

A PORTABLE MEASUREMENT SYSTEM BASED ON A PDA DEVICE FOR ACQUIRING AND TESTING ELECTROMAGNETIC FIELD LEVELS

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Abstract: In this paper an user-friendly and manageable measurement system for environmental monitoring and control applications is presented. The specific experimental case concerns the acquisition and processing of the exposure levels to environmental electromagnetic field (EMF). The proposed measurement instrument is equipped with a Personal Digital Assistant (PDA) device and a field probe sensing the electromagnetic field in high frequency range. The small dimensions make it a practical tool in order to monitor the pollution state in urban area. The embedded application allows user to acquire and test in real-time the field levels in order to verify their conformity with fixed exposure limits. The processing stage optimization is achieved by analyzing the influence of measurement uncertainty on the comparison process between measured values and tolerance limits. So, according to measurement result, a confidence level provides information on the response reliability about the compliance or non-compliance with the fixed thresholds. A final report on the PDA display shows user the general EMF trend and the possible limit overcoming happening. Then data can be transmitted to a remote client for further analysis, so designing timely appropriate intervention plans in order to safeguard population from potential hazardous situations.

Keywords: environmental measurements, electromagnetic pollution, uncertainty, limit-conformity, data-processing.

1. INTRODUCTION

In these years the Telecommunications Sector has got a considerable growth. The technological developments have involved an exponential diffusion of mobile communication systems using the electromagnetic field as means to convey information. So, today, the urban environment is characterized by exposure levels to electromagnetic field which are beyond the usual thresholds existing in nature. Common practices like watching TV, listening to Radio, phoning with a mobile phone, represent typical sources of electromagnetic pollution. Recent medical research would indicate possible effects on human body due to high exposure levels to EMF. The results would seem to single out a dependence link with some cancer types. But it needs to be said that in this regard different controversial opinions make the matter not completely clear. So there are not sure

proofs about the correlation between EMF and possible effects on human health. Therefore, for precautionary purpose, in several States laws and regulations set exposure and warning limits in order to safeguard population from potential risks. The main objective is to guarantee a suitable quality level of life. So, by systematic monitoring processes, it is possible to control the compliance with the fixed limits and consequently to plan corrective interventions in presence of out-of-control situations. To verify the pollution state in progress in a specific area, it is required a timely acquisition of the field levels and likewise a prompt data processing by reliable decision making procedures. In this way hazardous and alert occurrences can be characterized in short time, so reducing risky consequences. The matter needs suitable measurement systems which are able to provide reliable measures with appropriate accuracy. In fact measurement uncertainty could affect the results of the comparison between the measured values and the exposure limits, [1]. Therefore, during processing stage, the metrological characteristics of the measurement process have to be taken into account.

Typically, current instrumentation provides the only measure value without processing on the spot the acquired data according to the available uncertainty information. Moreover, the observed phenomenon is time-critical, and several factors are cause of temporal and spatial variations on its behavior. So, for obtaining meaningful information on the changing field trend, the measurement system must have particular features like reduced dimensions in order to be portable, it has to be user-friendly, but above all it has to be able to process data in real-time. An other important aspect concerns the metrological state of the instrument, in fact, in order to assure the reliability of acquired data, it needs periodic calibrations for guarantying suitable working conditions. In this sight, the authors propose in the present paper a portable measurement system being able to measure and test the exposure levels to EMF. By an embedded procedure, measured data are put in comparison with a specification limit to evaluate their conformity with law regulations. The implemented algorithm allows to take into account the measurement uncertainty of the system so qualifying the comparison process. An alarm report in real-time shows possible warning occurrences and then data can be sent to a remote user for planning corrective interventions. In the following sections they will be

described in more details the system project, its technical features and performances, and the data processing procedure.

