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An evaluation of the portable anechoic chamber for electromagnetic compatibility (EMC) studies

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Abstract – Electromagnetic compatibility (EMC) issues are an increasingly significant problem nowadays. Several electronic devices generate harmful radio frequency (RF) interference, which can cause operational errors in other electronic devices and systems. To manage these electromagnetic interference issues, it is important to have reliable electromagnetic interference measurements. These measurements require a specialized measurement system, usually performed in an anechoic chamber or a similar setting. In this work, we design a low-cost and portable anechoic chamber for small-scale electronic devices. The performance of the anechoic chamber is confirmed through several measurements, demonstrating a minimum attenuation of 15 dB. Additionally, the chamber's performance is verified with a real EMC measurement. A certain LED light driver is selected for the first test of the anechoic chamber. The driver produces a wide-band (50 MHz) and strong interference signal at a center frequency of 125 MHz.

Key words – anechoic chamber, electromagnetic compatibility (EMC), radio spectrum

Introduction

The rapid development of electronics and radio communication has brought challenges as well as benefits. Electromagnetic compatibility (EMC) issues are more common nowadays than in past decades, partly due to poorly manufactured electronics. When investigating the EMC properties of a device or system, it is important to reliably exclude other factors, such as signals generated by other devices and systems. For this reason, all EMC measurements should be conducted in a special environment, typically an anechoic chamber or a similar setting.

A radio frequency (RF) anechoic chamber is a shielded room designed to simulate a free-space environment while blocking unwanted signals. The main purpose of an anechoic chamber is to measure RF interference caused by the device under test (DUT) without any external interfering signals. A standardized anechoic chamber is a unique and typically very expensive infrastructure. However, a small portable anechoic chamber can be realized relatively easily and at a low cost.

With such a system, most necessary EMC measurements can be conducted. Nevertheless, some basic design rules must be considered to ensure the chamber is functional and operational. Without these considerations, the operation of the anechoic chamber will not be optimal.

Shielding effectiveness (SE) defines the electromagnetic shielding property of a material and how effectively the material attenuates RF signals. Shielding effectiveness is determined by dividing the incident electromagnetic power by the transmitted electromagnetic power through the material under test (MUT). The general guideline is that the attenuation should be 15 dB or more [1]. The anechoic chamber is typically constructed from a metallic (e.g., aluminum) cabin, which is lined with absorber material (wall absorbers) to prevent any reflections. Besides the material properties, it is important that any holes and inlets follow EMC installation guidelines. A properly designed anechoic chamber also functions as a Faraday cage, and any hole or inlet will compromise its effectiveness.

Characterization and validation of anechoic chambers (or semi-anechoic chambers) have been performed in previous studies, such as [2,3,4]. These studies mainly investigate unwanted reflections from both outside and inside the anechoic chamber. The absorbers used in anechoic chambers are typically carbon-based materials and are often pyramidal, horn, or dome-shaped [5].

Nowadays, a large amount of interference signals tend to be at high frequencies, in the MHz or even GHz ranges. One obvious explanation for this is the increasing switching frequencies of power semiconductors. In this work, we are focusing on frequencies from 100 kHz to 1.25 GHz. Our objective is to build a suitable anechoic chamber for that specific frequency range. The system must meet several requirements: it must be low-cost, portable, and modifiable.

Our aim is not to conduct standardized EMC measurements or to develop a measurement unit for such purposes, but rather to prevent unwanted signals from interrupting the device under test (DUT). Effective EMC measurements cannot be reliably performed in a general electronic laboratory because other electronic devices can interfere with the measurements. Additionally, we are focusing solely on radiating interference issues in this work; conductive interference mechanisms are out of scope.

In Chapter 1, we will present the design of the anechoic chamber, including its structure and manufacturing process. The evaluation of the anechoic chamber is presented in Chapter 2. We tested our anechoic chamber with an LED light, measuring the electromagnetic interference (radiative) produced by the light, as detailed in Chapter 3. Finally, conclusions and future development ideas are presented in Chapter 4.

