Minimizing of Transmitting Antenna's Reflections When Performing EMI Tests

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Abstract: -Within the framework of the electromagnetic compatibility tests performed on common communication systems, one of the most common tests is the immunity test according to the standard EN 61000-4-3. This test is usually processed inside a shielded anechoic chamber, meeting the appropriate standards. As the levels of the generated fields can be high and the output power of the transmitting amplifiers cannot be infinite, it is necessary to achieve a good performance of the transmitting antenna. The authors of this paper present the experiment performed in the anechoic chamber Frankonia SAC3 plus that shows that the height of the antenna above the chamber's floor affects the antenna's performance. Especially in vertical polarization, the performance of the antenna can be improved by slight adjustment of its height.

Key-Words: Communication Systems EMC, Immunity Test, Transmitting Antenna, Output Power, Standing Waves Ratio, Shielded Chamber

1 Introduction

Testing of electromagnetic susceptibility became one of the important disciplines as the complexity of electrical systems that must operate together has increased. In 1968, H. M. Schilke, one of the founders of the field of science related to the electromagnetic compatibility, claimed: "The system itself may be perfectly reliable, but practically worthless in operation unless it is not electromagnetically compatible at the same time." [1]. Since that time constructers faced many problems raising at the field of mutual electromagnetic compatibility of devices being in a concurrent operation. For example, as described in [2], in 1984 the NATO airplane "Tornado" crashed in Germany after its circuits interfered with a powerful transmitter in Holkirchen. In 1982, the British cruiser Sheffield was sunk by Argentine aircraft in the Falklands War, partly because its defence system abetting the enemy rockets was switched. Due to its electromagnetic incompatibility, it interfered with radio communication, crucial for the cruiser's crew. According to [3], there were several accidents reported in the Czech Republic.

Therefore, the electronic devices should be tested for their immunity to the radiated electromagnetic field. In addition, within the European Union, a set of immunity tests is prescribed by the Directive a set of immunity tests is prescribed by the Directive 336/EEC. These tests are mandatory for all communication devices sold on the EU's market. Once the device does not meet the requirements of the appropriate standards, it cannot be marked with the CE sign.

1.1 Standardization

In Europe the current basic definition of the test of the electromagnetic susceptibility of common devices against the radiated electromagnetic field is provided by the standard EN 61000-4-3 [4]. It defines the frequency ranges, modulations and intensities that are to be developed in the area in which the tested device is placed. The field intensity levels specified by the standard [4] are enlisted usually between 1 and 10 V/m.

The set of appropriate standards is provided in the framework of the standard EN 61000-6-1 [5], which defines general conditions under which the immunity tests should be performed and specifies what kind of tests is applicable to the tested device according to its construction and purpose of its operation. This standard also defines functional criteria [5, 9] that must be fulfilled in order to claim that the device meets the requirements needed to fulfil in order to be marked with the CE sign.

