Shielding Effectiveness Measurement Using a DTEM Cell

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Abstract - **This paper presents a shielding effectiveness evaluation for some metallic threads materials. The tests were performed using a non-standardized method in a dual transversal electromagnetic cell (DTEM). The materials' shielding characteristics must be properly evaluated in order to choose an appropriate shielding material. The tests were conducted for two different types of material designed for electromagnetic shielding. Material 1 has a low density structure, and Material 2 has a dense structure. The tests were performed with a non-standardized method which uses a simple and economical setup, in two different cases. For the first analyzed case only two components were used: a DTEM cell and an EMI Test Receiver. In comparison with the standardized methods, the non-standardized method one used, does not require large testing space and complicated setup, and the material probe needed for DTEM measurements is considerably smaller than the one necessary for the standardized tests. The second studied case comprised a DTEM cell, an EMI Test Receiver, and a hybrid junction. For the second case, the power level was measured with the hybrid junction connected at the inputs A and B, measuring the sum on the C port, and with the hybrid junction connected in the same way, but measuring the difference from the D port. Analyzing the obtained results with the non-standardized method, in all studied cases for the two materials, one can conclude that the shielding effectiveness is better for the high density material.**

Cuvinte cheie: *atenuare, celulă DTEM, eficiența ecranării, materiale de ecranare, ecranare electromagnetică.*

Keywords: *attenuation, DTEM Cell, shielding effectiveness, shielding materials, electromagnetic shielding.*

I. INTRODUCTION

Nowadays, the efficiency of the electromagnetic field shielding studies are an increasingly and ever-evolving trend. The need to improve the performance of shielding materials is an issue of global accuracy.

Design engineers must select adequate shielding materials for the equipment (converters, power supply, etc.) in order to fulfill EMC specifications, as well as to fulfill other requirements such as mechanical properties, appearance, environmental considerations, costs etc.

To choose a suitable shielding material, the materials shielding characteristics must be evaluated in a proper way. Usually, adequate shielding is achieved using materials with electromagnetic properties that are well understood. Technical domains such as consumer electronics, automotive, and avionics are using more and more new lightweight or low-cost materials such as composites. The shielding effectiveness (SE) of these materials can be hard to predict [1].

In order to prevent interfering signals from leaking out as well as making sure that the equipment is not susceptible to allowable amount of interference an electromagnetic shielding is required [2].

Thus, there is a significant interest towards developing measurement procedures which yield useful SE data. Existing techniques include the shielded-room approach based on IEEE-Std 299:2006 [3], the coaxial transmission line, the dual box, the transfer-impedance method, time-domain measurements, and waveguide approaches such as the dual transverse electromagnetic (DTEM) cell [4]. The dual TEM cell is one of the shielding measurement equipment that was thoroughly investigated [5], [6], [7]. A DTEM cell has many advantages: simple construction, handling convenience, large field scope, wide frequency band, low cost and ease of use [8].

Most often, shielding materials are evaluated in terms of shielding effectiveness (SE) [9]. However, it is known that the SE is not an intrinsic parameter of shielding material. The SE value depends on the condition of how the material is measured. To theoretically relate SE as a material parameter, or to physically understand the shielding mechanism, the equivalent circuit approach can be depicted in Fig. 1 [1].

Because a high shielding performance of the materials is needed, it is necessary to compare them in order to achieve their classification [10].

The effectiveness of shielding materials can be determined using standardized methods, according to IEEE-Std 299:2006 – "Standard method for measuring the effectiveness of electromagnetic shielding enclosures," which is an adequate replacement for MIL-STD-285, "Method of attenuation measurement for enclosures, electromagnetic shielding, for electronic test purposes" (that has been canceled) [3].

The test setup used for shielding effectiveness in compliance with the above standardized methods, involves a large testing area and a complex configuration. We chose to perform measurements using a method that does not meet the above standards, based on the use of a DTEM cell connected with a device that allows simultaneous use of the input and output function.

II. Evaluation Methods for Shielding Effectiveness

A. *Shielding Effectiveness Evaluation Using Only a DTEM Cell*

Fig. 1 presents the measurement of shielding effectiveness for two different materials used in electromagnetic shielding.

The setup contained the following components and devices:

•EMI Test Receiver ESCI 03, with the frequency range 9 kHz ÷ 3 GHz (manufactured by Rohde & Schwarz, Germany) [10];

•DTEM Cell;

•Coaxial measuring cables.

