THE EVALUATION OF SOME SHIELDING SOLUTIONS FOR AN EXPERIMENTAL SPACE EXPOSED TO MULTIPLE ELECTROMAGNETIC PERTURBATIONS

Petru Lucian MILEA[1], Valentin Gabriel VOICULESCU[2], Cristian Ovidiu OPRIȘ[3], Grigore ȚIPLEA[4], Orest OLTU[5]

Electromagnetic perturbations can cause operating problems to electronic devices. Specially designed rooms, fully shielded or anechoic are an expensive solution that is not always feasible. We study various and cheaper me asurement and shielding solutions to solve a complex situation of large spectrum electromagnetic perturbation in a faculty laboratory location.

Keywords: electromagnetic perturbation, shielding, sensitive equipment, RF measurement, EMF attenuation

1. Introduction

The avoidance of electromagnetic interference is accomplished usually through the improvement of immunity for the perturbed circuits or devices and the reduction of emissions for the perturbing devices. These being said, there are a lot of situations when neither one of the two measures is applicable. The broad input band measuring devices (such as the oscilloscopes), or the weak signal devices (like those specific for bioelectric measurements), are susceptible to interference in their work band through their intrinsic nature. On the other hand, the telecommunication systems (radio stations, television, other carriers or mobile emitters using GSM, CDMA, Wi-Fi, etc) or the power supply circuits (high power and/or high voltage) are perturbing systems for which the emissions cannot be reduced significantly without affecting their performance.

A solution that can improve on this problem is to make the electromagnetic interference susceptible measurements in rooms specially designed for this purpose, fully shielded or even anechoic chambers (rooms free of echo, internal reflexions).

[1] Lect., Dept.of Electronic Technology and Reliability, University POLITEHNICA of Bucharest, Romania, e-mail: lucian.milea@upb.ro

[2] Asist., Dept.of Electronic Technology and Reliability, University POLITEHNICA of Bucharest, Romania, e-mail: valentin.voiculescu@upb.ro

[3] Eng., Dept.of Electronic Technology and Reliability, University POLITEHNICA of Bucharest, Romania, e-mail: cristi_o@yahoo.com

[4] Asist. Dept. of Electronic Technology and Reliability, University POLITEHNICA of Bucharest, Romania, e-mail: grig_t@yahoo.com

[5] Assoc. Professor, Dept. of Electronic Technology and Reliability, University POLITEHNICA of Bucharest, Romania, e-mail: orest_oltu@yahoo.com

The ideal anechoic rooms are simultaneously shielded from outside generated electromagnetic radiations and have walls that are fully absorbing toward outside generated electromagnetic radiations (anechoic chambers). Experiments conducted inside these chambers are assimilable to those performed in a vast space that does not contain any sources of electromagnetic radiation nor obstacles to reflect the waves generated by the equipment under test. The real anechoic rooms present the characteristics mentioned above to a large degree for a given interval of frequencies. Such chambers are very expensive and have in general reduced dimensions (their dimensions being proportional to the price of their construction/setup) and are relatively heavy. Renting such a chamber/room is a solution only in the case of unique or rarely performed measurements.

In the case of frequent or periodic measurements, like those made in didactic laboratories, mobile verification measurements of electromagnetic compatibility of equipment (other than the target perturbations), non-metrologic measurements to show small signal phenomena (such as the acquisition of bioelectric signals, testing of field couplings, or experimentation of human-machine interfaces etc.), the people performing the experiments are often finding themselves in the situation of abandoning research or declaring them irrelevant, due to the presence of strong sources of perturbing signals nearby. Resolving this problem has both technical and scientific, as well as socio-economic impact, and the identification of solutions to decrease the perturbing fields in certain work environments as well as finding ways to make the measurements cheaper and more accessible to perform, are both of significant importance. Such a solution would have a great cultural value, since it would allow large scale utilization of wireless communications, without danger of perturbing the functionality of other systems (which they currently do).

