PAPER Nr.: 94

EMC CHARACTERISTICS OF COMPOSITE STRUCTURE
(ELECTRIC/ELECTROMAGNETIC SHIELDING ATTENUATION)

BY

P. WEGERTSEDER AND R. BREITSAMETER

MESSERSCHMITT-BÖLKOW-BLOHM GMBH
MUNICH, GERMANY

FIFTEENTH EUROPEAN ROTORCRAFT FORUM

SEPTEMBER 12 - 15, 1989 AMSTERDAM

"EMC CHARACTERISTICS OF COMPOSITE STRUCTURE"
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MESSERSCHMITT-BÖLKOW-BLOHM GmbH
Munich, Germany

1. Abstract

The development of new helicopters shows a world wide tendency to replace metalic structures by modern composite structures. The advantages of those composite structures made from glas, carbon, aramid and other suitable fibres are evident.

On the other side the low galvanic conductivity of carbon structures and the non conductivity of glas and aramid structures drastically increase problems concerning electromagnetic compatibility (EMC) of a helicopter. To achieve a specified electric/electromagnetic shielding attenuation of a helicopter fuselage special measures has to be applied to composite structures.

To gain practical experience concerning shielding attenuation of composite structures different test boxes with a volume of approximately 0.5 m x 1.0 m x 1.0 m each were built with the materials and processes as intended to use for the construction of the helicopter. Electric/Electromagnetic shielding attenuation measurements were performed on this boxes in the frequency range 14 kHz to 18 GHz investigating the influence of

- different composite materials
- jointing and bonding of structure parts of the box
- application and bonding of mesh
- construction of access panels
- conductive seals on access panels

2. Introduction

The helicopter is provided with several avionic bays in the center and foreward fuselage which mainly contains rack mounted avionic equipment boxes including cable harness. Large door with maximum dimensions of approximately 800 x 800 mm^2 shall allow good accessibility. They also have to be easily opened and closed without hand tools and shall avoid penetration of humidity.

According to the requirements of EMI/EMC specification the avionic bays/fuselage has to provide a certain shielding attenuation to reduce the fieldstrength of an external electromagnetic RF field. There are well known technics to assure shielding attenuation of a metal fuselage. High conductivity of used metals provide moderate shielding attenuation even in case the shielding enclosure is not optimized in construction concerning holes and access doors. On the other side modern composite structures made from carbon, glas, aramid or other suitable fibres provide no or, compared to metal, drastically reduced galvanic conductivity. This conductivity, however, is the basic requirement to obtain shielding attenuation against electromagnetic RF-fields. To regain shielding properties of non conductive composite structures all surfaces have to be covered with conductive coating e.g. mesh, metallic foils, flame sprayed or painted conductive materials. Structure made from carbon basically show shielding properties whose value depends on thickness of material and quality of bonding of adjacent panels. A possible low impedance bonding of structure parts may vanish if resin, adhesive or other non conductive materials reduce effective contact area.

There are many test results of shielding attenuation measurement on flat panels but this information is not very helpfull regarding shielding attenuation of volumic structures such as fuselages. Therefore, EMI test boxes were built in order to perform tests and gain practical experience on electromagnetic shielding of composite structures.

3. Description of Test Specimen

3.1 Test Boxes

Two test boxes were built with the materials and processes as intended to use for the construction of the helicopter fuselage. Both boxes were of the same dimensions as shown in figure 1.

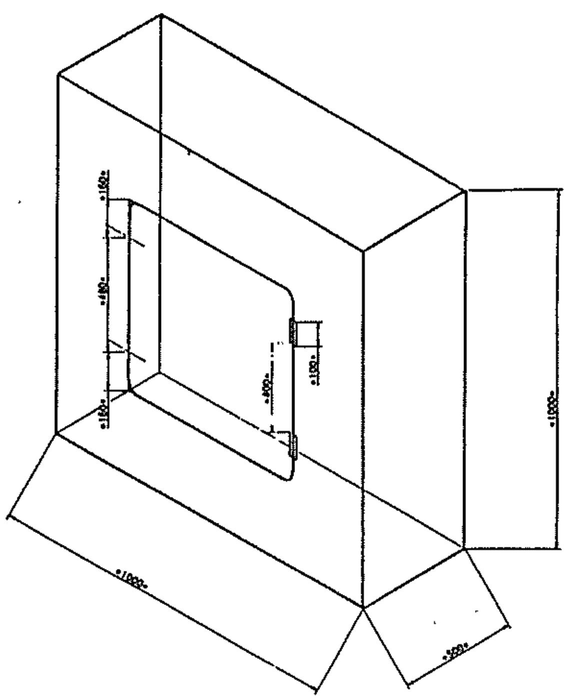


Figure 1

The surface of one box was totaly covered with copper mesh, required by EMI and lightning protection reasons, the other box was prepared without mesh. Figures 2 a, b, c show details of the lay out of box frame and skin.