The measurements conducted in this first part of testing, were performed using a test setup with a DTEM cell and an ESCI 03 receiver. The receiver has built-in the function “tracking generator” which allows the use of the receiver both as generator and as a receiver for a certain frequency range.

The DTEM cell, which comprises two cells with hexagonal shape, and a rectangular cut between them, it’s presented in Fig. 2. The connectors at the extremities of the two hexagonal cells are used for connecting the coaxial cables with a standard 50 Ω impedance at the two cell ports.

The cell has an internal field that is evenly distributed, and used for simulating the far field. The DTEM cell operates bidirectionally, the two hexagonal cells, coupled by the rectangular cutting, forming a measuring system [11]. The uniform field from the lower cell is generated in the upper cell through the cutting between the two cells. When inserting and measuring a material probe on the cut, the signal strength between the two cells decreases. The signal attenuation is the shielding effectiveness of the tested material.

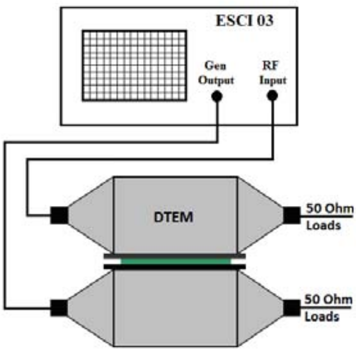

Fig. 1. Shielding effectiveness measurement schematic.

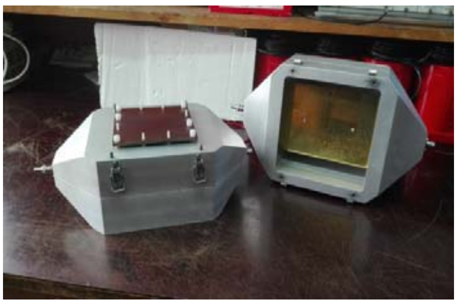

Fig. 2. DTEM Cell used for measurements.

B. *Evaluation of Shielding Effectiveness Using a DTEM Cell with Hybrid Junction*

Shielding effectiveness measurement for the two materials used in electromagnetic shielding was performed using the scheme depicted in Fig. 3.

The setup components were the following:

•EMI Test Receiver ESCI 03;

•DTEM Cell;

•Hybrid junction;

•Coaxial measuring cables.

The hybrid junction and its functional diagram are exposed in Fig. 4.

H-9 inputs are defined by port A and port B. These two ports are the input of the junction that will be connected in order to measure the field induced in the upper DTEM cell.

If two input signals are added to the A and B ports respectively at the same time, then their “Addition Power” signal is obtained at the Σ port (C port) while their “Subtraction Power” signal is obtained at the Δ port (D port).

From the C port (Σ port) the sum of the two inputs (A and B) was measured. The difference between A and B (phase difference at 180^0) was measured on the D port (Δ port).

Given the condition that the impedance of the four ports matches each other, the following performances are obtained [8], [13]:

(1) When the input signal is added to the Σ port, the signal is shared equally at the A and B ports, and both two output signals have the same phase. Δ port and Σ port are isolated here.

(2) When the input signal is added to the Δ port, the signal is shared equally at A and B ports likewise, but the two output signals of A and B ports just have opposite phases. The Σ port gains no signals here. In other words, the Δ port and Σ port are still isolated.

(3) When the input signal is added to the A port, the signal is shared equally at the Δ and Σ ports, and both two output signals have the same phase. The B port gains no signals here. In other words, the A port and B port are isolated.

(4) When the input signal is added to the B port, the signal is shared equally at the Δ and Σ ports likewise, but the two output signals of Δ and Σ ports have opposite phases. The A port gains no signals here. In other words, the A port and B port are still isolated.

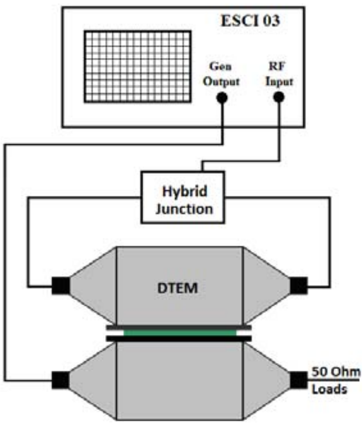

Fig. 3. Shielding effectiveness measurement schematic, with Hybrid junction.