The desired solution implies the combined and personalized use of directional, electrical, magnetical, electromagnetic shielding techniques, followed by, on a case basis, by usage of methods of rejection of perturbing frequencies.

2. The difficulty elements of the problem

The space in which we make the different measurements susceptible to electromagnetic interference are different from one instance to the next, both by the placement, the frequencies and the power of the perturbing sources, as well as through the geometry of the surrounding rooms and buildings (the source of reflexions). On top of this we also have the specifics of each measurement, in terms of being accomplished without being affected by perturbations. The most important elements of difficulty tend to be the identification of directions of each different perturbation sources, as well as the optimal ways to diminish them. In other words, the bigger challenges in measurement are related to the fact each case is practically unique and approaching it should be personalized, and there is no generally available and economically viable solution.

For this reason, what we want to obtain is a general working method combined with local-specific solutions to eliminate or diminish the electromagnetic perturbations. We will present a step by step approach of each case, from identifying sources of perturbation, to implementing and testing solutions. This kind of solution will greatly improve the measurement conditions in the given situation, while keeping the costs down.

Specific solutions will be tested experimentally on a didactic laboratory room, which is highly perturbed from multiple sources, with estimated frequencies ranging from 50 Hz to 3 GHz.

In this case, the problem to be solved is a very complex case of electromagnetic perturbation, since it involves a large number of power field sources, with varying frequencies and strength, uneven spatial distribution, placed in a relatively close area and surrounded by irregularly shaped buildings. The existence at University POLITEHNICA Bucharest (UPB) of such an experimental environment is both a chance, deserving to be tackled, as the cost of implementing a similar experiment is prohibitive for the majority for academic research.

Fig. 1. Perturbing signal caught in the didactic laboratory on a 18cm long conductor, connected to the input of a 150MHz band oscilloscope, on the 0.1 V/div. and 50 ns/div. scale. One can see the initial signal (left side), and the one reduced by 6dB (right), during a simple directive shielding test scenario

We should mention that protecting a chamber from outside perturbations, even for the partial scenario, is very difficult to accomplish in the case of large volume chambers such as didactic and/or research laboratories and has both novelty and definitive social and economic implications.

3. State of the art

The current approaches for research papers [1], [2], [3] is either to focus on full shielding of the workspace, in order to eliminate the influence of perturbing signals (in situations where there is a desire to measure low power signals, similar to our own), or in using an anechoic chamber [2], if the measured signals are strong (and there is a desire to eliminate reflexions).

There are limitations of these applications, for the cases we are referring to in this paper, since we are either in a situation where we can't perform a full shielding (mobile measurements), or in a situation where shielding is very expensive (large didactic laboratories, over 180 m3 in volume).

In this paper we aim to perform an evaluation of perturbing fields in a didactic and research laboratory and their effect on measurements currently being performed in the respective space, as well as to identify local and specific ways to shield and reject fields, or perturbing frequency ranges, starting from the solutions offered by the scientific literature ([4],[5],[6]), but without using full shielded rooms or anechoic chambers.

While it is true that through complete shielding of the workspace it should be possible to eliminate the influence of outside perturbing signals, but this is costly, not always practical, and also has the disadvantage of multiple reflexions appearing due to signals generated within [7].

For this reason, the solutions we aim to identify will be based on evaluating the characteristics of the perturbing signals (frequency, power, direction/predominant areas of influence etc.), followed by choosing and applying of adequate and directional shielding. It will consist in applying measures that permit making acceptable measurements with minimal intervention, based on identifying peculiarities and vulnerabilities specific to the application, the chamber and working instruments.