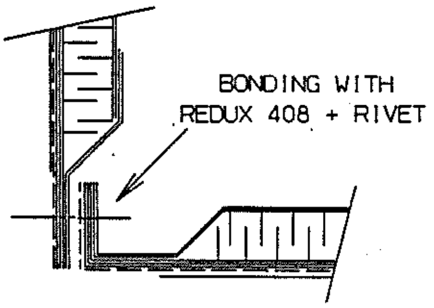


Figure 2 a

DETAIL FOR FRAME AND SKIN WITHOUT MESH

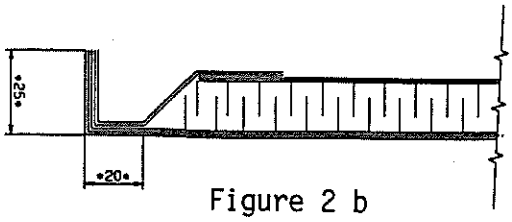


Figure 2 b

DETAIL FOR FRAME AND SKIN WITH MESH

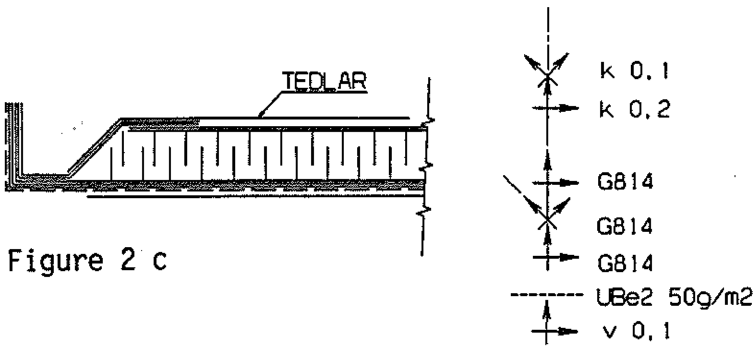


Figure 2 c

Since both boxes had been completely closed during production, the rear side was provided with a rectangular opening (300 mm x 300 mm) to find a possibility to put in the necessary reception antenna. After positioning of the used RX antenna this opening was closed by an aluminum plate which was bonded onto box. This plate was equiped with a coax feed through adapter. The front side of each box was prepared to be equiped with a door after shielding attenuation measurements of completely closed box had been finished.

3.2 Doors

After performance of measurements on completely closed box, the frontside of each box was cut out to take a door with the dimensions 800 mm x 800 mm. The doors were fixed by hinges and kept closed by simple fasteners (see figure 3). The lay out of the door structure is shown in figures 4 a, b.

