Wideband Measurement in a Small Shielded Box Using Equiangular Spiral Antennas

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Abstract. *Small shielded boxes are nowadays widely used for measurement of EMS, EMI and sensitivity properties of different devices. This paper deals with an improvement of commercial small shielded box parameters for a measurement of sensitivity of small mobile devices in 650 MHz to 4 GHz frequency band. Optimization of shielded box parameters is obtained by an inner area modification. Suitable wideband equiangular spiral antenna was designed for this measurement. Parameters of antenna inside the box, such as gain, impedance, directivity etc. are discussed in the paper. Effects of antenna positions in the box for a transmission are shown and the best configuration of antennas placing for the transmission in the shielded box is chosen.*

Keywords

Shielded box, sensitivity, wideband measurement, equiangular spiral antenna, electromagnetic compatibility measurement.

1. Introduction

Small shielded boxes (e.g. TC-5970B from TESCOM company in Fig.1) are specified for measurement of EMS, EMI and sensitivity properties of devices. The shielding effectiveness of the metal box TC-5970B is greater then 55 dB in DC – 6 GHz frequency band [1]. The measured devices (DUT) or antenna placed in the box radiates into the whole volume of the box. Receiving antenna receives different components of the signal in the box (direct signal from DUT and all reflected signals from the walls). A sum of all signals can create minimums on transmission characteristic (phases of signals in the box) and then quality and reliability of such measurement is lower. Elimination of reflected signals is ensured by covering of inner walls of the box with absorbers. So, the receiving antenna receives "only" the direct signal from DUT.

It was necessary to find a suitable type of antenna for measurement inside boxes and to compare results (transmission) in a large anechoic chamber and in the shielded box. Wideband equiangular spiral antenna with 1.75 turns (diameter of 165 mm) was chosen, because circular polarization enables receiving and transmitting of both linear components. Design, simulation and measurements are presented below.

Measurement in the box was performed using two antennas. The basic problem was to find the "correct configuration" of antennas positions in the box with minimum influences on transmission.

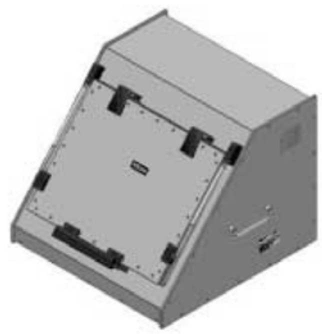


Fig. 1. Shielded box TESCOM TC-5970B [1].

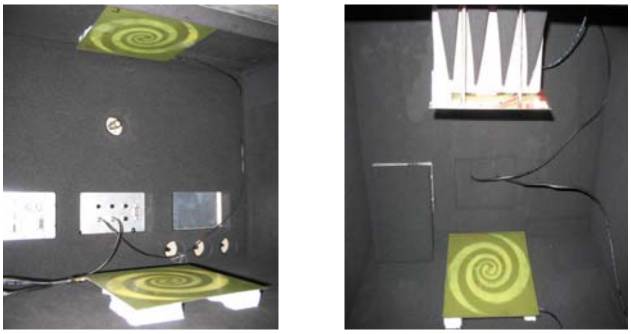
2. Shielded Box

The shielded box TC-5970B TESCOM company (Fig.1) was used for measurements. Inner dimensions of this box are 540(W) x 550(D) x 430(H) mm [1]. Its inner walls are originally covered with absorption material with relatively low absorption properties. Shielding effectiveness of this box is better then 60 dB for the frequency of 2.4 GHz [1]. This box is equipped with I/O standard PC and RF (N, SMA) connectors. Its inner electric parameters were improved by covering of inner walls with additional absorbers.

3. Measurement of Transmission in the Box

Measurements were requested in frequency band 650 MHz – 4 GHz by a user. Due to the user's request the suitable type of antenna for measurements inside enclosure was designed. The design of the antenna was limited by the inner dimensions of the enclosure and the antenna frequency band.

The first step was to verified influences of the box TC-5970B on transmission between two identical antennas. Transmission characteristic was measured in the shielded box without covering of inner walls with absorbers. Both antennas were connected to feed-through SMA connectors on the back wall of the box. The measurement configuration and transmission characteristic are in Fig. 2a and in Fig. 3. Resonances on transmission characteristic and a signal level are lower, compare to the measurement in the step 2 below. Therefore this configuration was not recommended for measurements in the box.



a) b)

Fig. 2. Configuration of measurement without polyamide-carbon absorbers (a) and with polyamide-carbon absorbers (b).

The second step was the covering of the inner walls of the box with new absorbers. Flat polyamide-carbon absorbers P-25 (thickness of 25 mm) were used. Then, the correct positions of both antennas for a flat transmission characteristic were necessary to find. The first antenna was placed about 20 mm above a bottom of the box. This antenna simulates DUT. The second one was placed at a top side. The improvement of transmission characteristic was obtained by placing of pyramidal absorber (thickness of 120 mm) to a back side of the antenna at the top (see Fig. 2b). The improvement is achieved by elimination of back lobe of the antenna to minimize reflected components. The measurement configuration is the same as in the previous paragraph. The final transmission characteristic is in Fig. 4.