The process we study is somewhat inverse to the one used in designing a reception antenna. In case of an antenna, the composing elements are placed so as to maximize the received signal. In our case, the shielding elements to be used will shield only certain directions and regions of the workspace and will be placed in order to minimize the received signals in the same workspace. We consider this approach to be new and having the potential to solve specific perturbation problems at lower costs. Such a solution would allow extending wireless communications with lesser perturbing effects on the functionality of other systems (that they currently perturb considerably [4], [8]). Solving this problem may have a significant impact, both in technical-scientific terms, as well as socioeconomic, since it could offer financially accessible solutions to reduce perturbing fields from the usual work and measurement spaces.

In order to find such specific solutions, we aim to study experimentally the effects of different ways to directionally shield work spaces, and the rejection factor for unwanted frequencies. For this purpose we began by evaluating the perturbing fields in the didactic and research laboratory, as well as their effects on current measurements in the respective work space. In the next phase we will aim to identify local and specific ways to shield and reject perturbing fields and frequencies, starting from the solutions offered by the specialized scientific literature, but without using fully shielded or anechoic chambers.

4. Accomplished achievements

In the first stage we aimed to map the spatial distributions of electromagnetic field (EMF) intensity from within the research laboratory, for each of the perturbing frequencies. We created an approximate map with the placement of potentially perturbing surrounding emitting antennas located in the proximity of the research lab, presented below.

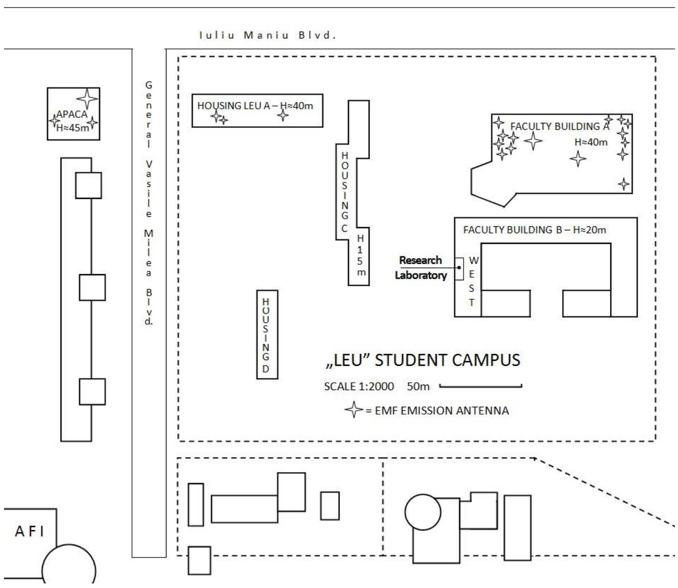

Fig. 2. Placement of emitting antennas on tops of buildings surrounding the laboratory

As it can be seen in Figure 2, in the investigation area there are a few dozen antennas. They have different purposes ranging from: radio and TV stations, GSM, data communication, etc. It is very probable that there are quite a few perturbing signal sources, for which we do not know the exact frequency, neither power, nor distance (the latter we are able to approximate though). As such, we have no ways to computationally establish the values for perturbing field intensity surrounding the lab. Therefore, it is imperative to measure the signal spectrum from the lab, in order to find out what frequency ranges we want to shield/reject.

For our experiments we had at our disposal two nonselective detectors [9] (one for RF electromagnetic fields in the 50 MHz – 3.5 GHz range, and another one for LF magnetic fields on 50/60 Hz), which measure the global intensity of the electromagnetic field, in a wide frequency range. Using these devices we made multiple measurements, before and after placing certain shields or reflectors, grounded or not, in order to observe their global effect.

We also considered if we could assess the relative strength of the signal of the surrounding mobile telephony networks. We considered using an Android phone as a cheap measurement device, considering also its ubiquity in modern households. For this purpose, we used a Nexus 5 Android phone, and reused a custom created app. The app's primary purpose is to set up the device to a known state (including setting the screen brightness and audio volume), to allow for reproductive measurements. Among the parameters measured we have the phone type, the mobile network type, and most importantly for our scenario the mobile telephony signal strength.

