# Conditions for testing effects of radio-frequency electromagnetic fields on electronic devices

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*Abstract:* - In the last years, a large growth of radio-frequency electromagnetic interference was detected, especially in the frequency bands from 0.8 GHz up to 6 GHz. Tests of immunity of electrical devices must be carried out, because this type of interference can significantly affect their functionality. The aim of this paper is to explain the issue of electromagnetic susceptibility and describe the conditions of testing the immunity of electronic devices against the radio-frequency electromagnetic field according to the relevant electromagnetic compatibility standards. Also, sample electromagnetic immunity tests on the basic set of the intrusion and hold-up alarm system will be presented.

*Key-Words:* - electromagnetic compatibility, electromagnetic interference, electromagnetic susceptibility, radio-frequency electromagnetic field

## 1 Introduction

Electromagnetic compatibility as an individual scientific and technical discipline was established in the United States in the sixties of the 20th century. At the beginning this topic was interesting just few experts working in the military and cosmic industry. With the progress of electronic, microprocessor and communication technology the electromagnetic compatibility reach our everyday life and still more and more scientists start to study it.

Electromagnetic compatibility (EMC) is the ability of equipment, system or device to function satisfactorily in its electromagnetic environment. In this environment are present sources of electromagnetic signals, which can have adversely effect. Electromagnetic signals can have natural or artificial character. Another part of EMC is the ability of equipment, system or device to function without introducing intolerable electromagnetic disturbances to anything in that environment. Figure 1 shows the basic breakdown of problematic of EMC.

Electromagnetic interference (EMI) is the process of transmitting signal, which is generated by the source of interference, into the disturbed system. This signal is transmitted by the electromagnetic binding. Particular it is about the identification of sources of interference, their description and measurement of interference signals, identification of parasitic transmission paths and establishing of actions primarily in the resources of interference and their transmission paths. EMI deals with the causes of disturbance and their removal. [1]

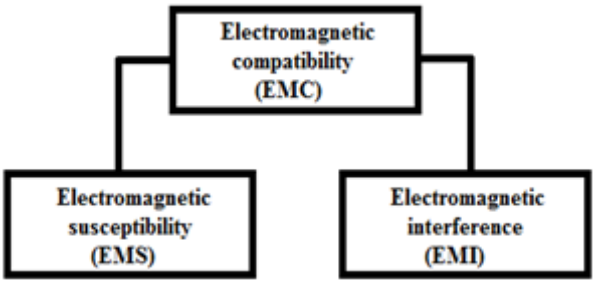


**Fig. 1.** The basic breakdown of problematic of EMC

Measurement and testing of electromagnetic compatibility of electronic devices are carried out according to standardized methodologies in a precisely defined environment. An ideal environment for testing the electromagnetic susceptibility of electronic devices would be the real environment in which the devices will work. However, such the environment is variable. So because of the reproducibility of the test, a simulated environment is selected according to the instructions that are given in the standards of the individual immunity tests.

One of the major types of electromagnetic interference, which affect electronic devices in their normal operation, is the interference with radio-frequency electromagnetic fields. This interference is generated by the mainly radio and television transmitters, industrial equipment and other transmitters and receivers in general use for communication. Testing of electromagnetic susceptibility of electronic devices on radiated radio-frequency electromagnetic field is governed by the basic standard IEC 61000-4-3 and the equipment under test are exposed to test electromagnetic fields with an intensity from 1 V/m to 30 V/m, the most often in the frequency range from 80 MHz to 2000 MHz.

Measurement of interference which is transmitted by the radiation is performed in anechoic or semi-anechoic chambers; respectively at the test site in open space OATS - Open Area Test Site. Testing for electromagnetic immunity in the test radiated radio-frequency electromagnetic field should be always carried out in shielded chambers due to the high intensity of the generated field. But in the case of large systems or devices, the measurements must be carried out at the installation site. [1, 2]

Electromagnetic susceptibility (EMS) is the ability of a device, equipment or system to function without degradation in the presence of an electromagnetic disturbance. They must work without failures or with a precisely defined allowable influence. EMS deals with the technical measures which increase electromagnetic immunity of receivers. EMS is focused on removing the consequences of interference, without removing their causes.