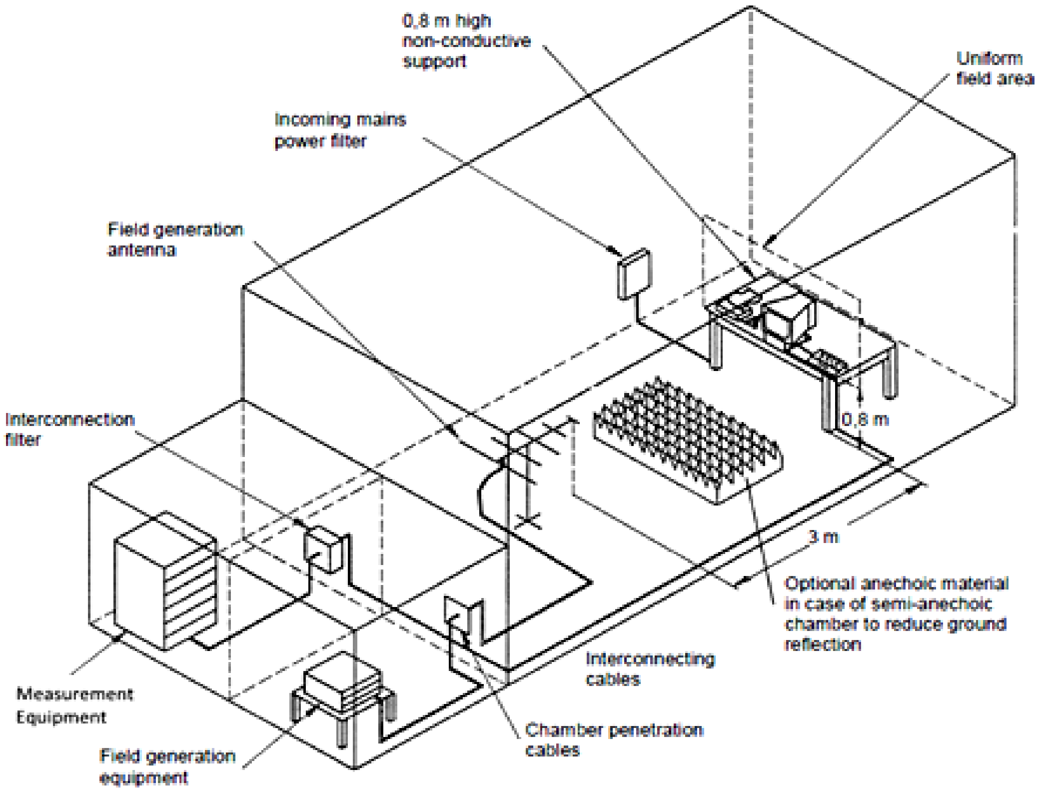

Fig. 1 Typical EMI test configuration

1.2 Basic Test Configuration

The basic configuration of the test according to EN 61000-4-3 is depicted in Fig. 1.

The tested device is placed in an anechoic chamber on a non-conductive table. It is irradiated by the modulated electromagnetic field generated by an antenna placed in the distance specified by the standards. The field intensity is checked inside the space called Uniform field area. Its dimensions as well as the tolerance for the intensity levels are specified in [4].

Usually, instead of the anechoic chambers, the semi-anechoic ones are being employed as they are also suitable for other EMC measurements like interferences, radiation patterns etc.

2 Problem Description

When the configuration as depicted in Fig. 1 is used, there exists a risk of interactions between the metal floor of the chamber and the transmitting antenna, resulting in changes in the antenna's impedance. This causes the impedance matching of the antenna to the amplifier is corrupted, resulting in the occurrence of standing waves on the cable between the antenna and the amplifier. The quantity of standing waves can generally be described as a voltage standing waves ratio (VSWR) by equation (1). It defines the ration between the maximum (V_{max}) and minimum (V_{min}) amplitude of the standing wave. Also the amplitudes of the incident (V_i) and the reflected (V_r) waves can be applied.

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{V_i + V_r}{V_i - V_r} \tag{1}$$

The amount of energy reflected back from the point of impedance mismatch can be described by means of the reflection coefficient ρ.

$$\rho = \frac{V_r}{V_i} \tag{2}$$

Therefore the equation (3) can be applied.

$$VSWR = \frac{1 + \rho}{1 - \rho} \tag{3}$$

The efficiency of transmitting the energy to the space is then affected by mismatch losses that are caused by the reflections from the antenna. According to [6] the mismatch loss ratio (ML) is the ratio of incident power to the difference between incident and reflected power:

$$ML = 10\log_{10}\frac{P_i}{P_i - P_r} \qquad = -10\log_{10}(1 - \qquad (4)$$

In (4), P_i stands for the incident power (generated by the amplifier) while P_r stands for the reflected power, that is not transmitted but loads the cable and the amplifier in the form of the standing waves.

In terms of the voltage standing wave ratio (VSWR) the following equation can be applied [6]:

$$ML = -10\log_{10}\left(1 - \left(\frac{VSWR - 1}{VSWR + 1}\right)^2\right) [dB] \qquad (5)$$

When the authors of this paper were performing the immunity tests inside the semi-anechoic chamber, they discerned a suspicious behavior of the antenna – the measured VSWR on the output of the amplifier largely depended on the antenna's height. Therefore they attempted to perform a systemized set of measurements in order to proof whether the antenna's impedance really noticeably depends on its distance from the conductive floor.