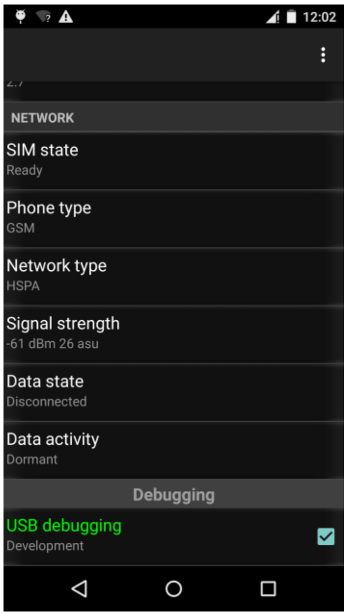

Fig 3. Aspect of the custom Android App

To detect the mobile SIM, the phone type (GSM, CDMA), the mobile network type (including but not limited to CDMA, EDGE, GPRS, UMTS), the app employs the Android class android.telephony.TelephonyManager [10]. For the purpose of measuring the signal strength the app employs the Android android.telephony.SignalStrength class [11]. According to Google's documentation [11], the SignalStrength class uses the Arbitrary Strength Unit (ASU), which then can be converted to dBm using formula specific for the network type [12]. The one downside is that in its current form the app requires root permissions so it cannot be used on any Android device. In Fig. 3 you will find a picture of the app section pertaining to mobile telephony network information. The line of importance is the Signal Strength line.

5. Experiments and results

In order to accomplish the directional shielding with minimal costs for the above mentioned laboratory, we aim to completely shield one of the walls of the room (the outside wall), and partially a second one. The two walls are facing the majority of the surrounding antennas, including those emitting in the FM radio spectrum.

Having in mind that, for practical reasons (the experimental space is a didactic laboratory), as well as economic reasons, we can't completely shield the room, so as to obtain a Faraday cage, we realized a series of partial shielding experiments with the nonselective measurement device and also with an Android application running on a mobile phone, in order to verify the validity of various solutions and to select the better materials for the job.

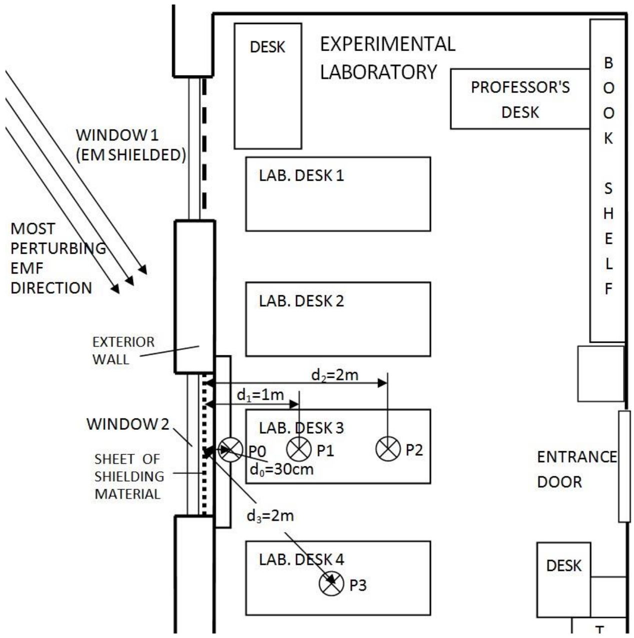

Fig 4. Location of measurement points inside didactic and research laboratory, in experiment 1

A first experiment (Fig. 5) involved covering the lower part of one of the windows (window no. 2) with various materials, each having shielding properties, followed by the measurement of the electromagnetic field in 3 points situated behind the shield. The other window (window 1) was shielded with the same material in all cases. All the shields had a height of 1m and a width of 1.75m. The following measurements were obtained with the nonselective device.