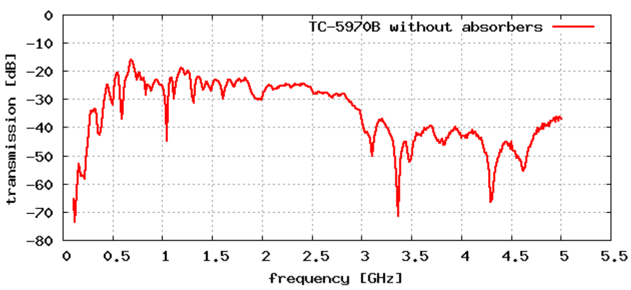


Fig. 3. The measured transmission in the box without additional polyamide-carbon absorbers.

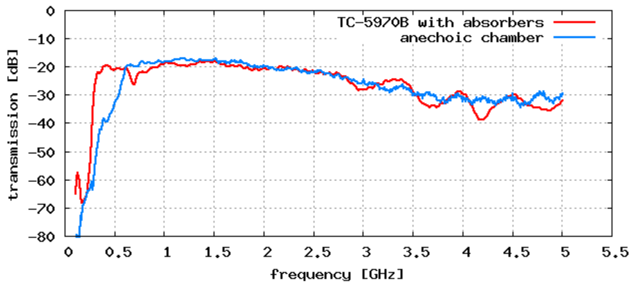


Fig. 4. The measured transmission of the final configuration in the box with additional absorbers in comparison with measurement in anechoic chamber.

The third step was the measurement of the transmission characteristic in an anechoic chamber [2]. The distance of antennas was the same as in the step 2 (300 mm) (Fig. 2b).

The VNA Agilent E8364 was used for all measurements of transmissions in the shielded box. A plane of calibration was outside of the box on an outer edge of the feed-through SMA connector.

4. Equiangular Spiral Antenna

The spiral antenna is a self-complementary arrangement [3] that has the frequency independent input impedance close to the theoretical value of 60π, however in reality [4] lower impedance is usually achieved.

The spiral antenna consists of two identical arms which are shifted by 180° with respect to each other (see Fig. 5). The shape of the spiral arm may be seen as a filling of two identical curves shifted by 90°. The whole spiral antenna is taken together from single curve rotated in four steps of 90°. The curve is described by the function [5]

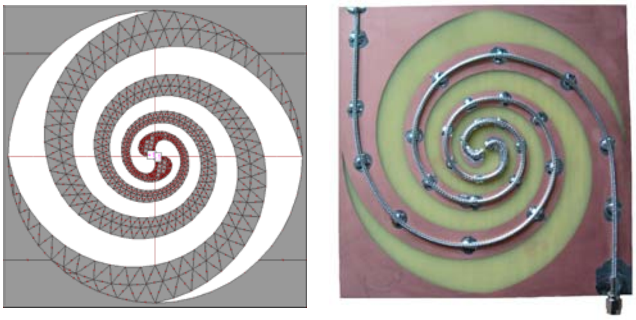
$$r = r_0 \, e^{a(\phi+\varphi)} \tag{1}$$

where r_0 is the starting distance at $\varphi=0°$, a determines the increasing rate of radius r, Φ is the variable angle and φ determines rotation of the curve. The outer curve is set up for $\varphi=0°$ and inner for $\varphi=90°$.

The design of the spiral antenna and its impedance and radiation properties in comparison of increasing rate of the radius and angles which describe widths of slots and strips are presented in [6].

4.1 Parameters of the Antenna

The self-complementary spiral antenna terminated into short with coaxial feeding was designed, see Fig. 5. Its parameters in accordance to above are: the rate of the radius increasing $a=0.19$, the outer dimension 165x165 mm and the number of turns 1.75. The spiral antenna was etched using FR-4 substrate of 1 mm thickness with the permittivity 4.2.

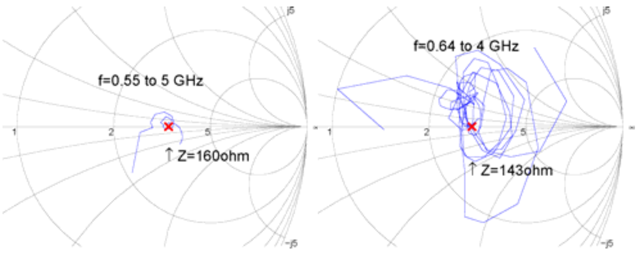


a) model b) practical realization

Fig. 5. The design of the equiangular spiral antenna.

The antenna is fed directly through the low-loss coaxial cable LMR-100A (the outer diameter of the conductive shield 2.3 mm). The cable is led from the outer edge along the arm to the center of the spiral, where the inner conductor of the cable is connected to the opposite arm of the spiral. A dump cable is connected on the second arm to respect the current symmetry.

