Broadband Measuring of Shielding Covers

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Abstract. *The novel method utilizing coupled lines for the dielectric property measurement of shielding covers of composite materials is described. Characteristics of coupled lines designed by two symmetrical strip lines with a common side wall, which is made of the tested material, are mentioned. It allows measuring the dielectric property in the frequency range up to 5 octaves. The circuit analyzer with a high dynamic range is used for parameters evaluation. The method was utilized at the research of the technology of abnormally shaped shielding covers of composite materials.*

Keywords

EMC, covers, shielding, coupled lines.

1. Introduction

The original technology utilized a cover, which consists of aluminum metal plate, made by a method of deep drawing in compression moulds. For the manufacture of a small number of pieces this technology is considerably uneconomical. Therefore, the manufacturing technology and the base material were changed. The new approach is based on composite materials. The vacuum hardening and the controlled grouting for abnormally shaped parts belong to common manufacturing methods. A method, which would carry out fast evaluation of shielding effects for several designs, has been searched.

Subsequently, we found out that the main limitation was the bandwidth according to the CSN EN 55 22 standard specification, which covers the band of 30 to 1000 MHz, together with the dimensions of samples. The supplier of samples was able to accept the dimensions 400 x 400 mm. Thus, in the case of waveguide technology utilization, the low frequency of a measurement would be limited to 400 MHz approximately.

Also the measurement based on antennas is not possible, because of insufficient dynamic range and moreover, sample dimensions could only be convenient for the frequency range of tens of GHz.

As the basic solution, we have chosen the measurement of isolation between two microstrip lines. This novel solution proved to be convenient to provide the adequate bandwidth and the sufficient dynamic range of measurement.

2. Coupled Lines Structure

A symmetrical strip line was used to the measuring equipment realization according to Fig. 1.

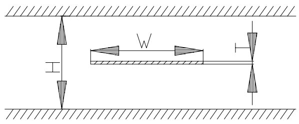

Fig. 1. Symmetrical strip line.

If we add another line to the given layout, coupled lines according to Fig. 2 with well-known following characteristics are created [1].

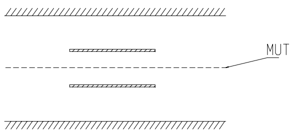

Fig. 2. Microstrip coupled lines.

Insertion loss

$$L = 10\log\frac{P_1}{P_2}\ , \qquad (1)$$

coupling

$$C = 10\log\frac{P_1}{P_3}\ , \qquad (2)$$

directivity

$$D = 10\log\frac{P_2}{P_4}\ , \qquad (3)$$

and isolation

$$I = 10\log\frac{P_1}{P_4} \qquad (4)$$

where utilized in the following measurement. In common applications of coupled lines the output isolation is unused.

If the coupled lines are designed optimally for the coupling and directivity parameters, almost no power passes to the output isolation port. Parameters *C, I* and *D* are interdependent. The following equation [1] is valid

$$I = D + C \ . \tag{5}$$

While the parameters *D* and *C* have the periodic coupling of geometrical dimensions to the frequency, the isolation parameter of the coupled lines designed on a wide microstrip line declares convenient features. The basic isolation without any MUT (material under test) has almost the linear shape with the slope of 6dB/octave, as shown in Fig. 3.

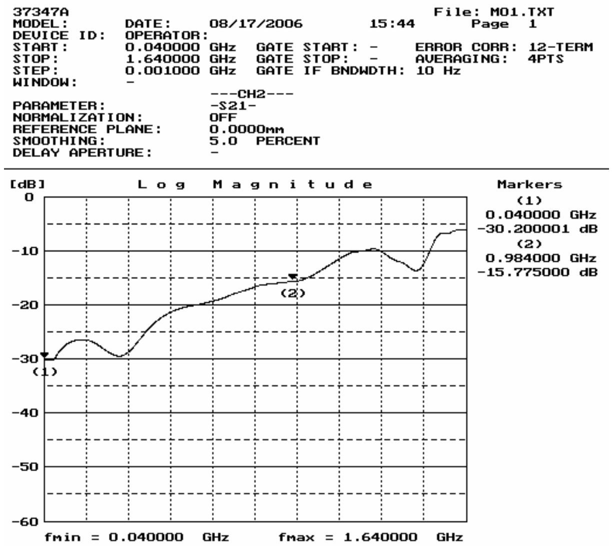

Fig. 3. Frequency dependence of coupled lines isolation without MUT.

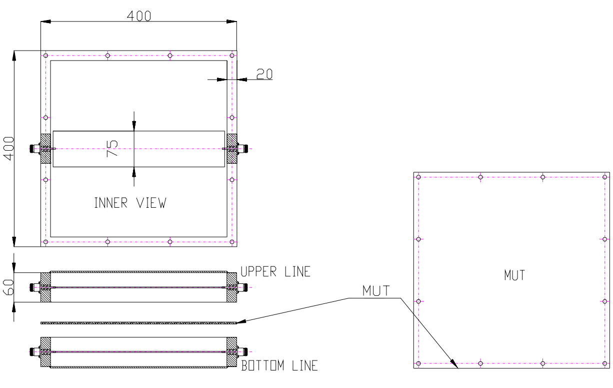

Fig. 4. Coupled line design.