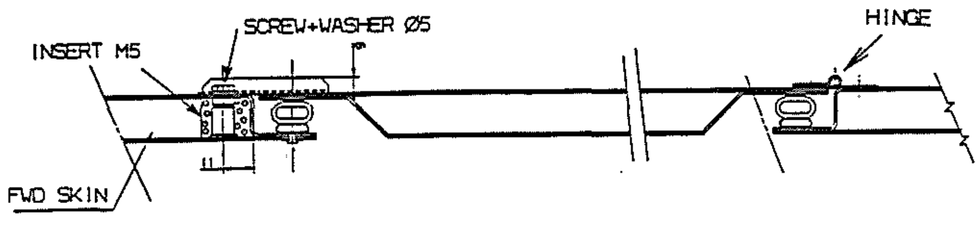


Figure 3

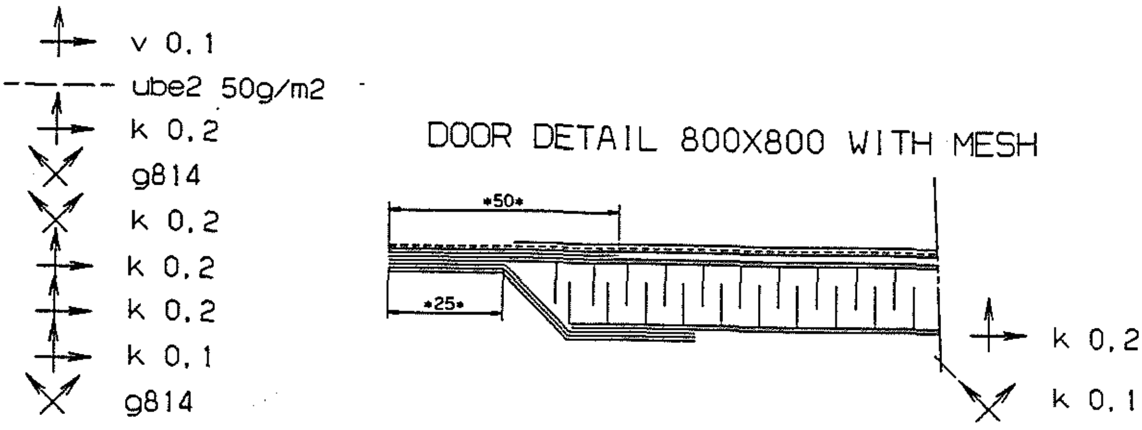


Figure 4 a

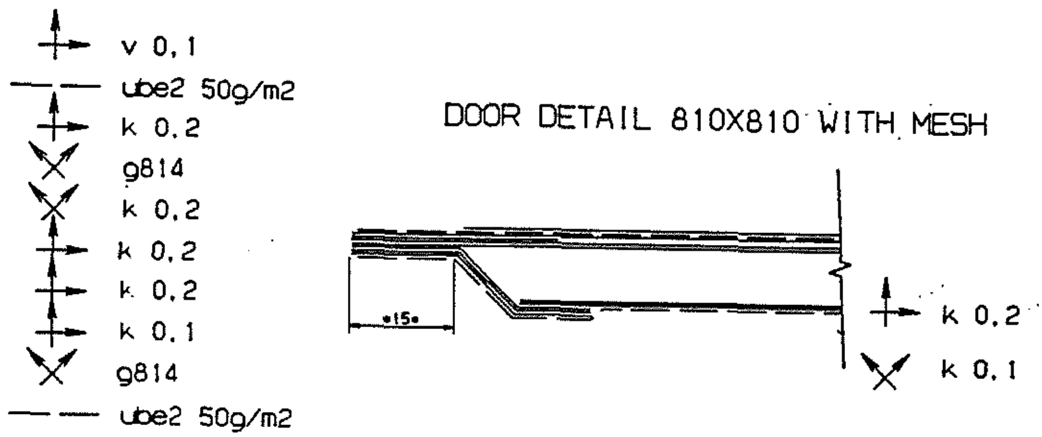


Figure 4 b

3.3 Seals

The seal has to provide two functions, first humidity seal, second to guaranty a high conductive path from the box forward shell towards the door to maintain shielding properties of fuselage. This has to be true even under the influence of mechanical stress, vibration, aging etc. During measurements two different types of seals were used:

- Elastomeric seals based on silicone, conductivity is achieved by metallic powder or conductive painting of the surfaces of the seals. This type of seal was fixed to the forward shell by means of an aluminum profile which was bonded onto the structure (see figure 3).

- Double function seal with non conductive elastomeric humidity seal and adjacent metallic gasket to verify a good conductive connection between foreward shell and door. This seal was fixed by clamping onto the flange of the foreward shell (see figure 5).

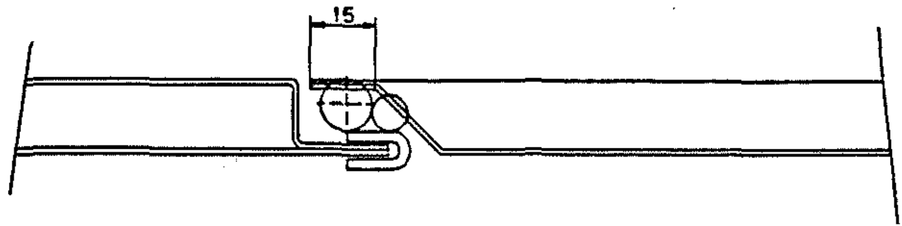


Figure 5

4. Test set up, Test Procedure

Shielding attenuation measurement was performed within a shielded anechoic chamber (see figure 6). Each test box was positioned upon a wooden table approximately one meter in front of the transmission antenna. To cover the desired frequency range a plate antenna and double ridged guide antennas were used as transmission (TX) antennas to generate the electric/electromagnetic field. A monopole antenna with groundplane and adjustable monopole length for measurements up to 1 GHz and a ridged guide antenna for the frequency range 1 GHz to 18 GHz were used as reception (RX) antennas. The connection from RX antenna towards the wall of the shielded chamber was performed by semi rigid and high quality coax cable to avoid undesired radiation coupling directly into the reception cabling.