Table 1

Electrical field intensity measurements in laboratory experiment 1

Measurement point / Shielding	P0	P1	P2	P3
	E [V/m]			
None	15.5	9.7	6.8	6.4
Galv. steel exp. mesh 28x13 mm	19.9	8.7	6.3	4.8
Copper sheet 0.5mm	15.4	9.5	5.2	6.3

Aluminum sheet 0.5mm	18.4	8.6	6.3	6
Steel sheet 0.8mm	20.5	8.1	6.7	6.3
Zinc sheet 0.5mm	16	7.2	5.9	6.1
F62 Transparent sheet	12	7.7	5.5	5.4
F72 Transparent sheet	18.2	9.2	5	5.9
Galv. steel wire mesh	9.1	6.8	7.3	5.7

The obtained results are neither very conclusive, nor do they show a dramatic reduction in electromagnetic field intensity.

An obvious phenomenon in most cases is that of increasing field intensity in the immediate vicinity of the shield (point P0, situated about 30 cm from the shield). This can be attributed to the fact our shields were not properly grounded at the time of the measurement. We also assume the shields behaved as either resonators (that retransmitted the electromagnetic field from outside) or discontinuities (that reflected it back from within).

Fig 5. The shielded window experiment (experiment no. 1)

The Android mobile phone application was used to evaluate the signal of two mobile networks in P1, when the window was free or obstructed with the aluminum sheet. The mean data (after few measurements) was: -59.6dBm with unobstructed window 2 and -63.6dBm with obstructed one, for Orange network. In Telekom network, the mean results were the same for both types of measurements: -76.3dBm. We think the reason was the mobile phone adaptively boosting the weak Telekom signal, in this area.

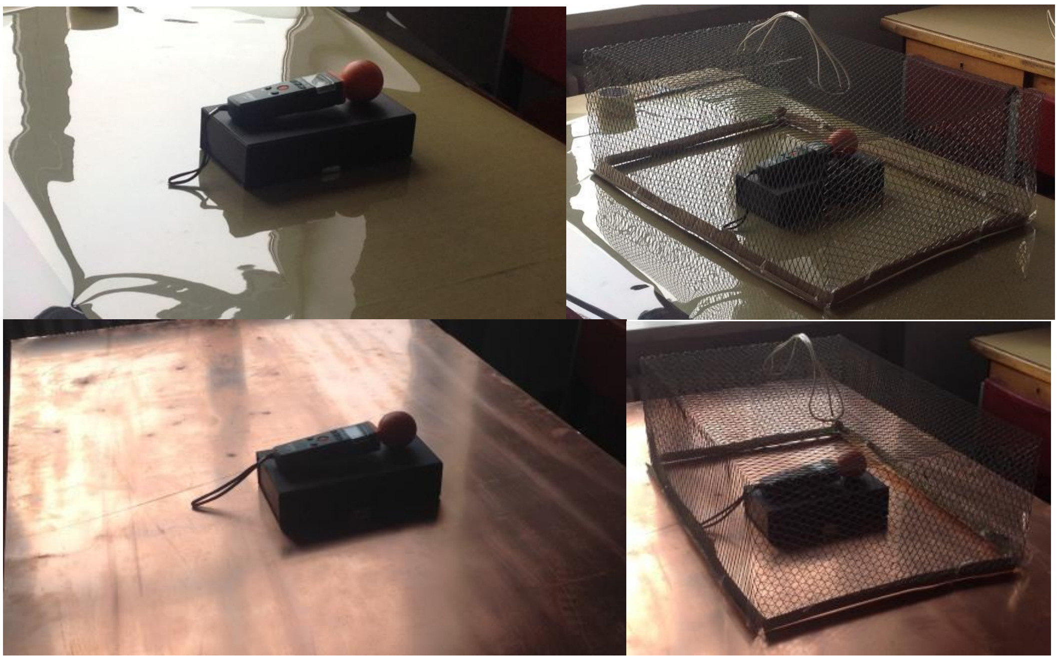

Fig 6. The shielding “cage and plane” experiment (experiment no. 2)

Considering the results of our first experiment as inconclusive, we imagined and performed a second experiment. In this experiment, we created a cage with 5 walls using expanded mesh (bottom missing in the cage itself), and placed the unselective equipment underneath, inside it, as depicted in the pictures below. The sixth wall of the parallelepiped cage (the horizontal side underneath) was made of different materials and was isolated from the top mesh cover. The purpose of the experiment was to evaluate only the effect of the material used in the bottom side of the cage. We avoided making galvanic contact with the top side mesh in order to prevent forming a Faraday cage (which would have shown other phenomena than those involved in the partial shielding of our laboratory).