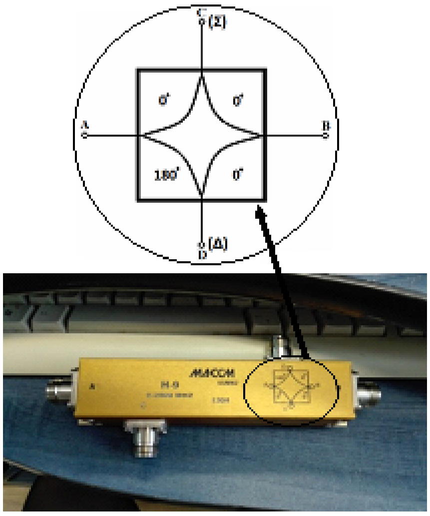

Fig. 4. Hybrid junction H-9 and functional diagram.

III. Test Results for Shielding Effectiveness Evaluation

Measurements were performed on two different types of materials in the frequency range from 8 MHz to 1 GHz. The materials are designed for electromagnetic shielding.

A. Test Results Using Only a DTEM Cell

The setup configuration used for SE measuring using only a DTEM Cell is depicted in Fig. 5.

The results obtained for the material shielding effectiveness, as a result of the measurements made using the DTEM Cell and the EMI Test Receiver ESCI 03, are shown in Fig. 6 – Fig. 8.

Analyzing the results obtained for each material, one noticed that the material with a high density of metallic threads presents raised shielding properties. In case of the Material 1, which has a low density structure, a low attenuation property is observed (Table I).

After computing and processing the measured values, the attenuation for each tested material was obtained. These values can be depicted in Fig. 9 and Fig. 10.

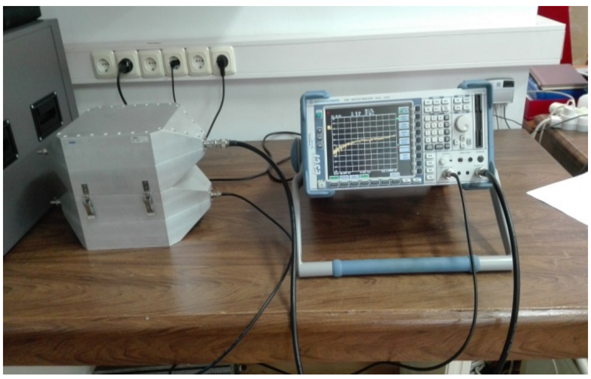

Fig. 5. Measuring shielding effectiveness using DTEM Cell.

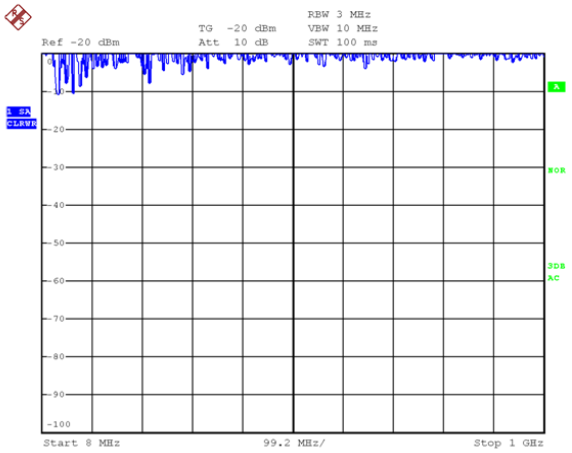

Fig. 6. DTEM cell signal strength level measured without the test sample (using only the DTEM Cell).

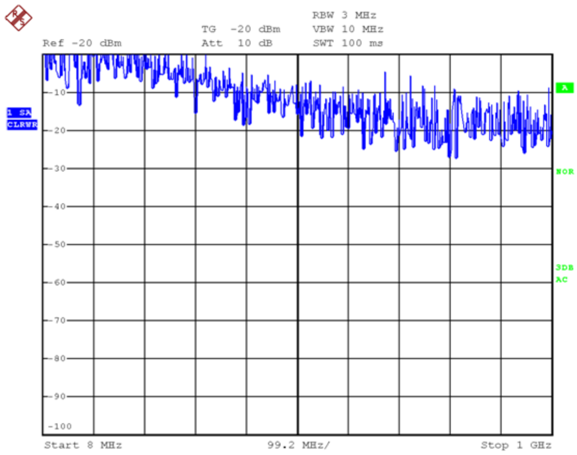

Fig. 7. Power level of the measured signal for Material 1 (using only the DTEM Cell).