Due to the limited bandwidth of the used power amplifiers and TX antennas the complete frequency range was divided into the frequency sections 14 kHz to 200 MHz, 200 MHz to 500 MHz, 500 MHz to 1 GHz, 1 GHz to 12,4 GHz and 12,4 GHz to 18 GHz. For each frequency section separate test runs were performed with the following procedure:

In a first test run a so called "Open Space" measurement without test box was performed. By means of a computer the signal generator/power amplifier output power to TX antenna was adjusted to obtain via RX antenna a reception power of 0 dBm at the input of the analyzer. TX frequency and the associated TX power were stored for all frequency increments over the desired frequency section. After this "Open Space" measurement the box was installed with the RX antenna at its center. TX power as stored in the first test run was injected once again into the TX antenna. According to shielding attenuation provided by the box in its special configuration RX power at the analyzer input was reduced below 0 dBm. The difference in RX power of first to second test run was expressed as shielding attenuation of test box and plotted against frequency.

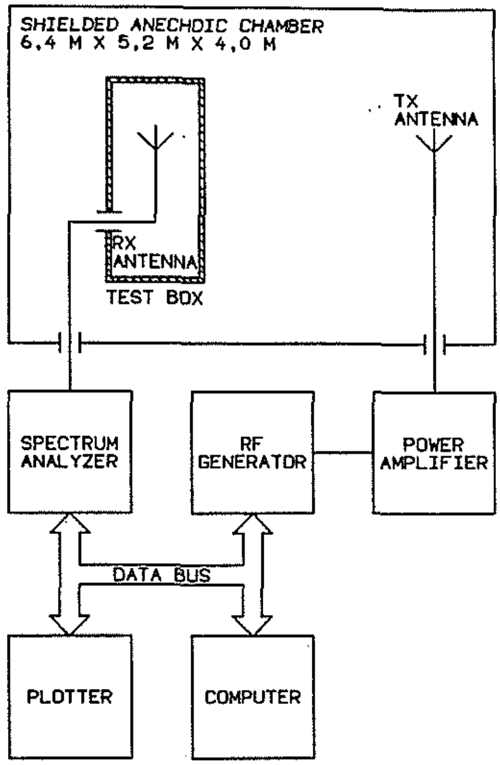


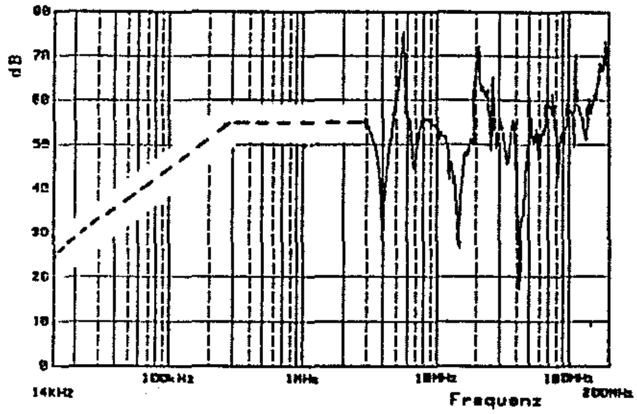
Figure 6

In the frequency range 14 kHz up to approximately 5 MHz the dynamic range of the test set up was to low to verify shielding attenuation of boxes due to low efficiency of TX antenna and unsufficient effective antenna height of RX antenna. In the frequency 1 GHz up to 18 GHz the monopole antenna was replaced by a double ridged guide RX antenna. Since this antenna shows a certain directivity in the antenna pattern compared to a monopole, electromagnetic radiation energy was picked up only from the direction of the main lobe of this RX antenna. This directivity provided virtual higher shielding attenuation values of the box. As indicated the shielding attenuation measurements were performed first on completely closed boxes than on the test box covered with mesh and equiped with door and seal.