1 THE STRUCTURE OF THE ANECHOIC CHAMBER

Our anechoic chamber is constructed from aluminum, chosen for its light weight and good attenuation properties. Only a few millimeters of aluminum thickness provides tens of decibels of attenuation. In Figure 1, the structure of the anechoic chamber is depicted without the cover panel. All seams of the chamber box were double-shielded with an additional layer of aluminum tape to ensure tight sealing. The dimensions of the anechoic chamber are 36 cm (L) x 23 cm (W) x 15 cm (H), with a wall thickness of 3 mm, resulting in a total weight of less than 2 kg, confirming its portability. The chamber's performance was verified through various attenuation measurements, and to maintain the required attenuation, the chamber cover is secured with special clamps, as shown in Figure 1 (on the right).

In addition to RF attenuation, the chamber interior is lined with absorber material optimized for lower frequencies (up to several MHz), as indicated by the red arrow in Figure 1 (on the left). The receiving antenna, a simple helix/spring-type antenna (helical), is also shown. The position of the Device Under Test (DUT) can be adjusted within a few centimeters on the rim plane visible in the left panel of Figure 1. This setup allows for interference measurements in the radiating far-field. Therefore, the DUT must be placed at a minimum distance (r) from the receiving antenna, which can be calculated as [6]

$$r \geq \frac{2D^2}{\lambda} \tag{1}$$

, where D is the aperture of the antenna and λ is the wavelength. In our case, the length of the antenna aperture is 6 cm. Taking into account the frequency range used (100 kHz - 1.25 GHz), the minimum distances between the receiving antenna and the Device Under Test (DUT) are 0.0024 m and 0.03 m, respectively. These distances can be easily achieved in our anechoic chamber. The receiving antenna is directly connected to the signal generator using a low-loss coaxial cable. In applications where the interfering signal is weak, an additional amplifier (such as a Low-Noise Amplifier, LNA) may be useful and in some cases, necessary.

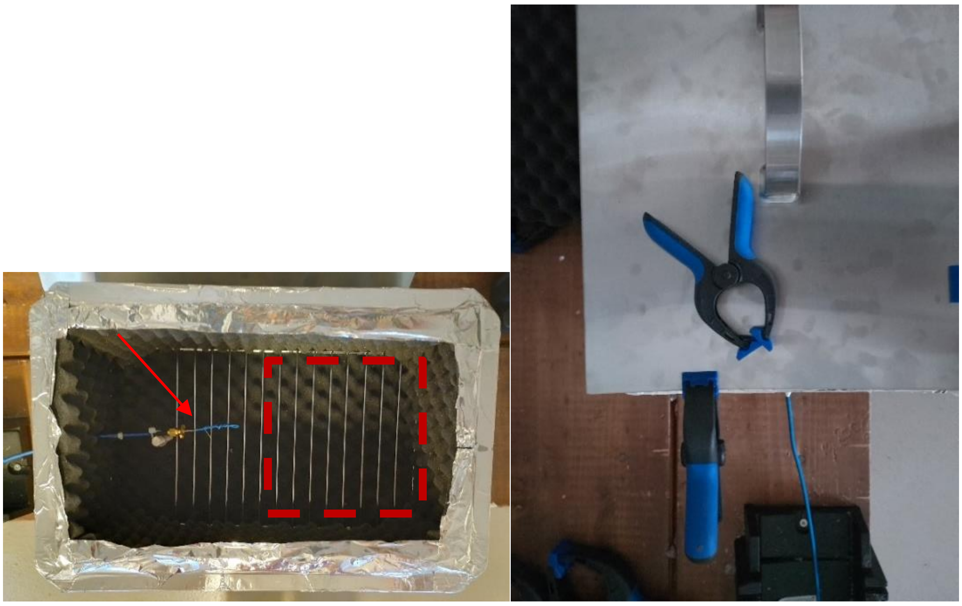

Fig. 1. The structure of the anechoic chamber is shown without the top cover panel (on the left). With a red arrow, the receiving antenna is marked. The dashed red line area indicated the area where DUT should be placed on. On the right, the special clamps are presented. With these clamps the anechoic chamber's cover will be tightened to the box itself. Without these clamps, the box performance is not at desired level; proper attenuation level cannot be achieved.