3. Line and Coupled Lines Design

The parameters design results from required features of composite structures at the successfully terminated development. At that time the coupled lines would be infinitely isolated and line parameters would approach to two independent symmetrical strip lines. For such line, a series of design programs such as [2] exists. It is necessary to select the width of a line to $\lambda/4$ at most from the maximum frequency [3] (which corresponds to the width of line of 75 mm). The length of a line (coupling section) is joined to sample dimensions (400 mm approximately). The sample's form is a square plate with the length about 400 mm and the thickness approximately 2 mm. The coupled lines design according to Fig. 4 is very robust, thus it enables unambiguous gripping of the measured sample.

4. Samples of Shielding Covers

The following types of shielding covers have been designed for the measurement:

- Composite structures of Kevlar with inserted metal meshes (100 mesh /cm^2).
- Composite structures of Kevlar with metal surfaces (silver color paint).
- Composite structures of Kevlar with conductive surfaces (color containing graphite).
- Composite structures of carbon fibers.

5. Measurement

The shielding can be evaluated considering propagation through several layers providing that layer material properties are known (see [5], [6]). That was experimentally proved both for metal layers and dielectrics for various frequency ranges. However, the broadband numerical simulations of composite structures evoke various problems. It is very difficult to evaluate the permittivity of composite structures for very broad frequency range. For example, metal meshes can be considered as homogenous structure for low frequencies, but they should be analyzed as discrete obstacles for higher frequencies. Similarly, dielectric permittivity could change with frequency [7] and it is very difficult to measure the composite structure permittivity for the frequency range from 30 to 1000 MHz. Therefore, the novel method utilizing microstrip coupled lines for the dielectric property measurement of shielding covers of composite materials, has been derived.

For the measurement, the vector circuit analyzer Wiltron 37347A was used providing in the considered band the dynamic range of 98 dB approximately (receiver section up to 126 dB) at the frequency of 2 GHz [4]. The measuring equipment has been calibrated for measurement in the range of 40-1640 MHz with a step of 1 MHz. Subsequently the basic isolation was measured (see Fig. 3) without the MUT sample and subsequently, a metal aluminum plate (1.5 mm thickness) was inserted between the lines. That determinates the maximum possible isolation in Fig. 6, which is limited by the equipment dynamic range, measuring cables, connectors and coupled lines design (in fact, the better shielding could be theoretically expected). During the measurement a minimum equipment bandwidth of 10 Hz was used. Interconnection of the device and coupled lines is depicted in Fig. 5.

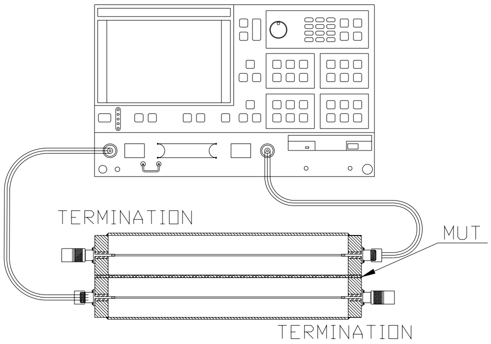

Fig. 5. Connection of the network analyzer Wiltron 37347A and the coupled lines.

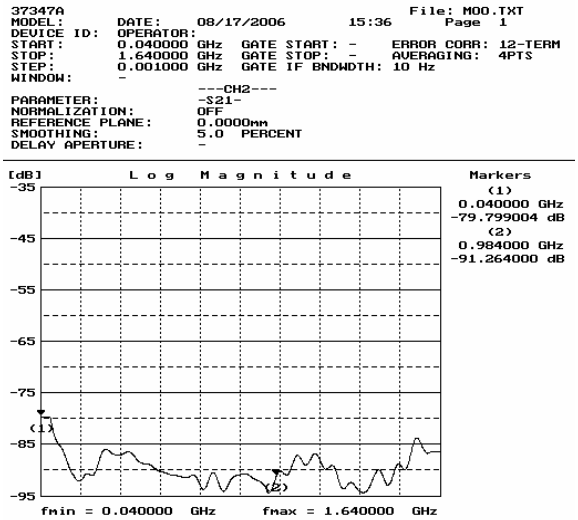

Fig. 6. Measurement of the maximal isolation with metal plate.

5.1 Measurement of Samples

Isolation measurements of composite structure samples are shown in Fig. 7 to 10. The measurement should be compared with the metal plate measurement. The analyses are summarized below.