3 Experiment Description

The experiment was held in the semi-anechoic chamber Frankonia SAC-3 Plus that is placed at the Faculty of Applied Informatics of Tomas Bata University in Zlin [7]. The signal was generated by the generator Rohde & Schwarz SMF 100 A and amplified by the amplifier Amplifier Research 150W1000. The signal was transmitted with the antenna Rohde&Schwarz HL046E. The frequencies and the modulation were set in accordance with the standard EN 61000-4-3, but the frequency range was limited to 250 MHz as the hereby described effects were observed in the frequency range from 80 MHz to 150 MHz. The power of the amplifier was set by means of a feedback field probe ETS Lindgren HI-6005 that was located in the middle of the Uniform field area. The required level of the electromagnetic field was set to 10 V/m and both antenna polarizations were applied: horizontal and vertical. The instruments were driven by EMC 32 software. The configuration of the semi-anechoic chamber was as depicted in Fig. 1, using the absorbers placed on the floor.

During the experiment, the antenna's height

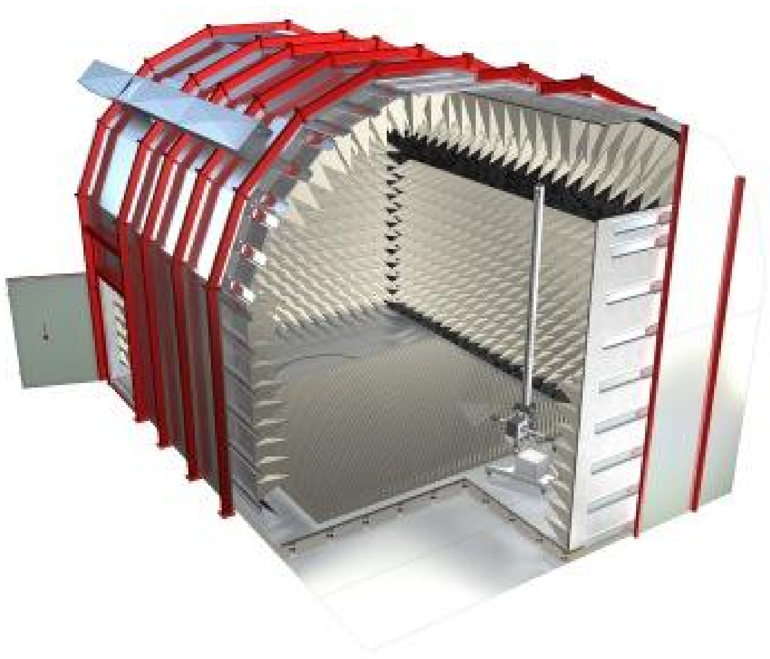

Fig. 2 Semi-anechoic chamber Frankonia SAC 3 Plus

above the floor was consequently changed from 90 to 135 cm with the step of 5 cm. For each of the heights the transmitting frequencies from 80 MHz to 250 MHz were applied increasingly with the step of 1 % and the response of the chamber (field level at the position of the probe) as well as the response of the transmitting system (output power of the amplifier and voltage standing waves ratio).

4 Results and Discussion

The results were obtained for both antenna polarizations – the vertical one as well as the horizontal one.

4.1 Vertical Polarization

In Fig. 3 the VSWR dependence on frequency and the antenna's height above the conductive floor is depicted. In Fig. 4 there is depicted the dependence of the output power of the amplifiers needed to generate the required field intensity strength of 10 V/m at the point where the feedback sensor was placed on the antenna height and the frequency. Although the level of the power generated by the amplifier does not directly reflect the antenna's VSWR as there may be reflections inside the chamber that affect the level measured by the sensor, a certain correlation between the measured values of the amplifier's output power and the