2 MEASUREMENT OF THE ANECHOIC CHAMBER'S PERFORMANCE

Figure 2 presents measurements with the top cover of the anechoic chamber open. Strong DTV broadcast signals around 800 MHz are clearly visible, with the strongest signal strength recorded at -53.1 dBm, approximately 25 dB above the background level. Other services with robust transmissions, particularly around 950 MHz reserved for mobile services, are also detected. Figure 3 shows measurements with the anechoic chamber's top cover closed. The previously observed transmissions appear significantly weaker compared to the open configuration. This indicates that the anechoic chamber provides attenuation of at least 12-15 dB, increasing to over 20 dB at higher frequencies (> 700 MHz). These measurements were conducted using a handheld spectrum analyzer (Rohde & Schwarz FSH).

Fig. 2. The spectrum at frequency range between 100 kHz and 1.25 GHz. The level of the most powerful transmission is -53.1 dBm (at 954.17 MHz). The spectrum is measured when anechoic chamber's top cover is opened. Both resolution (RBW) and video (VBW) bandwidths are 100 kHz.

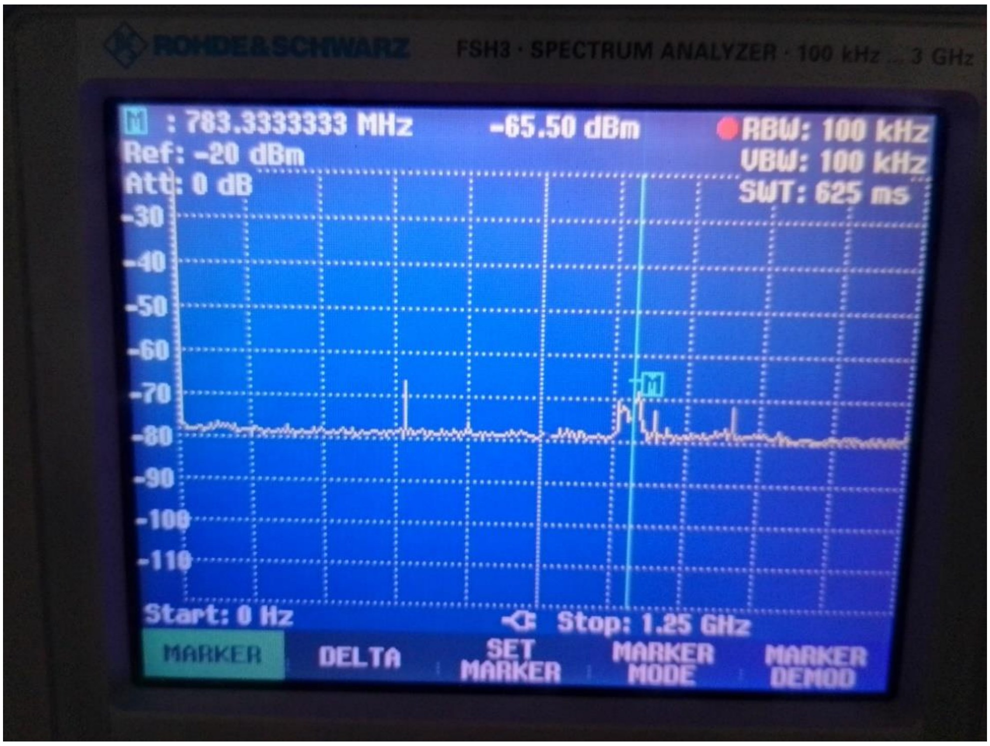

Fig. 3. The spectrum at frequency range between 100 kHz and 1.25 GHz. The level of the most powerful transmission is -65.5 dBm (at 783.33 MHz). The spectrum is measured when anechoic chamber's top cover is closed. Both resolution (RBW) and video (VBW) bandwidths are 100 kHz.