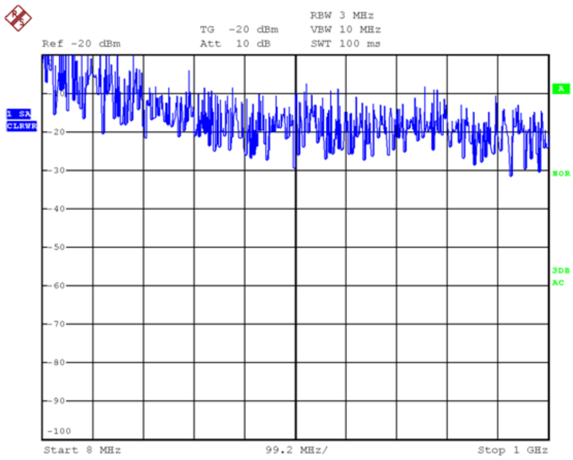

Fig. 8. Power level of the measured signal for Material 2 (using only the DTEM Cell).

TABLE I.
ATTENUATION MEASUREMENT RESULTS FOR THE ELECTROMAGNETIC FIELD IN CASE OF THE TWO MATERIALS MEASURED

Frequency [MHz]	Reference level [dBm]	Material 1 [dBm]	Material 2 [dBm]	Attenuation Material 1 [dBm]	Attenuation Material 2 [dBm]
100	2.38	-5.07	-4.12	7.45	6.5
200	0.4	-4.09	-7.9	4.49	8.3
300	-0.7	-1.5	-10.87	0.79	10.16
400	-1.19	-5.4	-9.92	4.21	8.73
500	0.34	-10.04	-14.1	10.38	14.44
600	-0.15	-22.16	-21.12	22.01	20.97
700	-1.01	-13.83	-24.48	12.82	23.47
800	1.01	-24.39	-10.01	25.39	11.02
900	-1.74	-14.19	-26.89	12.45	25.15
1000	-0.4	-20.17	-26.19	19.78	25.79

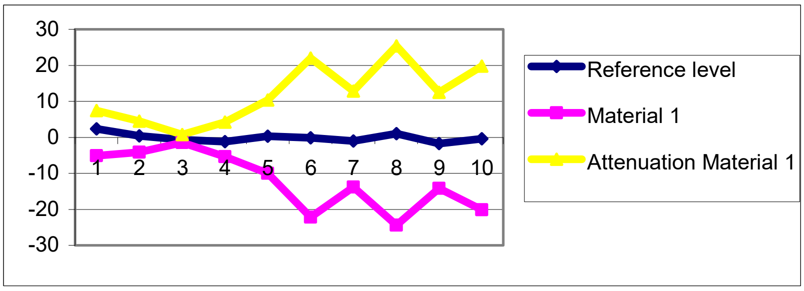

Fig. 9. Attenuation graphical representation for Material 1, using only the DTEM Cell.

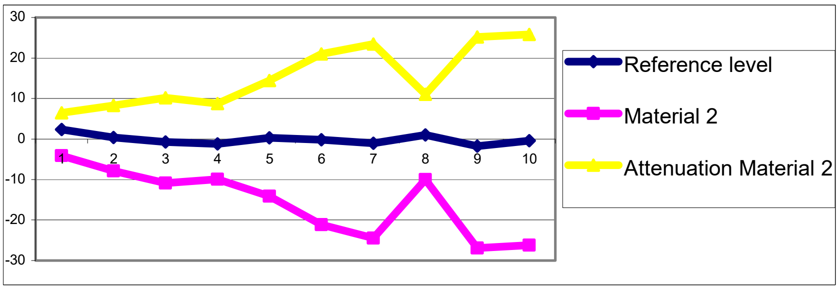

Fig. 20. Attenuation graphical representation for Material 2, using only the DTEM Cell.

B. Test Results Using Only a DTEM Cell and Hybrid Junction

The test setup one used for SE measuring using a DTEM Cell and a hybrid junction is depicted in Fig. 11 [14].

The second studied case comprised a DTEM cell, an EMI Test Receiver, and a hybrid junction. For this second case, the power level was measured with the hybrid junction connected at the inputs A and B, measuring the sum on the C port (A-C-B), and with the hybrid junction connected in the same way, but measuring the difference from the D port (A-D-B).