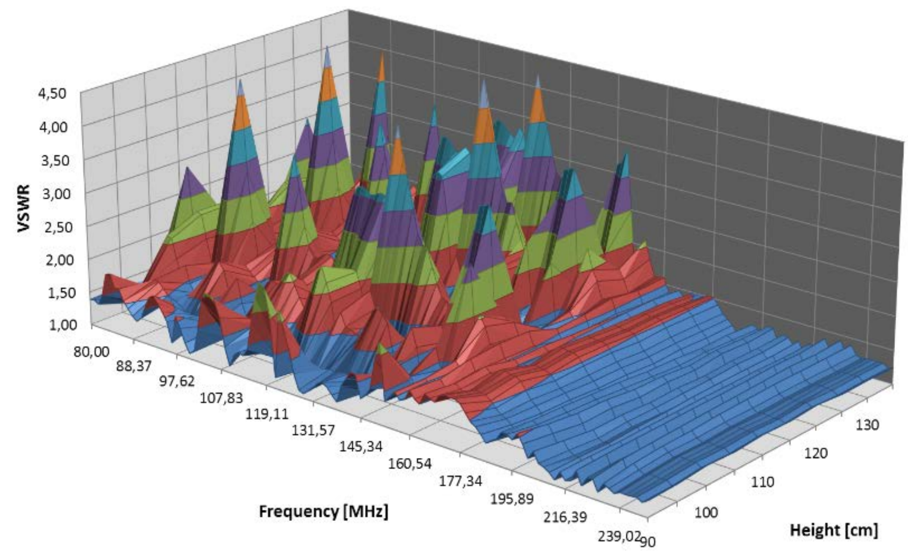

Fig. 3 VSWR versus antenna's height and carrier frequency (vertical polarization)

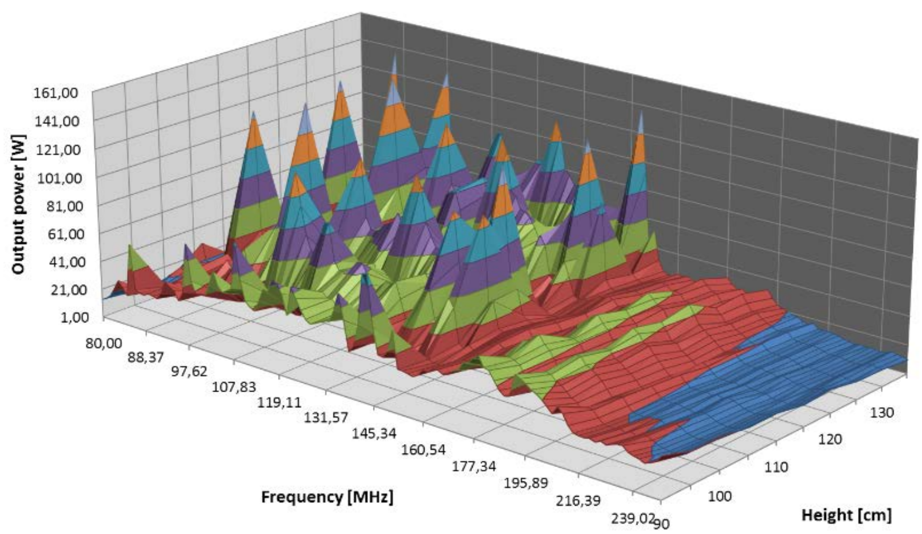

Fig. 4 Measured output power versus antenna's height and carrier frequency (vertical polarization)

measured antenna's VSWR has been observed by means of the following method. For each of the antenna's height, the maximum of VSWR and of the output power has been registered regardless of the carrier frequency.

From these values the graph depicted in Fig. 5 has been compiled. In this graph, the dependencies of three different variables on the antenna's height are depicted in order to show the abovementioned correlation:

- Maximum VSWR observed in the range from 80 MHz to 250 MHz,
- Maximum amplifier's power generated between 80 MHz and 250 MHz,
- Hypothetical output power that would be needed to generate the required intensity provided VSWR was as low as 1 in the whole frequency range calculated according to equation (5).

According to Fig. 5, it can be stated that for antenna's heights above approximately 110 cm the need for transmitting power mostly depends on the antenna's VSWR that changes with the antenna's height. If the reflections on the antenna were cancelled, the transmitting power needed to achieve the required level 10 V/m in the distance of 3 m from the antenna would be from 40 to 55 W. With the currently achieved VSWR the required output power varied from approximately 52 W at the antenna's height of 115 cm to approximately 142 W at 110 cm. For the antenna's heights below 110 cm the real output power needed to achieve the required field intensity has been even higher than expected. A capacitive coupling between the floor and the antenna is suspected to cause this phenomenon.