Testing the performance of the anechoic chamber with DTV-broadcast signals is straightforward and reliable because these signals are typically stable and sufficiently strong, observable from various locations. This simple performance test can be conducted without specific measurement devices like a signal generator or other signal (noise) sources. Similar performance (attenuation) tests for anechoic chambers have been conducted previously, as documented in [1,7]. The total cost of the designed portable anechoic chamber is approximately 100 euros, excluding measurement devices such as a spectrum analyzer. A low-cost signal generator can be purchased for around 100 euros, with higher-end models costing tens of thousands of euros. Since our anechoic chamber is designed for relatively low frequencies (< 1.25 GHz), a low-cost spectrum analyzer is suitable for our needs. Additional costs may arise if a low-noise amplifier (LNA) is required. Ideally, the amplifier should have a low noise figure, flat frequency response, and stable gain. However, for our studies, an extra amplifier was unnecessary as the interference signals were sufficiently strong. The measurements were conducted in a room without any major electronic devices; only the equipment used for the measurements and the lighting were present. Overall, the room was suitable for EMC measurements.

3 EMC – MEASUREMENT: CASE LED-LIGHT

The first EMC test was conducted on an LED (light-emitting diode) light, specifically the LED driver LMTC19W700 (a dimmable LED driver with an output power range of 5 to 9.8 W). Given our expectations of potential strong RF interference from the driver [8], we selected this specific model for testing. LED lights can be significant sources of interference, particularly if their design or manufacturing compromises shielding effectiveness. The driver was positioned approximately five centimeters from the receiving antenna inside the anechoic chamber, ensuring measurements were conducted in the radiating far-field. To prevent external signals from affecting the measurements, all cable inlets of the anechoic chamber were securely sealed with aluminum tape. Figure 4 illustrates the measurement setup.

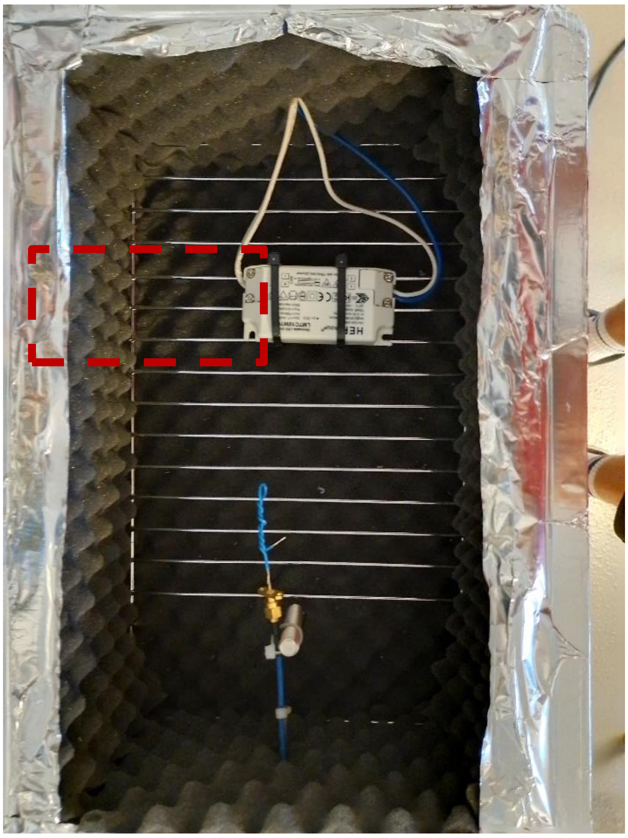

Fig. 4. Interference measurement setup. DUT is attached to the grid plan with cable ties. In the figure, DUT is rounded as a red dashed line. The top cover of the anechoic chamber was closed when measurements were made.