2. THE PROJECTED MEASUREMENT SYSTEM

The aim of an environmental monitoring campaign is to collect useful data and information in order to improve the available knowledge on the examined process. Such information not always is consequence of an 'a priori' knowledge, so it requires to perform measures on the phenomenon. When the matter concerns critical processes which can affect the quality of life, then environmental measurements are used for taking decisions on the possible corrective actions fit for reducing or preventing the relative consequences on environment or people. Therefore, both the adopted measurement system and the data processing stage represent two factors certainly influencing the performances of the monitoring. In other words, an inappropriate choice of the measurement system or its wrong management and maintenance may be cause of unreliable measures. So, a faulty working state due to lack of instrument calibration would imply an unknown measurement uncertainty and undefined metrological characteristics. Moreover, an unsuitable processing of data may lead to an incorrect or incomplete interpretation about the phenomenon behavior. Finally, when the monitored area is complex and wide like an urban one, several influence factors have to be taken into account, as the presence of metallic obstacles, the location of pollution sources and the weather conditions. In similar situations the measurement system must have reduced dimensions in order to make easier the monitoring procedures in places being accessible with difficulty, but above all, the system has not to perturb the neighbor environment so affecting the measures, in example, by field reflections. In this context, it has been developed the project of a portable and user-friendly measurement system. The instrument, depicted in Fig. 1, is based on a *PDA* device, it is able to acquire environmental EMF levels.



Fig. 1. The portable measurement system.

Then by a statistical analysis, the measured data are processed according to the available knowledge on the measurement uncertainty.

In details, the *Pocket PC* is linked to a probe sensing the electric field in the high frequency range. The sensor *PMM EP-330* is connected to an optical repeater *PMM OR-03*, [2]. The probe signals, opportunely conditioned, are sent by an optical link to the *PDA*. An optical/serial adapter allows the device to exchange data with the probe using the Standard RS-232. A last serial connector realizes the connection with the COM port of the device, [3]. By means of the extendable optical cable it is possible to perform measures without affecting the measured field by interferences due to the normal working of the *PDA*. The technical specifications and performances of the system are reported in Table 1.

Table 1. Technical and Metrological Specifications.

Frequency Range	100 kHz - 3 GHz
Level Range	0.3 – 300 V/m
Resolution	0.01 V/m
Sensitivity	0.3 V/m
Uncertainty	7.5% of rdg (normal distr.)
Calibration Interval	12 months

The user can program the optical repeater in order to ask sensor for information on its state and the residual charge of the battery. In fact by specific commands it is possible to set the correction factors, to specify a filter or to request the date of last calibration. Further commands allow to get the modulus of the total electric field or its value along one of the cartesian axes. The management of the communication between the probe and the *PDA* has been performed by developing a *Virtual Instrument* (VI). The embedded code has been realized in *LabVIEW*[®] Environment using the *PDA Module*, a graphic tool that allows to build files in *Visual C* executable with *Windows CE*, the operating system of the *Pocket PC*. The settings of the COM port are typical of a serial UART communication, with 8 bit data, one stop bit and a baud rate equal to 9600 bps. The built-in program allows user to set the preferred sampling specifications and to send the desired commands in order to ask for specific information. The acquired data are subsequently stored in a text file; the possibility to extend the memory by *Secure Digital* (SD) card makes possible a sufficient autonomy to the measurement system. Measured data are processed by a statistical procedure in order to evaluate possible alarm occurrences. As later on it is described, information on measurement uncertainty is used during processing stage so qualifying the comparison between the measured values and the law exposure limit.

The previous metrological and technical specifications are effective until the next fixed calibration, later they will be updated by the new metrological verification. For this reason, in order to guarantee a suitable operating state for the system, a warning message on *PDA* display informs user about the date for the next calibration of the sensor. When the maintenance time expires a further message highlights the possible unreliability of the measures, so alerting user on

the potential meaningless status of the results. A *Compact Flash modem* allows system to transmit data to a remote client by *GPRS* communication for further analysis of the results and timely intervention on the monitored area. By the embedded application the whole measurement and processing phase is automated, so user has the simple task to set the sampling parameters and to start the monitoring.