4.2 Horizontal Polarization

The same experiment has also been processed with horizontal antenna's polarization. The appropriate results can be found in the figures 6 to 8.

In contrast to the previous case, when the antenna was set to the vertical polarization, within the heights from 90 to 110 cm, its VSWR did not depend on its height above the floor.

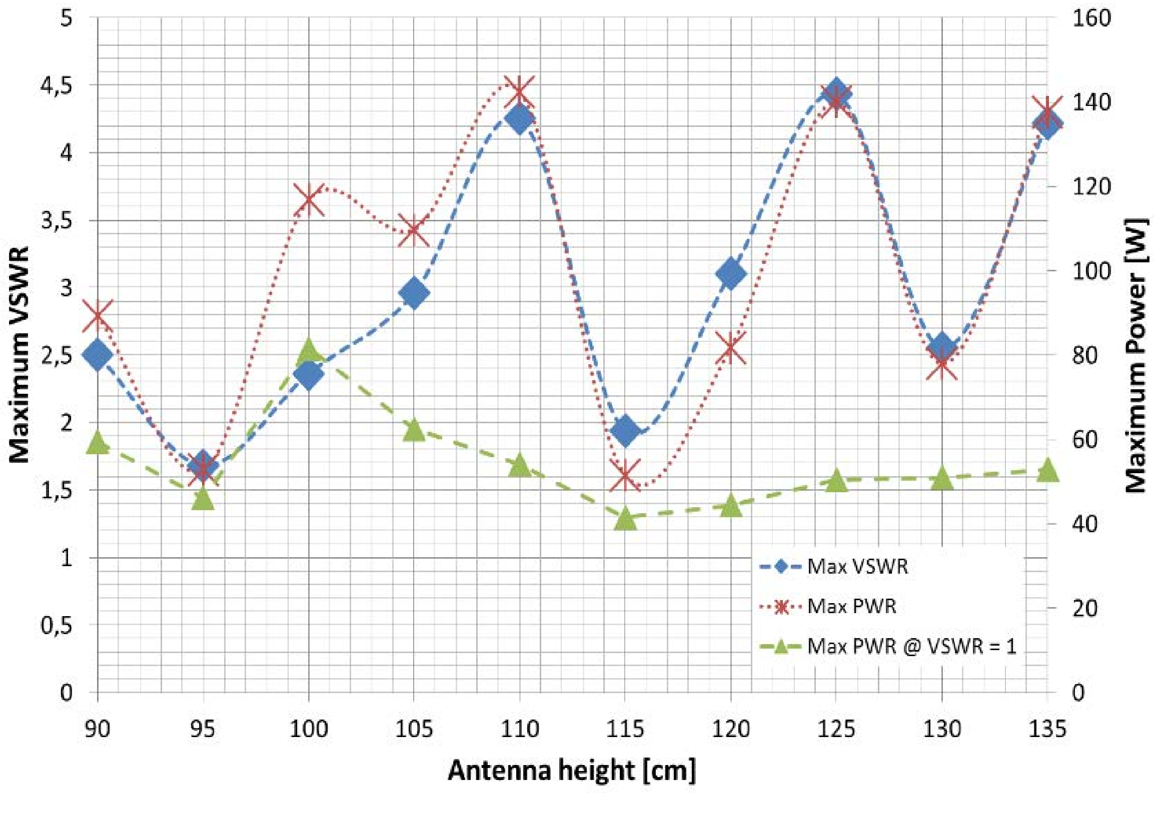

Fig. 5 VSWR, real output power and hypothetical output power at VSWR = 1 versus antenna's height (vertical polarization)