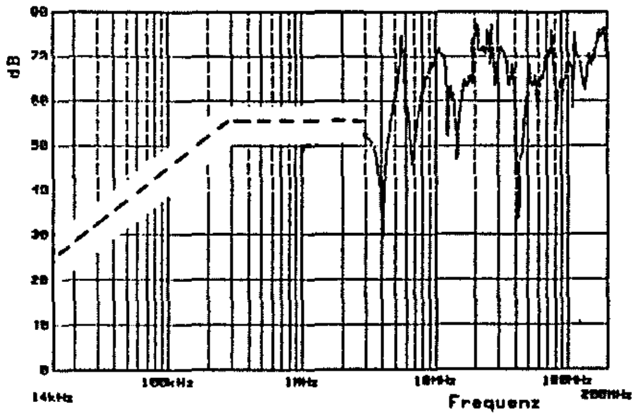
5. Measurement Results

From the huge amount of test results the most significant plots will be presented for each frequency section as a comparison between

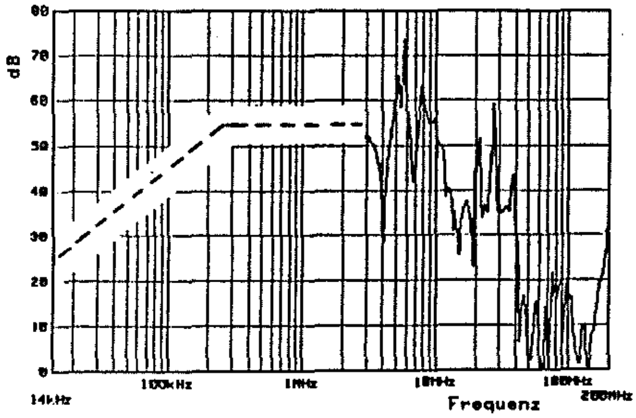
- closed box without door, no mesh on box surface (figures 7 a, 8 a, 9 a, 10 a, 11 a)
- closed box without door, mesh on all box surfaces (figures 7 b, 8 b, 9 b, 10 b, 11 b)
- box with mesh on all surfaces, door and elastomeric seal of poor conductivity (figures 7 c, 8 c, 9 c, 10 c, 11 c)
- box with mesh on all surfaces, door and seal with high conductive gasket (figures 7 d, 8 d, 9 d, 10 d, 11 d)



