. It was assumed usually that errors will be similar like errors in planar surface, which is naturally true but it is necessary to investigate some sources of errors that have different impact. Similar analyses have indicated that errors resulting from the measuring system are main sources of errors.

2. ERRORS OF SETTING OF THE MEASURED AERIAL

We will consider ***spherical (R,θ,φ) and cylindrical (r,φ, z)*** system of coordinates according to Fig. 1 for next analysis. The vertical axis (z axis) will usually be the axis of rotation for scanning on cylindrical surface.

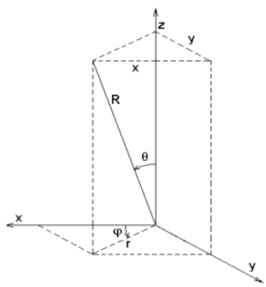

Fig.1. Spherical system (R,θ,φ) and cylindrical system (r,φ, z)

It is possible to use theoretical analysis for planar scanning in the plane x,y, that is mentioned in [3] and [5] to estimate errors in the position of the probe in the direction of axis z. In case when the main bundle is approximately perpendicular with respect to z axis, the errors for maximum gain and lateral lobes are as follows:

$$\Delta G(\theta,\varphi)_{dB} \leq \frac{8{,}7\Delta_z(\text{rms})}{\eta D_z} g(\theta,\varphi) \qquad \text{for the main lobe,} \qquad (1)$$

$$\Delta P(\theta,\varphi)_{dB} \leq \frac{4{,}3\Delta_z(\theta,\varphi)}{D_z} g(\theta,\varphi) \qquad \text{for the lateral lobes,} \qquad (2)$$

where G is aerial gain, P is relative diagram, D_z is main aerial dimension, η is efficiency of aerial aperture and Δ_z is position error in the z axis. The function $g(\theta,\varphi)$ is a ratio of diagram maximum with respect to amplitude in the considered direction. E.g. for the lateral lobe -40 dB, $g(\theta,\varphi)$ equals to 100. We consider a spectrum of errors for angles (θ,φ) in the equations (1) and (2). To eliminate a random error, errors with the same effective value (standard deviation) are considered, which is emphasized using rms denomination. When considering analysis, it is obvious that all conclusions associated with scanning in plane (error of position x, y) including the mentioned examples apply similarly. If you know the spectrum of errors Δ_z of the z position, you will get very realistic estimates of errors in the near zone. The upper limits of errors when we consider only the maximum value of errors will be created in relatively special cases.

3. LIMITED MEASUREMENT SURFACE

For planar scanning in the near zone, the aerial is installed in a *fixed manner* and the probe in the near zone moves along the planar surface in both x and y directions so that it is possible to scan matrices of samples of field (both amplitude and phase). Similarly, when scanning on the cylindrical surface, a matrix of samples of field for movement in z direction and in azimuth φ is scanned. The range of scanning for measurements in the z direction indicated in Fig. 2 is important when accuracy of measurements on cylindrical surface in the near zone is considered. The size of the measured aerial and the size and location of the final scanning surface (cylinder) is defined with the critical angle Φ. Calculated emission characteristics of the aerial will be applicable in the zone between ± Φ. The following equation applies to the given scanning range L:

$$L = D + P + 2d \operatorname{tg} \Phi, \tag{3}$$

where D is measured aerial diameter, P is probe diameter and d is the distance between the probe and the measured aerial. Complete angular covering can be achieved only by means of scanning on fully spherical surface in the near zone. For example, critical angle Φ = 70° can be achieved using scanning that is larger by six wave lengths on each side than the aerial aperture in the distance of two wave lengths from the aerial. The restricted scanning area has two effects. Firstly, the resulting emission areas are applicable only inside of the zone defined in Fig.2 for the area larger than the area aperture. This criterion is used for determination of the minimum dimension of the scanning plane for the given required zone of angles and separation distance *d.* As the lower limit for *d* is given by physical structure of the area and multiple reflections, compromise both between the maximum angular covering together with reduction of errors as a consequence of limited scanning (when small d is required) and minimum multiple reflections (when big *d* is required) is usually required.