Figure 5 displays the RF interference spectrum in the frequency range between 100 kHz and 300 MHz. The measured spectrum reveals wide-band interferences generated by the LED light driver in the frequency range of 100 to 150 MHz. The interference signal level is approximately 15 dB above the background level. The plastic frame covering the driver of the LED light is identified as the primary source of electromagnetic interference (EMC). Replacing the plastic cover with a metallic one would likely resolve the interference issue. Many EMC problems can be effectively addressed with relatively simple and cost-effective solutions that are technically straightforward to implement.

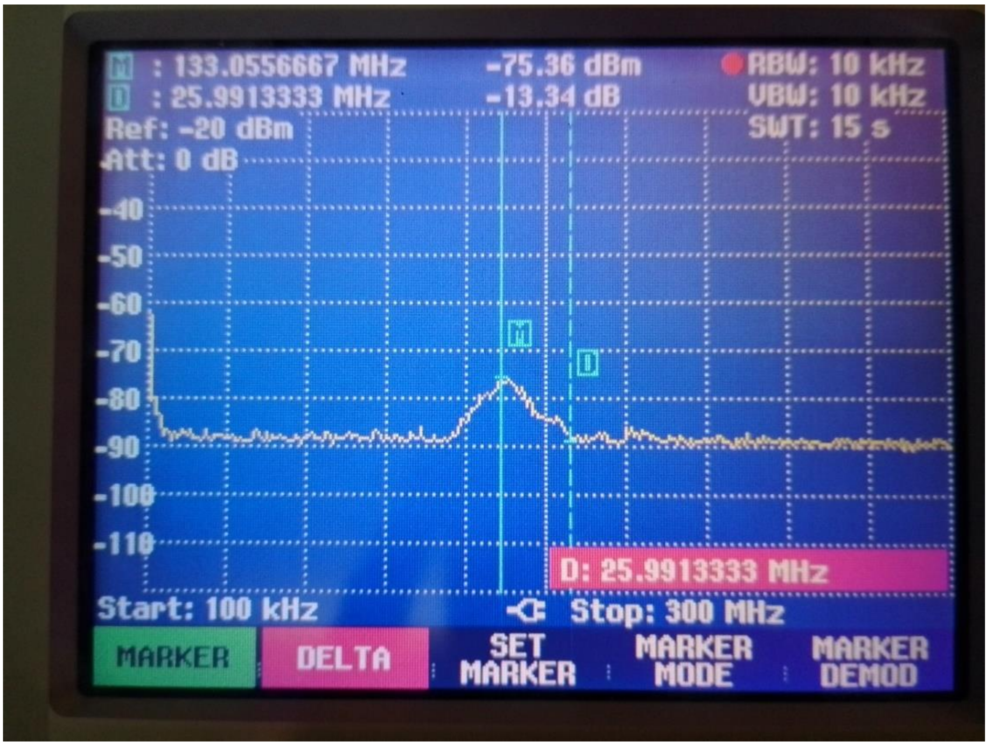

Fig. 5. LED driver's interference spectrum at frequencies between 100 kHz and 300 MHz. Both resolution (RBW) and video (VBW) bandwidths are 10 kHz.

Figure 6 replicates the previously presented measurement, with the distinction that the LED light was turned off. The spectrum now shows no signals whatsoever; it is completely clean. This further validates the functionality of our anechoic chamber, demonstrating that we are indeed measuring interferences generated specifically by the LED light driver.