The results obtained for the material shielding effectiveness, as a result of the measurements made using the DTEM Cell, hybrid junction A-C-B, and the EMI Test Receiver ESCI 03, are shown in Fig. 12 – Fig. 14.

Table II contains the result for shielding effectiveness measurement performed with hybrid junction A-C-B.

After computing and processing the measured values, the attenuation for each tested material was obtained. The graphical representations for these values can be depicted in Fig. 15 and Fig. 16.

The results obtained for the material shielding effectiveness, as a result of the measurements performed using the DTEM Cell, hybrid junction A-D-B and the EMI Test Receiver ESCI 03, are shown in the figures below: Fig. 17 – Fig. 19. The results for shielding effectiveness measurement made with hybrid junction A-D-B are exposed by Table III.

After computing and processing the measured values, the attenuation for each tested material was obtained. These values can be depicted in Fig. 20 and Fig. 21.

Fig. 31. Test setup for shielding effectiveness measuring, using a DTEM Cell and a hybrid junction.

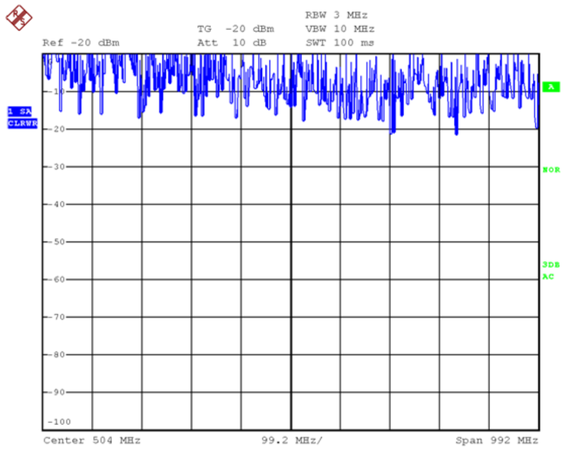

Fig. 43. Power level of the measured signal for Material 1, using hybrid junction A-C-B.

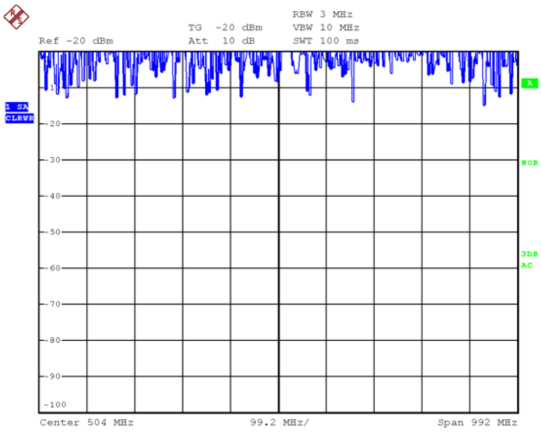

Fig. 12. DTEM Cell signal strength level measured without the test sample, with hybrid junction A-C-B.

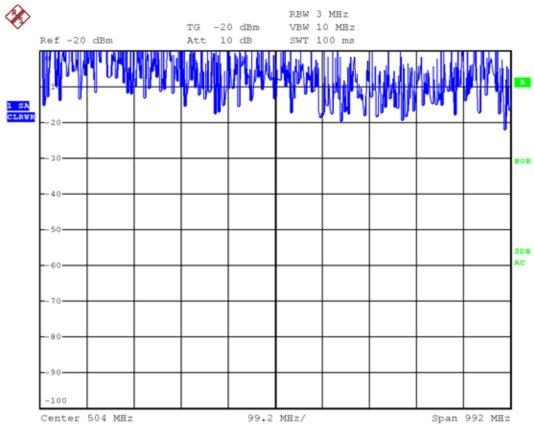

Fig. 14. Power level of the measured signal for Material 2, using hybrid junction A-C-B.