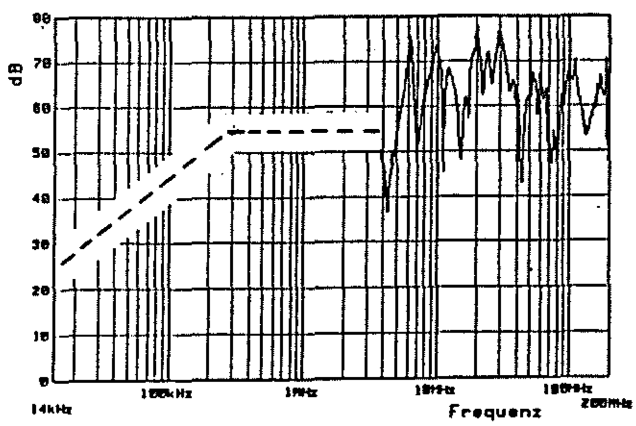
7 a: Closed box without mesh



7 b: Closed box with mesh

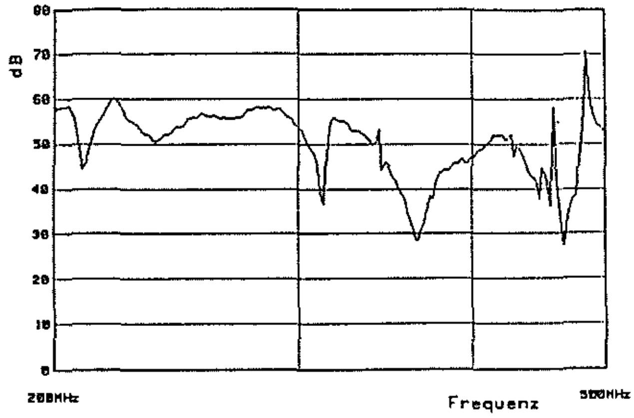


7 c: Box with door low conductive seal

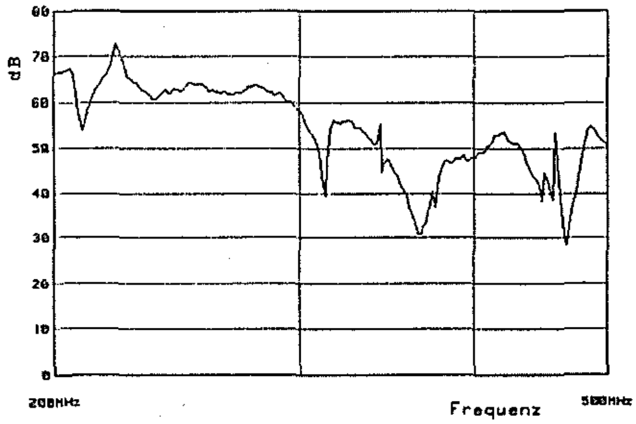


7 d: Box with door high conductive seal

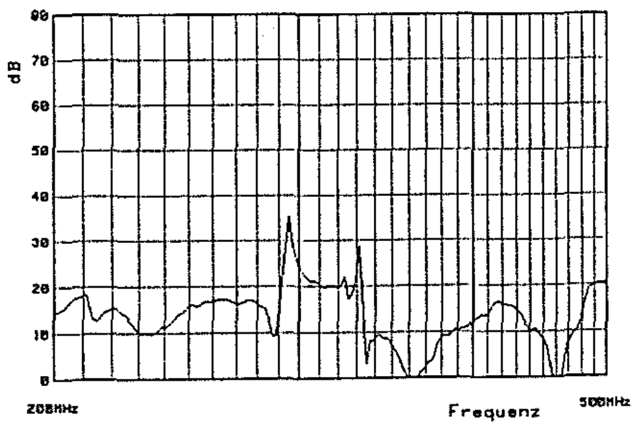
Figure 7: Shielding attenuation 14 kHz - 200 MHz