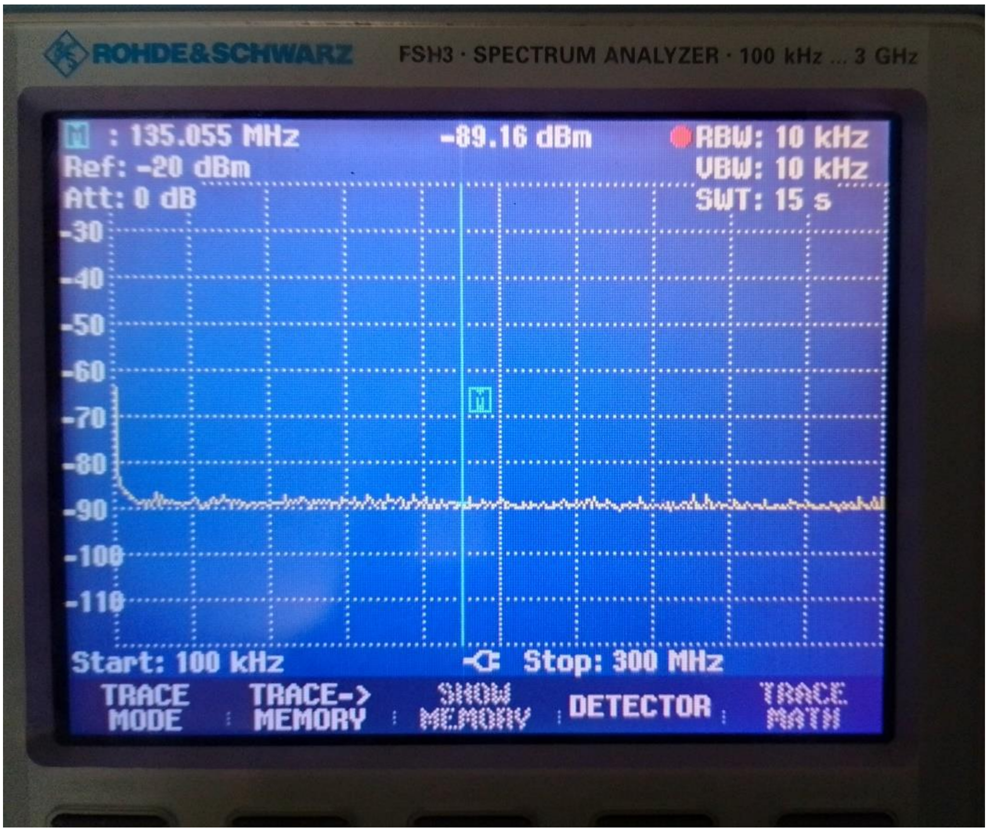

Fig. 6. LED driver's interference spectrum at frequencies between 100 kHz and 300 MHz when the light was turned off. Both resolution (RBW) and video (VBW) bandwidths are 10 kHz.

4 CONCLUSIONS

We have successfully developed a functional and low-cost anechoic chamber, confirmed through various measurements and tests. The chamber's portability is facilitated by its compact dimensions, allowing easy relocation to different locations. Testing of small electronic devices can be efficiently conducted within a short timeframe using our setup, which costs approximately 100 euros in total.

However, a limitation of our current solution is its size, restricting testing to small-scale devices and systems. Scaling the system to larger dimensions would sacrifice portability, a key feature of our design. The absorber properties were not thoroughly investigated in this study and could be a focus for future research. Additionally, while our anechoic chamber effectively attenuates signals, it cannot completely eliminate the strongest environmental signals, such as DTV broadcast signals.

Improvements are needed in attaching the anechoic chamber's top cover to optimize performance. Despite this, the current performance is satisfactory. Our interference measurements are not calibrated; future work could explore calibration methods proposed elsewhere [9,10] with slight modifications. Another potential enhancement could involve grounding the entire chamber to evaluate its impact on overall performance, potentially improving its effectiveness.

As interference issues become more prevalent, understanding their fundamentals is crucial. Interference measurements can be challenging due to competing signals, highlighting the importance of solutions like our developed anechoic chamber for rapid and reliable electromagnetic interference studies.

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