TABLE II.
MEASURING THE SHIELDING EFFECTIVENESS WITH HYBRID JUNCTION A-C-B

Frequency [MHz]	**Reference level [dBm]**	**Material 1 [dBm]**	**Material 2 [dBm]**	**Attenuation Material 1 [dBm]**	**Attenuation Material 2 [dBm]**
100	8.67	1.83	-0.89	6.84	9.55
200	-0.12	-3.57	-10.35	3.45	10.22
300	1.80	-4.30	-8.91	6.10	10.71
400	-0.15	-11.54	-15.93	11.38	15.78
500	0.09	-8.55	-18.95	8.64	19.04
600	-3.02	-11.99	-16.15	8.97	13.12
700	-1.80	-11.05	-15.66	9.25	13.86
800	-2.14	-13.46	-17.30	11.32	15.17
900	-1.46	-18.65	-24.66	17.18	23.20
1000	-2.04	-17.43	-22.19	15.38	20.14

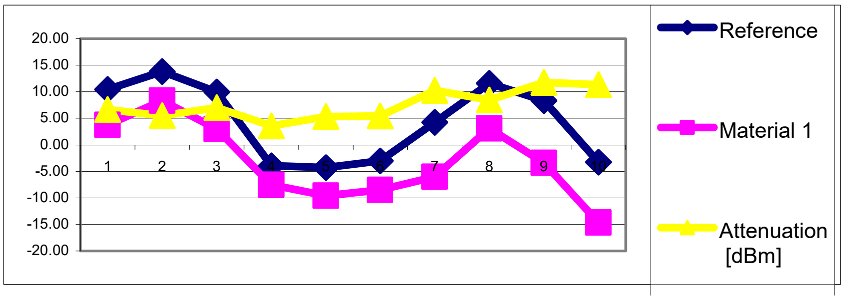

Fig. 15. Attenuation graphical representation for Material 1, using hybrid junction A-C-B.

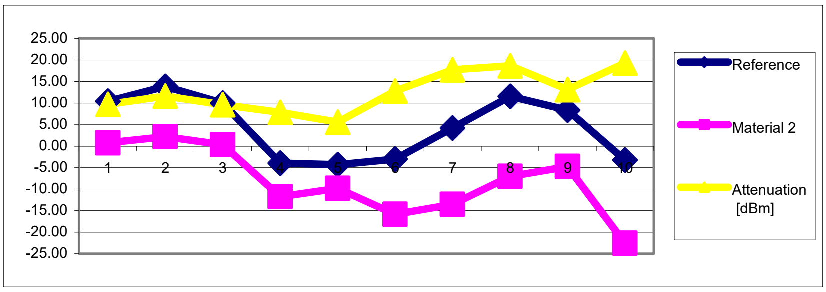

Fig. 16. Attenuation graphical representation for Material 2, using hybrid junction A-C-B.

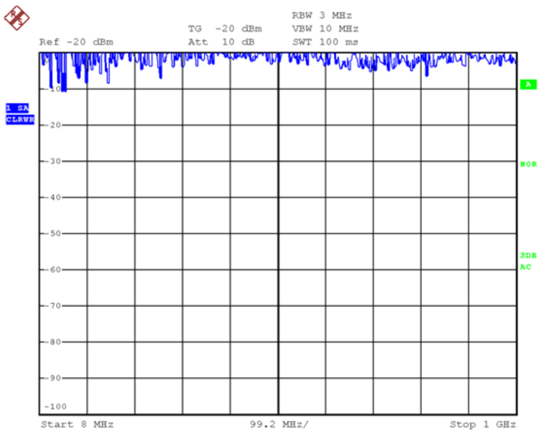

Fig.17. DTEM Cell signal strength level measured without the test sample, with hybrid junction A-D-B.

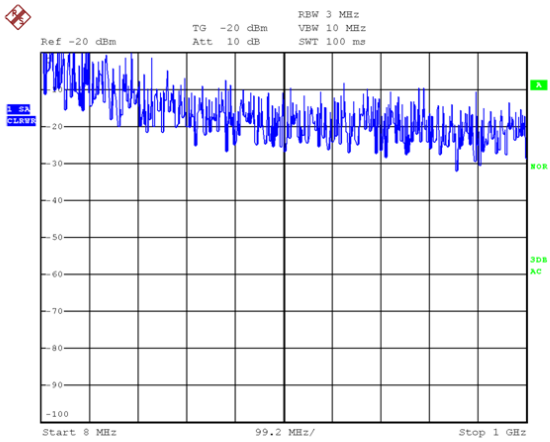

Fig. 19. Power level of the measured signal for Material 2, with hybrid junction A-D-B.