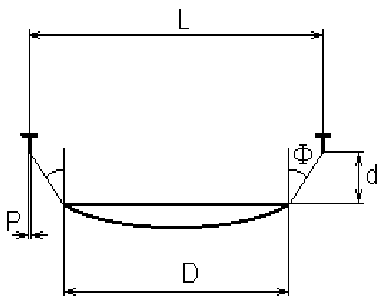

Fig.2a. Scanning range determination

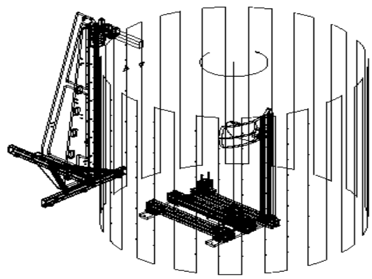

Fig.2b. Measuring on cylindrical area

Occurrence of errors for calculation even for the “applicable zone” illustrated in Fig.2 is another effect of the limited scanning area. The following equation applies to preliminary estimate of errors as a result of the limited scanning area for measurements in planar surface:

$$\frac{|\Delta I(\mathbf{K})|}{|I(\mathbf{K})|} \leq \frac{\alpha \lambda L_m b_m(\rho', \varphi_\rho)}{2S \cos \gamma_m} \frac{|I(\mathbf{K}_0)|}{|I(\mathbf{K})|} \tag{4}$$

where S is aerial aperture area, L_m is maximum width of the scanning area, $\alpha \approx 1 - 5$ is a coefficient of amplitude drop (1 for uniform exposure, but practically not more than 4 commonly used exposures), $b_m(\rho', \varphi_\rho)$ is maximum amplitude of probe output on the edge of the scanning area with respect to the maximum probe output on the scanning area and $|I(\mathbf{K}_0)/I(\mathbf{K})|$ is a ratio of the maximum amplitude in the direction $\mathbf{K}_0$ with respect to the amplitude in the direction $\mathbf{K}$ (so called inverted value of standardized diagram in distant zone). (11) applies as the upper limit for angles up to 90°, but it can be said very approximately that the equation (4) represents a relatively reasonable estimate of the upper error for the zone of angles smaller than Φ/2 while the estimate (4) is much higher than the actual errors are for larger angles. The mentioned equation requires less information, however, it generally provides, much more higher upper limit of errors. This equation can be used according to [5] also for the aerials that are separable in the *x,y* plane only when scanning along aerial axes as was demonstrated not only theoretically but also experimentally.

$$\mathbf{E}_{o,p} = \frac{\Delta_x \Delta_y}{2\pi} \sum_{m=(-N_x/2)}^{(N_x/2)-1} \sum_{n=(-N_y/2)}^{(N_y/2)-1} \mathbf{F}(m\Delta_x, n\Delta_y) \exp\left[-j2\pi\left(\frac{om}{N_x} + \frac{pn}{N_y}\right)\right], \tag{5}$$

However, it is necessary to mention that the above mentioned equation does not consider a change of phase along the scanning area periphery when measuring along the aerial axes and for that reason, it could give bigger errors in most cases. It means that it can be assumed that this equation for planar scanning can be used as upper estimate also for cylindrical scanning.

4 CONCLUSIONS

The paper is based on the analysis of errors made in a number of studies. All significant sources of errors were specified, all sources of errors of measurements in the near zone were measured and estimated and the shape of the function dependence of errors was determined in many cases. Equations of errors among errors of measurements in the *near zone* and results of calculations for the *distant zone* were derived within the framework of the scientific plan MSM 7088352102. Combinations of individual components of errors were ascertained in order to obtain a realistic estimate of the resulting measurement errors.

ACKNOWLEDGMENTS

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Reviewer: MSc. Martin FUSEK, Ph.D., VŠB-Technical University of Ostrava, CZ