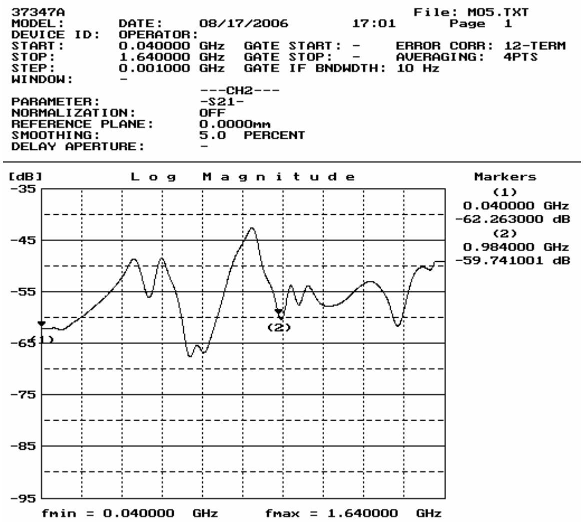

Fig. 7. Composite structure of Kevlar with inserted metal screen (100 mesh/cm^2).

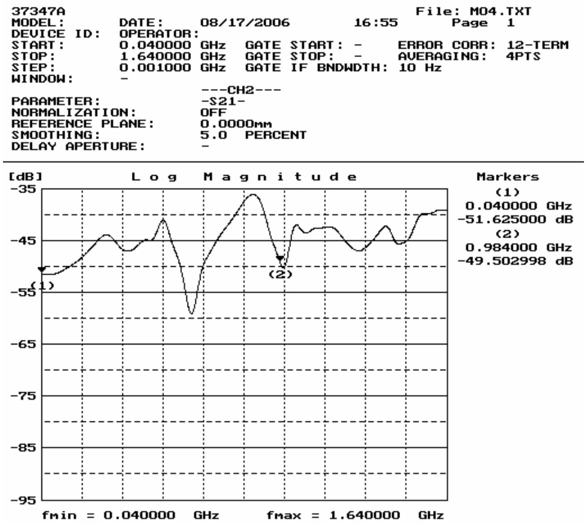

Fig. 8. Composite structure of Kevlar with a metal surface (silver color paint).

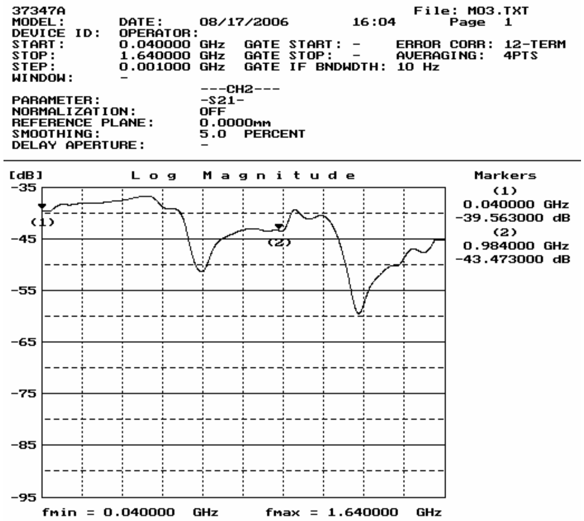

Fig. 9. Composite structure with a conductive surface (color containing graphite).

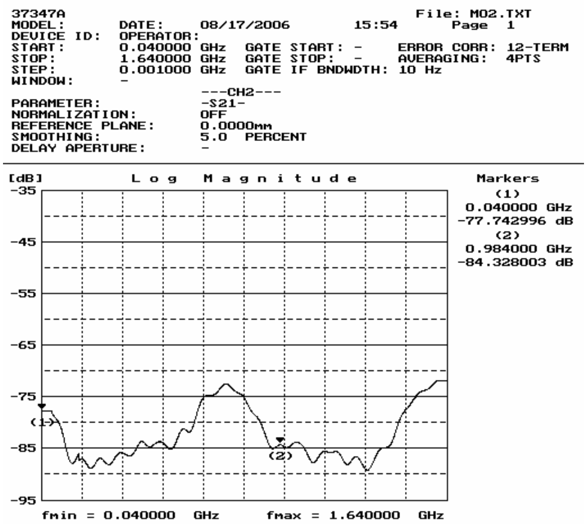

Fig. 10. Composite structure of carbon fiber.

6. Conclusion

The above measurements represent the possible quality measurement method of shielding covers in the frequency band of five octaves. Worse isolation parameters of samples b) and c) have been expected. The sample a) with a metal screen (high-quality of perforation) shows the shielding values 30 to 40 dB worse than the original material (aluminum plate).

On the other hand, very good results with the sample from carbon-fiber have been achieved. That complies with the requirements for the shielding effect and possibilities of easy shaping.

Samples a), b) and c) proved worse repeatability of measurement due to the non-conductive connection of both halves of coupled lines. Therefore, it is convenient to glue samples into a metal frame or to take out conductive layers on both sides of a sample in the contact surface widths of coupled lines.

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