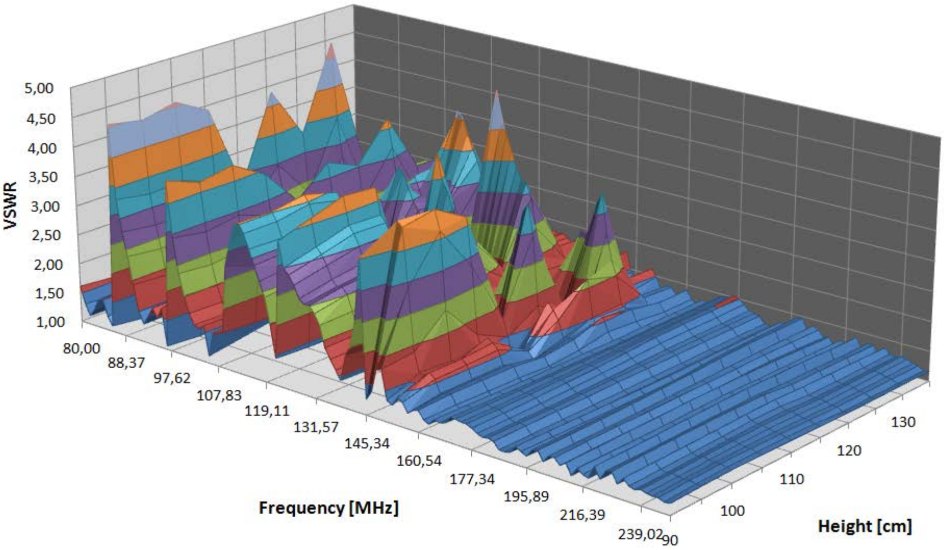

Fig. 6 VSWR versus antenna's height and carrier frequency (horizontal polarization)

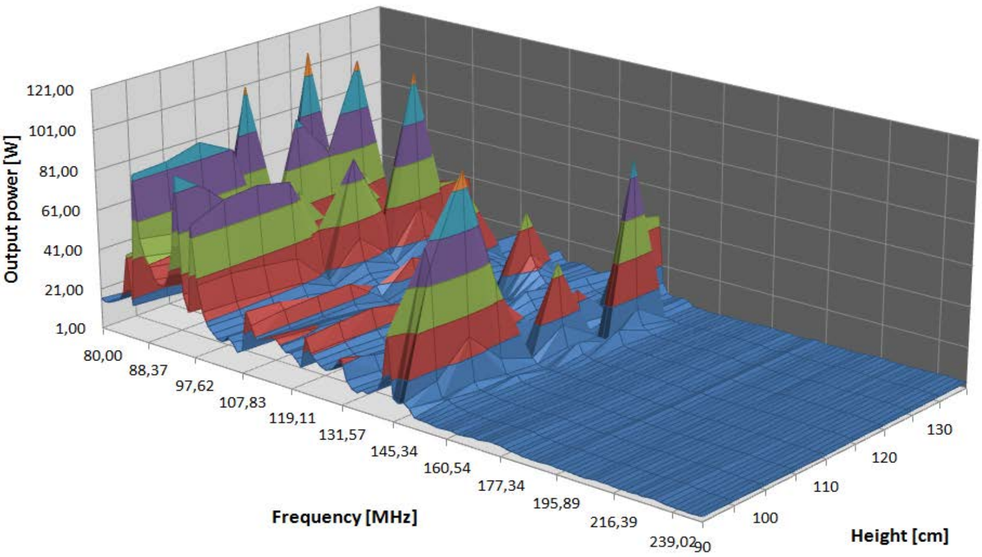

Fig. 7 Measured output power versus antenna's height and carrier frequency (horizontal polarization)

For higher heights, the VSWR variation according to the antenna's height has been observed, but the effect was not as significant as in the previous case.
The possible explanation for this phenomenon is as follows. The antenna's dimensions are comparable to its height above the floor. The dominant E component of the transmitted field is now parallel to the floor and also the capacitive coupling between the antenna and the floor is different due to changed geometry.