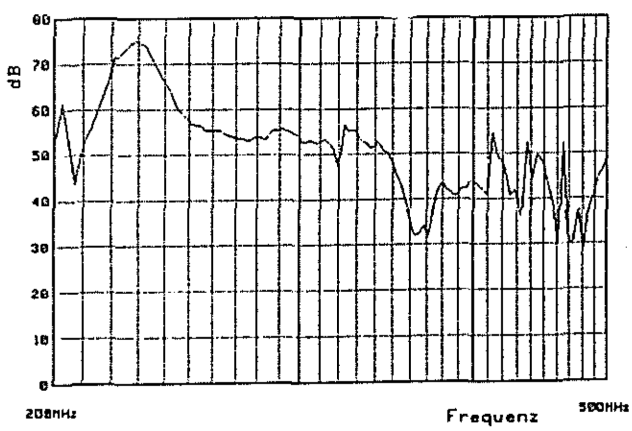
8 a: Closed box
without mesh



8 b: Closed box
with mesh

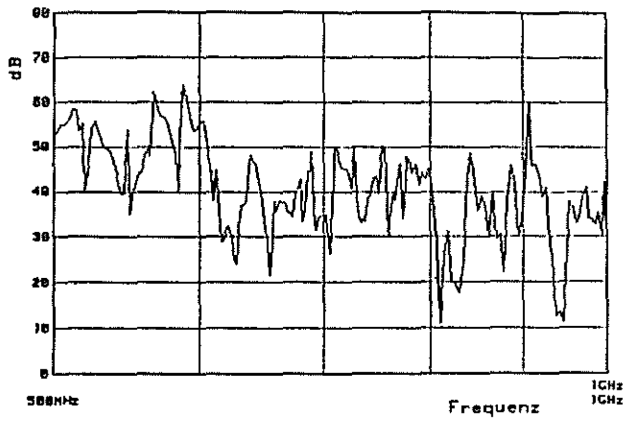


8 c: Box with door
low conductive
seal

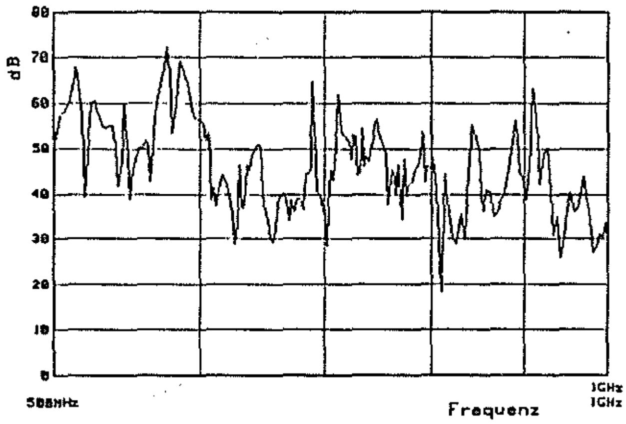


8 d: Box with door
high conductive
seal

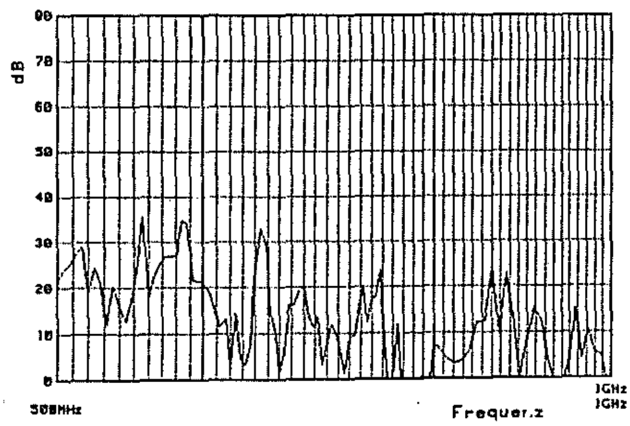
Figure 8: Shielding attenuation 200 MHz - 500 MHz