The directional measurement device was placed on a thick isolated support, approximately 7cm in height, which in turn was placed, on the horizontal shield foil, on top of a table in the laboratory (Fig. 6).

Table 2

Electrical field intensity measurements in laboratory experiment 2

Exp. mesh cage / Shielding plane	No cage	Cage	Plane efficiency	Cage efficiency	Overall efficiency
	E [V/m]		%		
None	5.20	1.40	-	73.08%	73.08%
Rare galv. steel mesh	1.90	1.00	63.46%	47.37%	80.77%
Dense galv. steel wire mesh	1.40	1.10	73.08%	21.43%	78.85%

Copper sheet 0.5mm	1.25	1.15	75.96%	8.00%	77.88%
Aluminum sheet 0.5mm	1.30	1.10	75.00%	15.38%	78.85%
Steel sheet 0.8mm	1.50	1.45	71.15%	3.33%	72.12%
Zinc sheet 0.5mm	1.35	1.25	74.04%	7.41%	75.96%
F62 Transparent sheet	1.25	1.00	75.96%	20.00%	80.77%
F72 Transparent sheet	1.25	0.95	75.96%	24.00%	81.73%
F62 Tr. sheet rotated 90^0	1.25	0.82	75.96%	34.40%	84.23%
F72 Tr. sheet rotated 90^0	1.25	0.9	75.96%	28.00%	82.69%

The data in the above table (Table 2) show that applying a simple shield plane on the worktable produces an attenuation close to 75% (12dB). Applying a cage of metallic mesh on top of the device introduces, as well an attenuation close to 73% (11.4dB). Experiments show their effect is not cumulative (applying both the mesh and the plane does not increase the attenuation further).

On the other hand, by analyzing the respective combinations we notice that the best results were obtained for the rare galvanic steel mesh (in particular - with the same material as that of the mesh itself) and for foil type F62, especially when the cage is placed with the long axis perpendicular on the direction of the surrounding field. It is interesting to notice that neither the copper and aluminum foils did give results quite as good as that of expanded galvanic steel mesh, nor foil F72 (theoretically much better) has proven to be a lot better than foil F62. While we investigate this phenomenon further, it’s possible that a large variation between upper cage and lower plane conductivity could introduce a larger contact impedance or the induced surface current caused by the surrounding electromagnetic field to generate second degree effects inside the cage, reducing the attenuation. Another possible explanation is that the upper cage and lower plane hold different potential, becoming a weak electric dipole, increasing near field in proximity to our nonselective equipment, and for which our nonselective equipment is sensitive to.

We made measurements in the same points in the laboratory 1 experiments, using the Nexus 5 Android device, for two mobile telephony networks (Orange Romania, and Telekom /Cosmote). Before performing any shielding experiments inside of the target laboratory room we got the following measurements, by placing a smartphone on a table, directly.

Table 3

Mobile telecom measurements using Nexus 5 in the laboratory room before shielding

Room	Position	Orange [dBm]	Telekom [dBm]
Target laboratory	P0	-57	-75
	P1	-61	-77
	P2	-55	-75
	P3	-53	-77

We also did a series of experiments where we placed the phone either on a table, either on a thin metallic sheet, either underneath a five-sided expanded metallic mesh cage (diamond shaped expanded mesh, with 10x20 mm holes), or both underneath a metallic cage and on top of a thin metallic sheet, similar to the experimental measurements performed in table 2. We performed a series of measurements for each point, in close temporal proximity one of the other, then computed the average across measurements to account for mobile signal strength variability over small time intervals.