In higher antenna's heights than 110 cm the VSWR of the antenna also varied according to its altitude, but there was only a limited correlation between the antenna's VSWR and the transmitted power needed to generate the appropriate field intensity. This phenomenon will stand out in the figure 8 in which the maximum measured levels of

VSWR and output power for each antenna's height are depicted together with the estimated output power that would be necessary if the antenna's VSWR. The fluctuations of the required output power are most likely caused by imperfectly damped reflections inside the chamber. From this

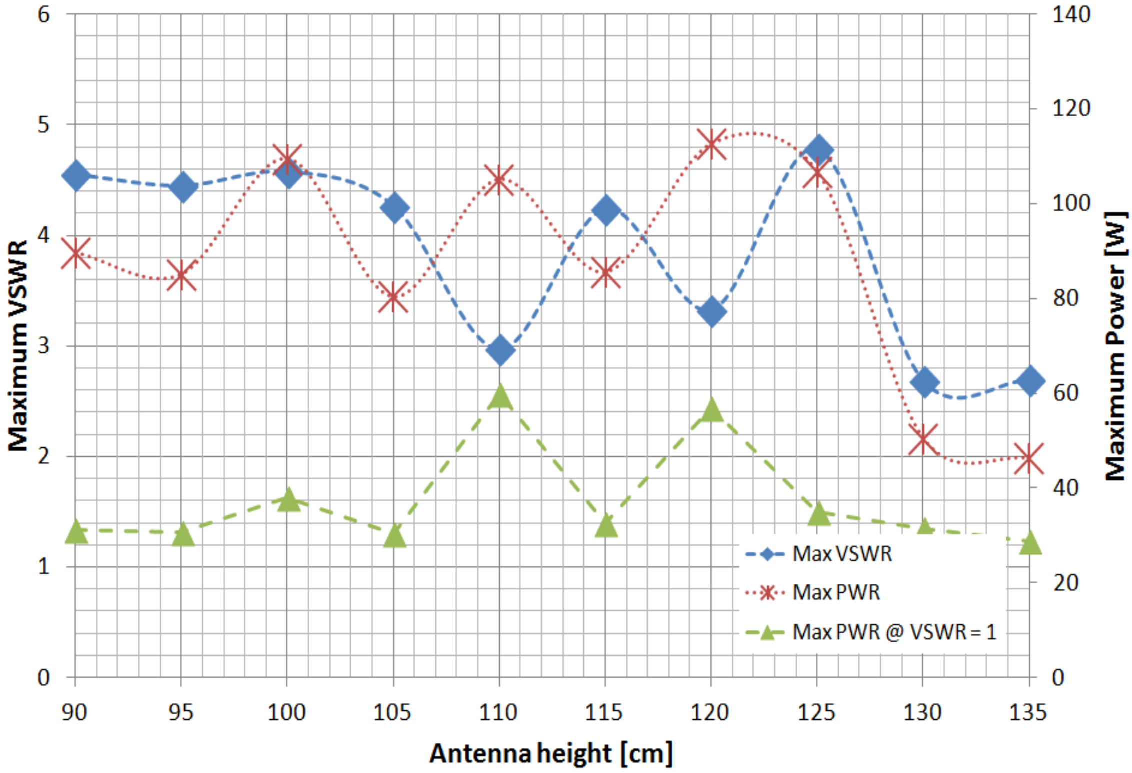

Fig. 8 VSWR, real output power and hypothetical output power at VSWR = 1 versus antenna's height (horizontal polarization)

Fig. 9 Transmitting antenna Rohde&Schwarz HL046E

point of view it must be stated that more research is needed to be done in the case of the horizontal polarization.

5 Conclusions

This paper describes the experiment in which the dependence of the transmitting antenna's VSWR was observed according to its height above the conductive floor. A typical situation of EMC susceptibility test on a common communication device in a semi anechoic chamber has been modelled. According to this experiment it can be generally stated that when vertically polarized, the coupling between the antenna and the chamber's floor affects the antenna's VSWR which results in increased requirements on the power of the transmitting amplifiers. Because the standard EN 61000-4-3 does not accurately specify the antenna's height, it is advisable to search for the optimal antenna's height prior to performing of the uniform field area calibration.

When the antenna's polarization was set to horizontal, the measured data did not provide clear explanation of this phenomenon. For this polarization, more research is needed, consisting of a set of measurements with different mutual geometry of the antenna and feedback field probe.

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