There are two limitations, the first is in the outer diameter of the cable which limits using of the antenna at higher frequencies over the minimal radius of the spiral and the second one is in the numbers of turns with respect to the cable attenuation.



a) modeling b) measurement

Fig. 6. The modeled and measured input impedance of the antenna structure with marked effective value of impedance [6]

The antenna was modeled using IE3D Zeland Software, Inc. [7]. The impedance of the antenna was modeled without the cable. The results of the modeled and measured impedances with the calibration plane at the center of the antenna are shown in Fig. 6. The impedance of the antenna was measured with the calibration plane at the edge of the connector and then recalibrated to the center of the antenna using measurement of short at the center of the antenna and "de-embedding" by the equation for transforming of reflection coefficient

$$\Gamma_T = \frac{|\Gamma_M|}{|\Gamma_K|} e^{j\arg(\Gamma_M) - \arg(\Gamma_K) - \pi} \quad (2)$$

where Γ_M is the measured reflection coefficient of the antenna, Γ_K the measured reflection coefficient with short at the center of the antenna. This simple transforming omits reflections of the cable.

In addition, the radiation parameters of the antenna are in Fig. 7, 8, 9. Antenna radiation was measured in the anechoic chamber with two identical antennas. The transmitting antenna was placed at two positions separated by 90° and then the results were averaged for partial eliminating imperfect clean circular polarization.

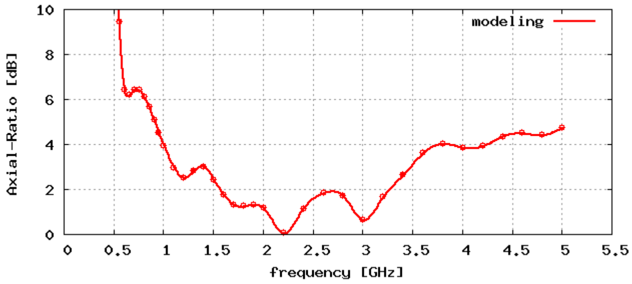


Fig. 7. Simulation of axial ratio as a function of frequency.

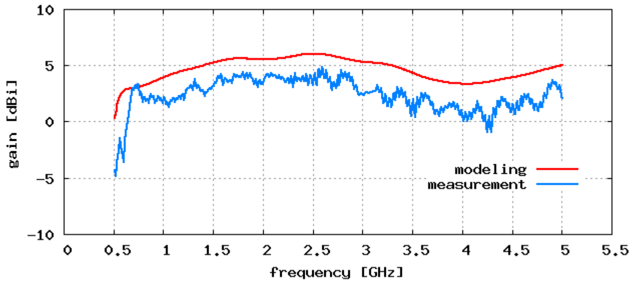


Fig. 8. The simulated gain of the antenna structure (Fig. 5a) and the measured gain of the antenna with a cable (Fig. 5b).

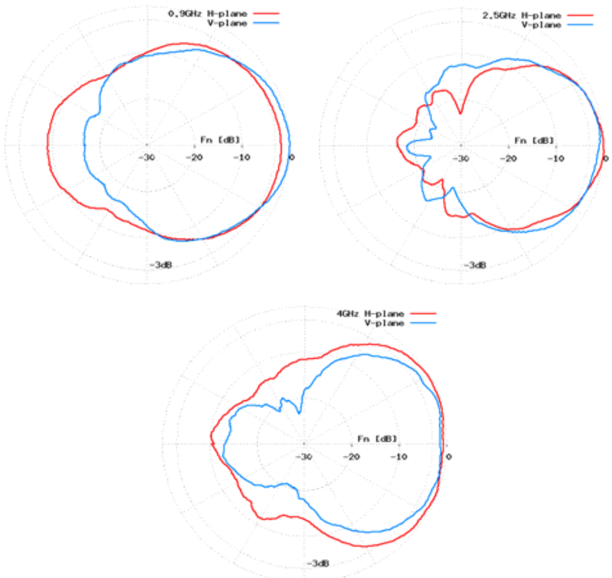


Fig. 9. Measured radiation patterns of the antenna.

5. Conclusion

The application of a small shielded box - enclosure for sensitivity measurements of devices inside was shown. The main problem was found the flat and stable transmis sion characteristic of two antennas in the box compare to the transmission characteristic in the large anechoic chamber. The second problem was the design of a wideband antenna with small dimensions for the required application and frequency band. The improvements of the box were monitored using the transmission characteristic which was measured inside the box by two equiangular spiral antennas. The final result is shown in Fig. 4. Very good agreements between measurement in the anechoic chamber and in this small box were achieved.

This wideband equiangular spiral antenna is suitable for such measurement (sensitivity measurement) and also for the measurement of a shielding efficiency of the "small" shielded boxes [8]. Suitability of this antenna is given by its wideband properties and small dimensions of the antenna.

Acknowledgements

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