Experimental Analysis of Electromagnetic Interferences Absorber Influence on Metal Enclosure Immunity

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***Abstract*—This paper considers the experimentally conducted analysis of shielding effectiveness of an enclosure with electromagnetic interferences absorber placed at different positions inside. Dimensions of an absorber sheet are fitted to affect the enclosure's first resonant frequency in order to improve its protective function. An absorber sheet inside measured enclosure has an impact on the shielding effectiveness values not only at the first resonance but also in a wider frequency range.**

***Index Terms*—Absorber, Enclosure, EMI absorber sheet, Measurements, Shielding Effectiveness.**

I. Introduction

A common technique to protect electronic equipment from an external electromagnetic (EM) field and an electromagnetic interference (EMI) as well to limit a level of EM field, caused by equipment itself and radiated to surroundings, is to apply shielding [1]. A shielding enclosure may be constructed using steel, aluminum, copper or any other highly conductive material. Still, there are a number of different multipath coupling mechanisms, such as through apertures and cables, which can reduce a protective function of enclosure, usually expressed as the shielding effectiveness (SE). The SE can be determined as logarithmic ratio of electric field with and without shielding enclosure, in the same probe point. Also, the shielding characteristics of an enclosure can indicate negative values of the SE, especially at resonant frequencies of enclosure. Thus, the useful frequency range, in which EM shielding is provided, might be compromised.

To improve the shielding properties, several techniques can be applied. For instance, in [2] and [3], the SE of enclosure was increased by using absorbers or conductive foam. In [4] and [5], the authors proposed to suppress the first resonance in a metal enclosure by putting small antenna elements with loaded resistance. By placing a small dipole or loop antenna structure on the enclosure wall opposite to the enclosure aperture, it was shown that the EM shielding could be improved. In addition to that, it was numerically demonstrated in [6] and the experimentally confirmed in [7] that the physical dimensions of receiving-antenna, often used in experimental set-up to measure a level of EM field, could also affect the SE of enclosure.

In this paper, an influence of an EMI absorber on the SE of enclosure having the frontal wall with rectangular aperture is experimentally studied. During this study, this thin EMI absorber sheet is placed on one or more inner enclosure walls with the goal to consider how the position of absorber affects the SE behavior at the first resonance of enclosure but also at higher resonances. Some other EMI absorber positions inside the same considered enclosure are discussed in [9]. The paper is organized as follows. Section II refers to a physical enclosure's model with the EMI absorber material and a receiving-antenna inside. In Section III, the experimental set-up and measurement procedure are described. Section IV provides discussion of the experimental results. Finally, Section V summarizes the work.

II. Physical Model of Enclosure

The physical enclosure, which is used in the experimental measurements, with the monopole-receiving antenna and the absorber inside is shown in Fig.1. It has a front wall with rectangular aperture (not shown in Fig.1). The enclosure walls are made from copper material. The thickness of the enclosure walls is t = 1.5 mm. The metal enclosure entitled by D has a rectangular shape, with internal dimensions of (300x300x120) mm^3. On the front wall of the enclosure, a slot of dimensions (100x5) mm^2 is positioned symmetrically around the center on the frontal wall. An in-house monopole antenna is placed in the middle of the enclosure to measure the level of EM field inside. An antenna is made of copper wire with a length of 60 mm and radius of 0.1 mm. In order to prevent EM wave leakage from the tested enclosure, a copper strip is bonded to the joints.

Specifically, the absorber material is thin as a sheet of paper and it does not occupy significant space inside the enclosure. The 3M™ EMI Absorber AB7050 from AB7000 Series was available and therefore, it is used in this paper. One side consists of a flexible polymer resin loaded with soft metal flakes and on the other side is covered by an acrylic pressure-sensitive adhesive allows for easy application. This absorber is typically used for applications requiring EMI control and signal integrity improvement in the 50 MHz to 10

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GHz range. It is a broadband EMI absorber designed to work in near-field applications inside and around electronic devices and assemblies [8]. Many factors determine the true attenuation of an EMI absorbing material, including shape and thickness, intimacy of substrate contact, smoothness of application surface, strength and frequency of the EMI signal, etc. [8].