3. THE DEVELOPED VIRTUAL INSTRUMENT

In the introduction it is highlighted the key role of the data-processing stage during the monitoring in order to obtain useful and timely information on the EMF status in the monitored area. So, the realized measurement system is able to elaborate on the spot the electromagnetic field levels by an embedded decision making algorithm. The present measurement system has been employed in the monitoring of a wide urban area. For simplifying the sampling procedures the whole area has been divided in several local zones according to topographical and environmental information. In this way using further correlated information like the population density distribution and the presence of sensible targets in the area, the obtained results have allowed to single out indications about the priority of intervention for the several zones. The experimental application has made possible to identify in some zones the presence of exposure levels beyond the law limit, so putting population safety at possible risks. The knowledge of the geographical location of alert or warning occurrences represents an useful information for the supervision activities of the concerned authority, in order to plan systematic corrective actions so minimizing the associated effects on people and environment.

3.1. User Interface

In the Fig. 2, it is possible to see the software control panel of the *Virtual Instrument* built. The user by a practical window can select the desired command to send to the probe, so obtaining information on its operating status or asking for the total EMF modulus or its value along the axes *x*, *y* and *z*. Specific controls allow to set the sampling time and the sample size. The sampling specifications represent

variables defined from user, because they are requirements fixed according to the desired level of ‘resolution’ and ‘accuracy’ for the monitoring. In example, if the investigated area is characterized by a high population density then it requires a greater number of samples with a high sampling frequency. A further button starts the sampling process. When the required sample is collected, it is possible to stop the acquisition and to display the trend of the EMF over time. Two windows provide preliminary statistical information on the mean and standard deviation of the acquired measures. The embedded processing algorithm implements a decision making procedure to support of the comparison process, as detailed in the following subsection. So, starting from information on the measurement uncertainty, it estimates the conformity of the measured data with the fixed exposure limit. In this way a warning light indicates the possible occurrence of an alarm situation if data overcome the specification limit. A confidence level provides information on the reliability of the response. Therefore, by a first analysis, user has the possibility to characterize out-of-control conditions for the monitored process. When the measurement process is finished it is possible to stop the run of the application by the ‘end’ button so exiting from program. By an other software application, user can send the stored data file to a remote client using the *GPRS* modem.

3.2. The compliance with specifications procedure

As it has been said before when a measured value has to be put in comparison with a specification level or threshold, the measurement uncertainty plays a key role in order to make a decision. As a result of it, the matter cannot be reduced to a simple mathematical comparison between two single values. In fact, because of the measurement uncertainty the acquired value may seem over the fixed limit while it is really in compliance with it. So, an erroneous interpretation of the uncertainty influence on the comparison process can lead to wrong decisions. Consequently, incorrect decisions are cause of superfluous costs if the possible consequences due to the relative undertaken actions are considered. According to the guidelines of *GUM Standard*, [4], by a statistical approach to the measurement uncertainty, it is possible to associate to the single measured value a confidence level and an expanded measurement uncertainty. In this way the comparison concerns a single value (the limit) and an interval of possible values (the measure). Starting from the *Standard EN ISO 14253-1*, [5], it can be determined a simple decisional rule. The criterion, by putting in comparison the limit value and the ‘measure interval’ allows to make a decision on the conformity or non-conformity with limit. The developed procedure provides a reliability level so qualifying the final decision. According to the sensor specifications, a *type B evaluation* allows to characterize the measurement uncertainty by a statistical distribution. Typically, the most cases concern normal or uniform probability density functions. In the considered case (see for reference the *Table 1*), the distribution is a normal or gaussian type. It is possible to estimate the probability that the measure *m* overcomes the specification limit *SL* taking into account the measurement

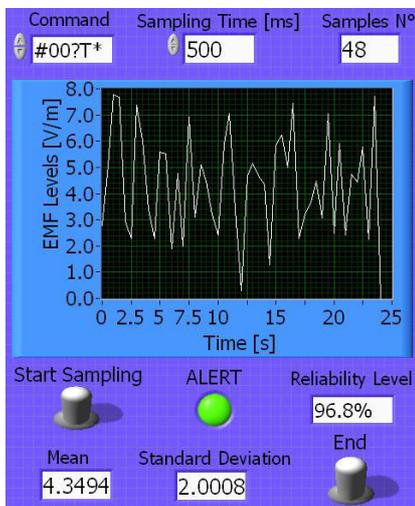


Fig. 2. The software user interface.