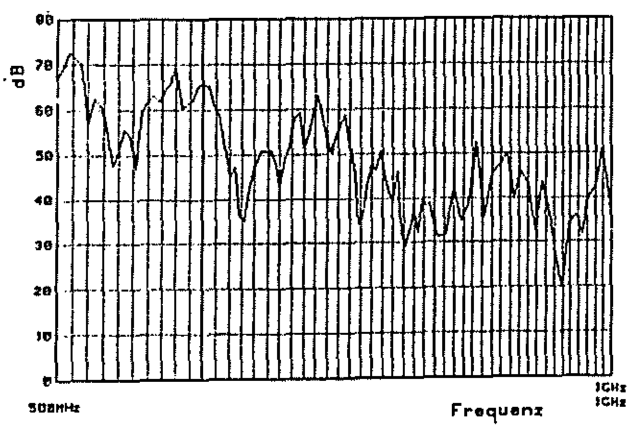
9 a: Closed box without mesh



9 b: Closed box with mesh

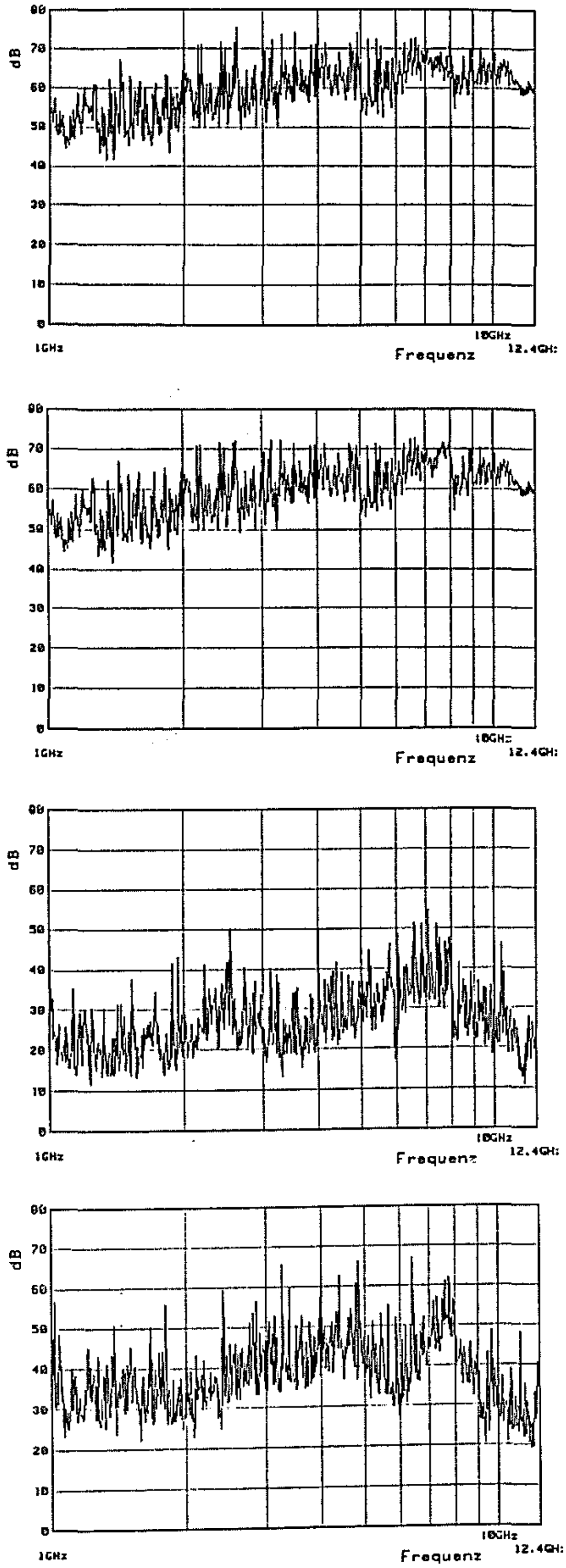


9 c: Box with door low conductive seal



9 d: Box with door high conductive seal

Figure 9: Shielding attenuation 500 MHz – 1 GHz



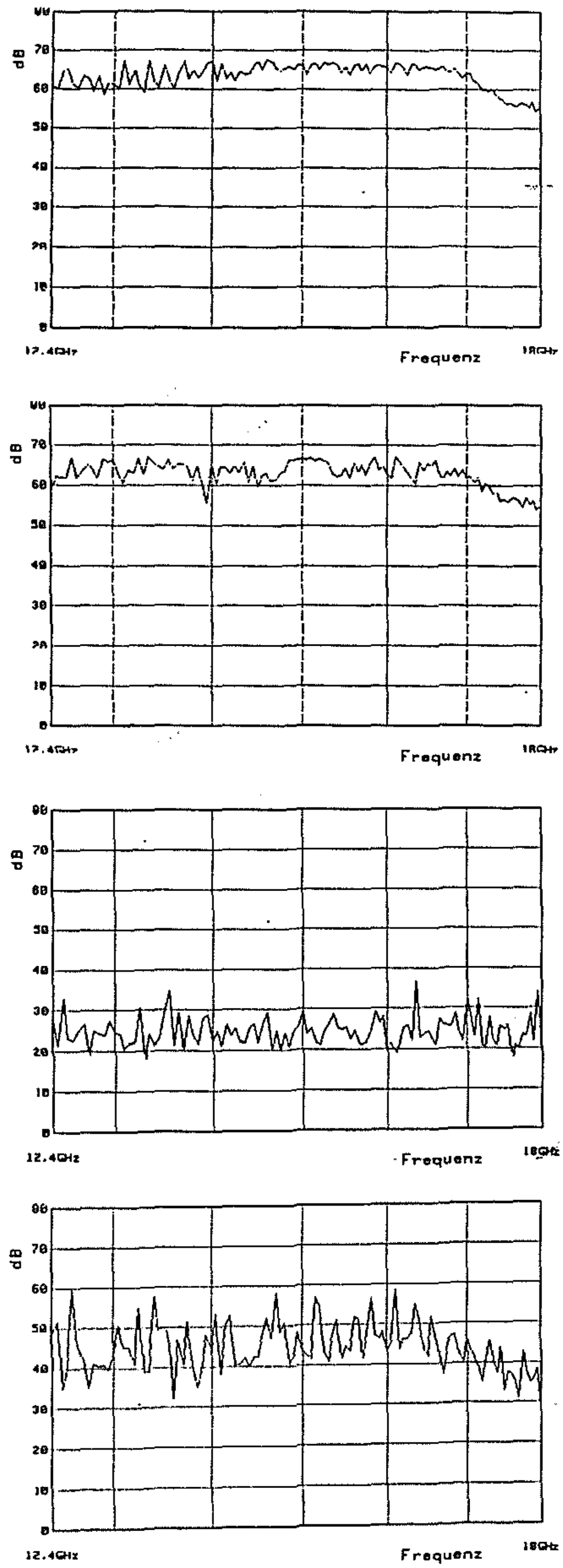
10 a: Closed box without mesh

10 b: Closed box with mesh

10 c: Box with door low conductive seal

10 d: Box with door high conductive seal

Figure 10: Shielding attenuation 1 GHz - 12,4 GHz



11 a: Closed box without mesh

11 b: Closed box with mesh

11 c: Box with door low conductive seal

11 d: Box with door high conductive seal

Figure 11: Shielding attenuation 12,4 GHz - 18 GHz

6. Conclusion

Measurements on EMI test boxes showed that moderate electromagnetic shielding attenuation values can be achieved by composite structures made from carbon. In case high shielding attenuation is required over a wide frequency range special care has to be taken to the following items:

- Bonding of adjacent carbon structure parts has to be optimized. Non conductive materials (resin, adhesive etc.) reduce contact area and galvanic conductivity of the joint.

- Application of mesh to increase shielding attenuation shall be in a way to ensure galvanic and low impedant connection between mesh layers.

- Doors/access panels shall be equiped with high conductive seals to maintain shielding attenuation. Additional requirements (e.g. humidity sealing, mechanical properties, corrosion, weight, costs etc.) shall not compromise conductivity of the seal.