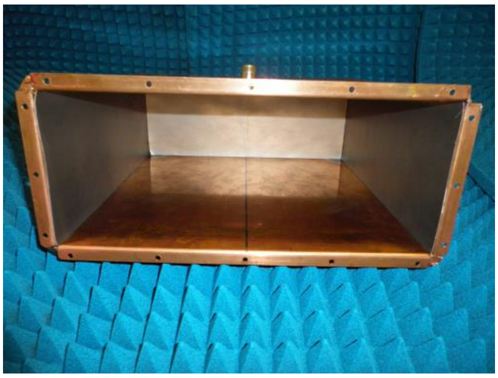

Fig. 1. Physical model of *D* metal enclosure with the EMI absorber on the wall opposite to the frontal enclosure wall and on both side walls.

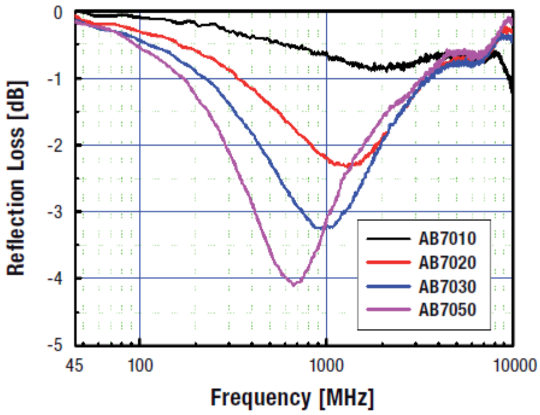

Fig. 2. The reflection loss of the EMI absorber AB7050 sheet which is used for measurement purposes, [8].

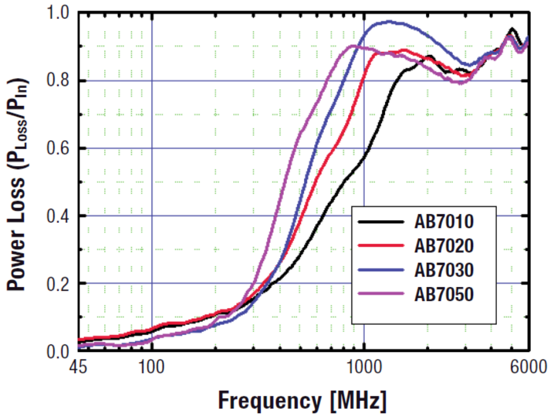

Fig. 3. The power loss of the EMI absorber AB7050 sheet which is used for measurement purposes, [8].

Figs. 2 and 3 present the reflection loss and the power loss of the EMI absorber, respectively, taken from [8]. The absorber characteristics and physical dimensions are given in Table I.

The EMI absorber sheet inside the enclosure *D* is placed in different positions in order to see how it will enhance the shielding characteristics of enclosure especially at the first resonant frequency. Firstly, the absorber is employed on the wall opposite to the front wall with an aperture which is entitled by BcW (back wall). Its dimensions correspond to the internal dimensions of the back enclosure's wall. Secondly, the absorbers are put on both side enclosure walls – entitled by 2SW (two side walls). The dimensions of the absorber are cut to fit the enclosure's side walls which is (297x120) mm^2. In the third case, the absorbers are employed at the same time on all above-mentioned positions, as depicted in Fig. 1. The SE characteristics obtained for this case will be called BcW+2SW.