uncertainty. In more details, by following the GUM guidelines, it may be assumed that the nominal value or the measured datum represents the middle of a ‘measure interval’ which distribution around the expected value has a standard deviation that is equal to the measurement uncertainty with a known statistical probability function. If u is the standard measurement uncertainty, $f_u(x)$ represents its probability distribution function (pdf), so $f_u(x-m)$ can express the pdf of the measurement result around the measured nominal value m . In this way, the reliability level RL associable with the limit overcoming is estimable by integrating the function as in the equation (1), see Fig. 3:

$$RL = \int_{SL}^{+\infty} f_u(x-m) dx \quad (1)$$

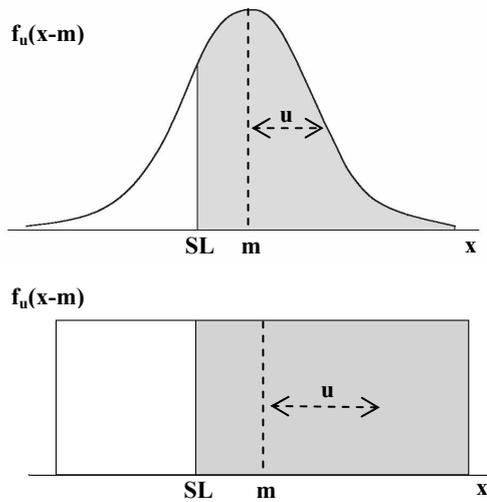


Fig. 3. Probability distribution of uncertainty.

With reference to the above figure, the first plot indicates the examined case of normal distribution with a mean $\mu=m$ and a standard deviation $\sigma=u$; the second plot shows another typical experimental case of an uniform distribution with expected value equal to m and a semi-interval $\Delta=u \cdot \sqrt{3}$. As a result, the parameter RL indicates the probability that the ‘measurement result’ overcomes the limit SL in a statistical approach according to the type B evaluation of GUM. The reliability level has been used in order to have an indication on the credibility of the non-conformity occurrences so qualifying the decisional criterion. In this way, once it has been fixed a reference value for the reliability level, if for a measured m the obtained RL level is over the reference then the measure has to be considered non-compliant with the limit, thus turning on the warning light on the *PDA* display. In order to perform the proposed comparison procedure in the specific application, the table of the standardized normal pdf has been stored in a text file, so allowing the software algorithm to estimate the previous integral. Qualitative and quantitative information alerts user to the warning occurrence taking into account the influence of the measurement uncertainty on the possibility to make a wrong decision.

4. CONCLUSIONS

In this paper has been presented a measurement system being able to acquire and process environmental data. The specific application concerns the monitoring of the exposure levels to EMF in an urban area. Principal features of the used instrumentation are the reduced dimensions and the possibility to elaborate acquired data on the spot. In fact, according to information on the measurement uncertainty, the embedded code is able to estimate the conformity of single measured datum with the specification limit. By a statistical approach to uncertainty and according to the guidelines of the GUM Standard, the built-in comparison procedure allows to make a decision on the possible overcoming occurrence of the specification limit. A reliability level provides an indication of the credibility of the final response. In this way, following the sampling process, the user can test the EMF behavior in real time, so characterizing possible risky occurrences for the exposed population. The *PDA* provides a final report describing the EMF trend in the investigated zone with a timely identification of overcoming happenings. Moreover a set of commands and controls allows user to specify the desired sampling specifications and the type of measure to be executed. The system stores data in a text file and can send it, by the *GPRS* communication, to a remote workstation for a further analysis stage. The main advantage of the realized instrument is the data-processing procedure embedded in the same measurement device. In addition, the automated control on the metrological state of the system allows user to get information on the next foreseen calibration of sensor, so guaranteeing the measurements quality assurance. It wants to be an useful and practical tool in monitoring processes of environmental quantities, in fact the general features of the system allow, by changing the sensing unit, to perform several specific applications.

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