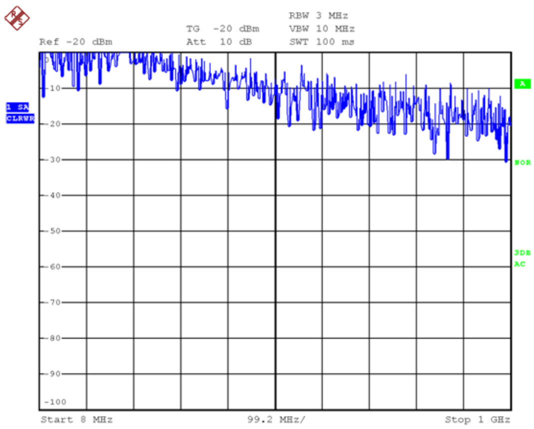

Fig.18. Power level of the measured signal for Material 1, with hybrid junction A-D-B.

IV. CONCLUSIONS

The paper objective was to demonstrate that the results obtained during test period are conclusive, even though a non-standardized method was used.

The conducted comparative analysis yielded that a high attenuation is achieved for the materials which have a high density of metallic threads.

Measurements performed with only the DTEM cell and the "tracking generator" function of the EMI Test Receiver ESCI 03, allowed conclusive testing regarding the material shielding effectiveness with a non-standardized method. In comparison with other standardized methods designed for this kind of measurements, the non-standardized method one used has the advantage of performing the test with probe materials that presents reduced dimensions.

TABLE III.
MEASURING THE SHIELDING EFFECTIVENESS WITH HYBRID JUNCTION A-D-B

Frequency [MHz]	Reference level [dBm]	Material 1 [dBm]	Material 2 [dBm]	Attenuation Material 1 [dBm]	Attenuation Material 2 [dBm]
100	8.67	1.83	-0.89	6.84	9.55
200	-0.12	-3.57	-10.35	3.45	10.22
300	1.80	-4.30	-8.91	6.10	10.71
400	-0.15	-11.54	-15.93	11.38	15.78
500	0.09	-8.55	-18.95	8.64	19.04
600	-3.02	-11.99	-16.15	8.97	13.12
700	-1.80	-11.05	-15.66	9.25	13.86
800	-2.14	-13.46	-17.30	11.32	15.17
900	-1.46	-18.65	-24.66	17.18	23.20
1000	-2.04	-17.43	-22.19	15.38	20.14

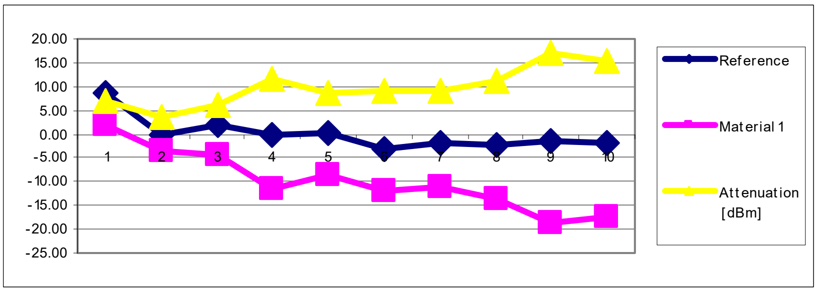

Fig. 20. Attenuation graphical representation for Material 1, using hybrid junction A-D-B.

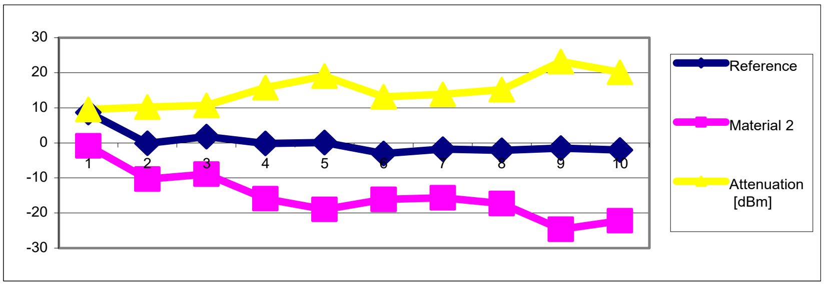

Fig. 21. Attenuation graphical representation for Material 2, using hybrid junction A-D-B.

Using the H-9 hybrid junction, the results of the measurement lead to the conclusion that the material with a higher density has a higher attenuation than the low-density material both in A-C-B mode and in A-D-B mode.

One can conclude that relevant results are obtained using a non-standardized method, and the shielding effectiveness is better for the material with a high density.

Contribution of authors:
First author – 50%
First coauthor – 10%
Second coauthor – 10%
Third coauthor – 10%
Fourth coauthor – 10%
Fifth coauthor – 10%

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