TABLE I
THE EMI ABSORBER CHARACTERISTICS [8]

Property	Typical Value			
Adhesive	Acrylic non-conductive pressure-sensitive adhesive (PSA)			
Type of backing	Polymer resin with magnetic metal flake filter			
Product number	AB7010	AB7020	AB7030	**AB7050**
Backing thickness	0.1mm	0.2mm	0.3.mm	0.5mm
Adhesive thickness	0.03mm	0.05mm	0.05mm	0.05mm
Standard packaging	210 mm x 297 mm			
Temperature range	-25ºC ~ 85ºC			
Surface Resistivity	1 x 10^6 Ω (min)			
Initial permeability	110			
Typical performance	Refer to S_{11} attenuation and power loss graphs			

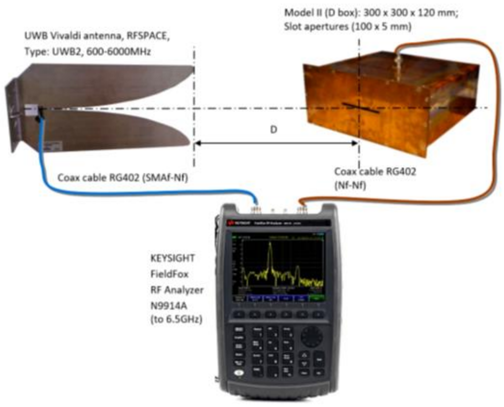

Fig. 4. The sketch of the measuring set-up: transmitting antenna, VNA and EUT (enclosure under test *D*).

III. EXPERIMENTAL PROCEDURE

The measurements are performed in a semi-anechoic room and the measuring set-up is illustrated in Figs. 4 and 5. The Keysight Field Fox RF Analyzer N9914A 6.5 GHz, with a resolution of 100 Hz and a maximum power of 3 dBm, is used as vector network analyzer (VNA). It is connected via cables to a transmitting antenna and a receiving antenna. A vertically polarized dipole antenna of type Vivaldi, as a broadband-antenna with a frequency range from 600 MHz to 6 GHz, is used as a transmitting antenna. As already mentioned, an in-house monopole antenna is used as a receiving antenna. All measurements are taken in the frequency range from 600 MHz to 2 GHz. The measurements are performed in the far-field. The distance is calculated to match that the enclosure under test (EUT) is in the far-field, which is marked as distance (*D*) in Fig. 4. The EMI absorber used in the experimental analysis is cut to fit the inner enclosure's sides.

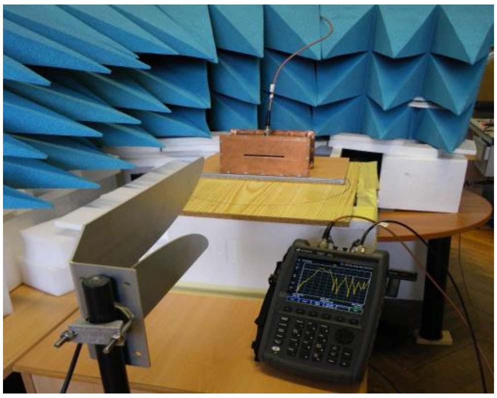

Fig. 5. The measuring configuration used in the semi-anechoic room.

The SE of enclosure is obtained by measure the electric field of EUT with monopole antenna inside and by measure the electric field of monopole antenna without enclosure, in the same probe point (the center of the considered enclosure) [7]. The SE of EUT is obtained by measuring the transmission parameters by using the network analyzer. It is measured twice, without and with enclosure which are marked as s_{21n} and s_{21e}, respectively. Therefore, the SE can be calculated by the following equation: SE [dB] = s_{21n} - s_{21e}.

IV. Discussion of Results

This section presents the experimental results of the SE of enclosure with the EMI absorber inside. To start with, the SE measurement results of enclosure *D* with the absorber employed on the wall opposite to the frontal wall with an aperture, are presented in Fig. 6. The SE results are obtained based on the measured level of EM field inside the enclosure. Figure 6 contains also the SE results for the case of enclosure without absorber (empty enclosure with only receiving antenna inside). As it can be seen from Fig. 6, a physical presence of the absorber led to the SE improvement of enclosure *D* in comparison to the empty enclosure case. In terms of shape, the compared SE curves are similar, however it can be observed that both curves differ regarding the SE levels not only around the first resonance but also at the second resonant frequency. The first resonance of empty enclosure is 686 MHz and the SE value is equal to -14.95 dB, which is critical and might compromise enclosure's shielding properties. On the other hand, the first resonance of enclosure with the EMI absorber occurs at 694 MHz and its SE has a positive value of 5.45 dB. The difference between the SE levels (ΔSE) at the first resonant frequency is 20.4 dB and the frequency shift (Δf_{r1}) related to the first resonance position without and with absorber is 8 MHz, i.e., the first resonant frequency is shifted toward higher frequencies when the EMI absorber is placed inside.