Table 4

Mobile phone measurements with a diamond shaped mesh cage and shielding plane

Exp. mesh cage / Shielding plane	No cage	Cage	Cage rotated 90^0	No cage	Cage	Cage rotated 90^0
	Orange [dBm]			Telekom [dBm]		
None	-59	-61	-63	-75	-77	-77
Copper sheet 0.5mm	-61	-65	-65	-77	-79	-79

There seems to be an impact in signal strength received by the phone, by using either the cage or sheet, but the effect is not additive.

While the selective equipment measurements was able to pinpoint the frequency bands causing the most electromagnetic perturbation to bands not used by mobile telephony networks, we intend to pursue more experiments to study the effect of shielding on mobile signal strength.

6. Post measurements data

In order to have an improved image over the spectrum of the perturbing electromagnetic field, we also acquired a third-party service of selective electromagnetic field measurements [13], using an expensive selective measurement equipment [14]. The results were received after the completion of the above measurements. The most significant values of electromagnetic field intensity were obtained for the frequency ranges surrounding the values presented in Table 5. Taking into consideration the significant frequencies from equation (1) above, we can compute their corresponding wavelengths using the speed of electromagnetic waves in the air (approximated to the speed of light) and their frequencies.

Table 5

Post measurements data with most perturbing frequencies in the target laboratory

Main frequency (MHz)	89.0	91.7	93.0	101.5
Wavelength (m)	3.371	3.271	3.225	2.955
Field intensity (V/m)	2.0	3.7	1.5	2.3

So we can say for the case of the electromagnetic field surrounding our laboratory location, we would expect shielding objects with dimensions close to 3 m (the approximate wavelengths of the significant portions in the surrounding electromagnetic spectrum) to have little impact, as the electromagnetic waves can get around obstacles close to the predominant wavelength. This may explain the poor attenuation values obtained in the first experiment.

7. Conclusions

In this paper we drew the plan of the area affected by electromagnetic perturbations, both at the zone scale, but also at the building and laboratory scales. Next, we performed few shielding experiments to verify EMF attenuation qualities of different materials and enclosures.

In a first experiment, we used various sheets of shielding materials to obstruct a window which is most exposed to EMF field and then compared the results. The second type of experiment involved using a five-sided mesh enclosure combined with a sheet of copper, in order to compare the inner and outer field intensities. In these experiments we used a nonselective measurement device for RF EMF (50 MHz – 3.5 GHz) and also an Android mobile phone with an application able to estimate the signal strength for different mobile networks.

The results, obtained with the non-selective RF field measuring device, shown that the best shielding (yet modest, of about 3-4 dB) was obtain in specific measurement points for copper and F72 sheets, while the most uniform attenuation was obtained using the F62 sheet. On the other hand, the use of a horizontal shielding plane under the measuring device was proven as the most efficient method for EMF reduction in our specific case. The obtained attenuation was about 12dB, similar with that obtaining using a five-walled shielding mesh cage, placed over and around the measuring device. The combination between the horizontal shielding plane and mesh cage provided only a small additional improvement of the attenuation, between 8 and 47%, with an overall shielding efficiency (attenuation) of 16dB.

The results obtained using the Android mobile phone and evaluation software shown a maximum reduction of the field of about 4dB, when the most perturbing window (the middle one) was obstructed with a dense wire mesh sheet. The second experiment shown also different results compared with the wide band (non-selective device) ones. Either the horizontal plane or the mesh cage have produced an attenuation of about 2dB, while their combination produced an additional one of 2 to 4dB (in different networks).

The differences between the two measurement devices suggests that the most important band in the perturbation spectrum is at lower frequencies than those used by the mobile networks (0.9, 1.8 and 2.1 GHz). After the experiments, we received the results of a third-party measurements set, done with a selective equipment. These results shown that the most important perturbation band is the

FM one. This result confirmed the conclusion of the non-selective (and low cost / accessible) measurements methods.