Secondly, the measurement results for the SE of enclosure with the EMI absorbers placed on both side walls are compared to the empty enclosure case. It can be seen that the SE curves do not differ in terms of shape in whole frequency range, see Fig. 7, but the SE levels are different at resonant frequencies around 700 MHz, 1100 MHz and 1650 MHz, respectively. It can be observed a very good absorber efficiency at lower frequencies, while it is weaker at higher frequencies in observed range. Since a very thin EMI absorber is used, the additional TE and/or TM modes are not introduced inside enclosure. The respective SE level difference between compared cases is 23.65 dB, while the frequency shift of the first resonance, Δfr_1, is 8 MHz.

Further, the EMI absorbers are placed at the same time on the wall opposite to the front wall with an aperture and on both side walls of enclosure. The measured SE results are compared to the empty enclosure case in Fig. 8. For this case, the highest SE values are obtained at resonant frequencies of enclosure. The difference between the SE levels (ΔSE) at the first resonance for this case and the case of empty enclosure is 26.5 dB, while the first resonant frequency shift, Δfr_1, is 10 MHz. Again, at higher frequencies, the insertion of absorbers for this case led to the decrease of the SE, as depicted in Fig. 8.

Finally, Fig. 9 presents the zoomed view of the SE around the first resonant frequency for all considered positions of EMI absorber. It can be observed that the SE enhancement is achieved for every position of absorber inside. Moreover, the more absorbers are placed inside the enclosure on different walls, the more significant improvement in the level of the SE characteristics is obtained, especially at the first resonant frequency.

Table II summarizes the measured values of the SE at the first resonant frequency as well as the relative shift of this resonance and SE difference from the case of enclosure without absorber. Definitely, the most prominent frequency shift is obtained for the third case, see Fig. 9. The highest SE value of 11.55 dB at the first resonant frequency is achieved for the case with three absorbers giving the difference of 26.5 dB compared to the SE of enclosure without absorber.

V. Conclusion

In this paper, the presence of the EMI absorber inside the metal enclosure has been considered from the viewpoint of the values of SE of enclosure at its resonant frequencies. The most significant improvement of SE value at the first resonant frequency is obtained for the case with absorbers on the back wall and two side enclosure walls. However, it should be taken into consideration that the EMI absorber presence may also reduce the SE peaks at the higher frequencies in observed frequency range.

Future work will include the numerical analysis together with a developed numerical model of used absorbers, to support the experimental study conducted here. Based on simulated distribution of the EM field inside the enclosure, it would be possible to determine the optimal position of the absorbers inside that can increase the protective function of enclosure at resonant frequencies but also keep its high SE values at other frequencies.

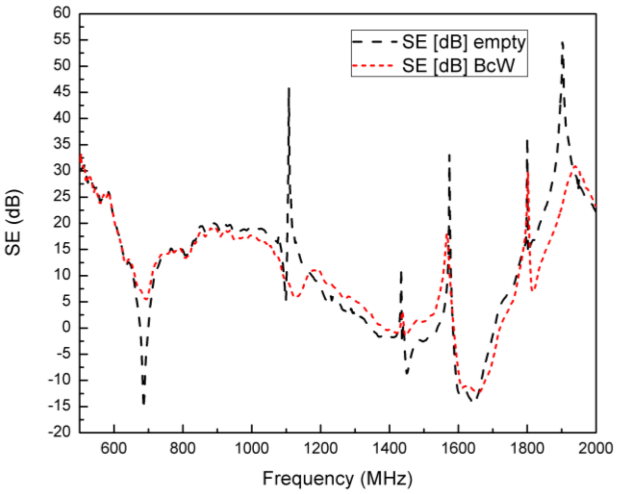

Fig. 6. The measurement results for the SE of the enclosure with the absorber placed on the wall on opposite side from frontal enclosure wall (case BcW).

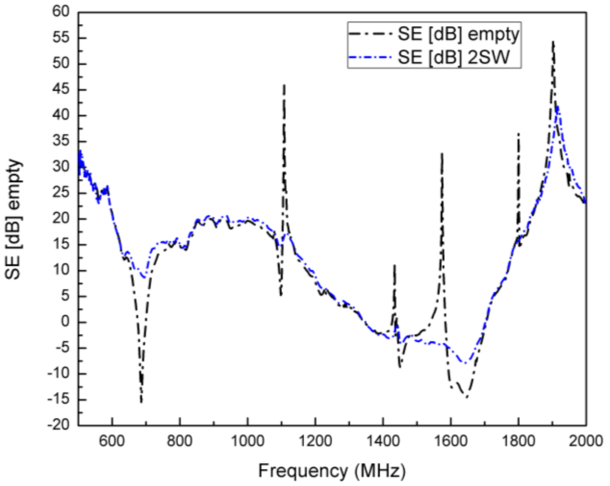

Fig. 7. The measurement results for the SE of the enclosure with the absorber placed on both side walls (case 2SW).

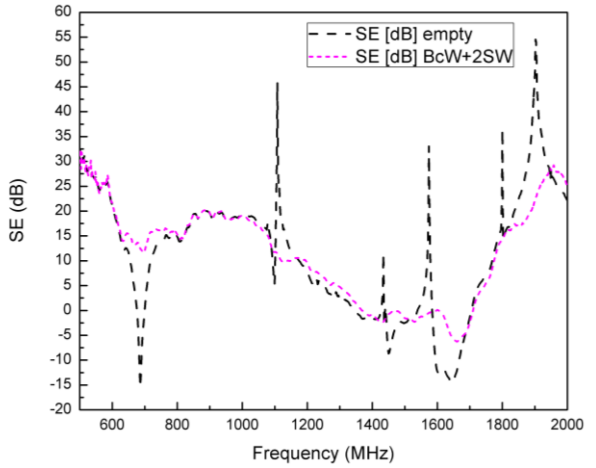

Fig. 8. The measurement results for the SE of the enclosure with the absorber placed on the wall on opposite side to the frontal wall and on both side walls (case BcW+2SW).

ACKNOWLEDGMENT

This work has been supported by the EUROWEB+ project, by the COST IC 1407 and by the Ministry of Education, Science and Technological Development of Republic of Serbia (Grant No. 451-03-9/2021-14/200102).

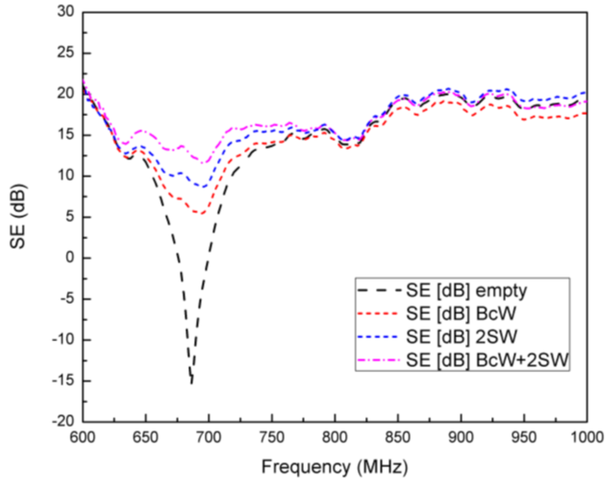

Fig. 9. The measurement results for the SE of enclosure, with the absorber inside, around the first resonant frequency (all three cases).

TABLE II
THE SE VALUES AT THE FIRST RESONANCE OF ENCLOSURE

EMI absorber position	***fr_1_meas* [MHz]**	***SE_meas* [dB]**	***Δfr_meas* [MHz]**	***ΔSE_meas* [dB]**
BcW	694	5.45	8	20.4
2SW	694	8.70	8	23.65
BcW+2SW	696	11.55	10	26.5
Empty	686	-14.95	-	-

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