The experiments suggested that the most useful transparent sheet for windows shielding is F62. Also, based on the conclusion that the wavelengths of the most perturbing signals are around 3m, we assume that a bigger shielding (aka one complete wall, of about 4m high and 10m long) is needed to obtain a considerable attenuation of the FM perturbations.

These results are useful as a reference in order to verify the efficiency of the shielding and rejection solutions used and also to validate the non-selective measurements results and their interpretation. For the final tests there is a plan to make another set of selective measurements (also using a third-party service), in order to highlight the spectral effects of the solutions which will be applied.

Acknowledgements

This work was supported by the EMLAB grant, UPB-GEX 103/2016, “Arranging an experimental space to improve the measurements susceptible to electromagnetic interference, without the use of anechoic chambers”.

R E F E R E N C E S

[1]. *S. Radu*, Engineering Aspects of Electromagnetic Shielding, EMC Design Engineering / Sun Microsystems, Inc.

[2]. *M. I. Montrose, E. M. Nakauchi*. Testing for EMC Compliance: Approaches and Techniques. First edition. Hoboken: Wiley-IEEE Press. ISBN-10: 047143308X, 2004

[3]. *H. W. Ott* Electromagnetic Compatibility Engineering. Hoboken: John Wiley & Sons. ISBN-13: 978-0470189306, 2009.

[4]. *A.J. Lozano-Guerrero, M. P. Robinson, A. Díaz-Morcillo, J. V. Balbastre-Tejedor*, Benefits of using conductive plastics in shielding configurations to reduce radiated electromagnetic interference, Microwave and Optical Technology Letters, **Volume 52**, Issue 11, pp 2476–2480, Nov. 2010, Wiley Periodicals, Inc., DOI: 10.1002/mop.25499

[5]. *G. Ababei, V.David, V.Dafinescu, I. Nica, A. Pica, H. Chiriac.* Omni-Directional Selective Shielding Multilayered Material for High Frequency Radiation, IEEE Transactions on Magnetics, **Volume 48,** Issue 11, Nov. 2012, pp 4309 - 4312, ISSN 0018-9464

[6]. *S. Rea, D. Linton, E. Orr, J. McConnell*. Electromagnetic Shielding Properties of Carbon Fibre Composites in Avionic Systems, Microwave Review, Jun 2005, 29-32

[7]. *D. G. Svetanoff et. al.*, IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures, Standards Committee of the IEEE Electromagnetic Compatibility Society, IEEE Std, 299-1997

[8]. *D.C. Smith*, “Signal and noise measurement techniques using magnetic field probes.”IEEE 1999 International Symposium on Electromagnetic Compatibility, 1999, 559-63.

[9]. *ROM TECH*, Devices to measure electromagnetic radiation, http://romtech.ro/store/index.php?route=product/category&path=85_119, accessed Aug 1 2017

[10]. *Android Developers*, Public class TelephonyManager, https://developer.android.com/reference/android/telephony/TelephonyManager.html, accessed Aug 4 2017

[11]. *Android Developers*, Public class SignalStrength, https://developer.android.com/reference/android/telephony/SignalStrength.html, accessed Aug 4 2017

[12]. *ETSI*, 3GPP TS 27.007 version 8.5.0 Release 8, http://www.etsi.org/deliver/etsi_ts/127000_127099/127007/08.05.00_60/ts_127007v080500p.pdf accessed Aug 4 2017
[13] *Radiocom S.A.*, Electromagnetic field measurements, http://www.radiocom.ro/business/servicii/Alte-Servicii/Masuratori-camp-electromagnetic/ accessed Aug 1 2017
[14]. *NARDA*, SRM-3006, https://www.narda-sts.com/en/selective-emf/srm-3006/, accessed Aug 1 2017