The electromagnetic susceptibility of the technical system is divided into:

- Internal EMS - it is system immunity against interfering sources contained inside its own system.
- External EMS - it is the resilience of the system against external sources of electromagnetic interference (EMI). [1, 3]

This paper describes the electromagnetic immunity test of the basic set of the intrusion and hold-up alarm system (I&HAS). This basic set consisted of a control panel with an accumulator stored in a plastic box, the keypad, PIR detector and siren. This set has been tested to the effects of EMI (radiated, radio-frequency, electromagnetic field), and system failures or unintentional behaviour of components of I&HAS were monitored during the immunity tests. A semi-anechoic chamber was used for EMS tests and the test set was in two basic states (ON state and state of alarm).

In Section 2, the (semi) anechoic chamber is described and Section 3 focuses on the basic characteristics of radio frequency electromagnetic fields and the conditions of the immunity tests according to the standard EN 61000-4-3 (testing levels, environmental classes and frequency range). Section 4 describes an workplace for EMS testing and a basic set of intrusion and hold-up alarm systems, which was tested for resistance against radio-frequency interference in the semi-anechoic chamber. The next section (Section 5) shows the results of the selected measurements.

## 2 (Semi) anechoic chamber

An ideal space for testing and measuring of EMC parameters of electronic equipment is an absorption chamber. This chamber is electromagnetically impermeable (electromagnetic shielding) through the outer structure of a well-conductive metal material. In our case, the semi-anechoic chamber was built from the panels that were of galvanized sheet steel with a thickness of 2.0 mm.

The interior of the chamber is covered with an electromagnetically absorbent material which significantly reduces the internal reflections in a broad frequency. This absorbent material can be made of a ferrite or a carbon with a styrofoam. The absorption chamber exists in two versions both as the anechoic chamber or semi-anechoic chamber.

The size of the chamber depends on the size of the objects to be tested and the frequency range of the signals used, although scale models can sometimes be used by testing at shorter wavelengths (higher frequencies).

The test and supporting equipment, that to be used within chambers shall be constructed of low conductive material, because there is a risk of unwanted reflections. From this reason, structures from non-conductive plastic or wooden structures for supporting the equipment under test are used. Components of measuring equipment (as opposed to the equipment under test) could be placed inside or outside the chamber. Typically most of it is located in a separate screened room attached to the main test chamber, in order to shield it from both external interference and from the radiation within the chamber. Mains power and test signal cabling into the test chamber require high quality filtering, for example optic cables are used for the signal cabling, as they are immune to ordinary frequency interference and also cause little reflection inside the chamber. [4]

The anechoic chamber has covered with an absorbent material, not only interior walls and ceiling but also the entire floor. As such, the anechoic chamber simulates unlimited open area. In practice, we often encounter a semi-anechoic chamber (shown in Figure 2), which has covered with an absorbent material only the ceiling and walls and simulates the open area with reflections from the ground plane.

The absorbent material can be placed on the floor in the semi-anechoic chamber if it is required under the technical standards or requirements of the manufacturer of the equipment under test (EUT).

**Fig. 2.** Semi-anechoic chamber

The absorbent material converts the energy of the incident wave into heat using the magnetic or dielectric losses. Due to the price, dielectric materials are preferred, such as the different toughened foam materials of polystyrene, polypropylene or polyurethane that contain electro-conductive or graphite fillers. Most frequently, these materials have the shape of a pyramid or cone, but we can also encounter the absorber surface area. The main disadvantage is that a quality anechoic chamber is technologically and financially very demanding. [4]

# 3 Radio-frequency electromagnetic field

Testing of electromagnetic susceptibility of electronic devices on radiated radio-frequency electromagnetic field is governed by the basic standard IEC 61000-4-3 Electromagnetic compatibility (EMC) Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test.

Radio-frequency field is mostly generated by a tiny system transmitter/receiver used by staffs that ensure operation, maintenance and safety in manufacturing. Other systems that generate radio-frequency electromagnetic fields can be, for example, stable radio or television transmitters, vehicles transmitters, and other industry electromagnetic sources. In the last years, a large growth of radio-frequency interference was detected, especially in the frequency bands from 0.8 GHz up to 6 GHz. [1, 5]

## 3.1 Testing levels

The following table (Table 1.) shows an intensity of the testing field based on testing level according to IEC 61000-4-3. Testing levels are used for general purposes, digital radiotelephones and other devices which emit radio-frequency radiation.

**Table 1.** Intensity of radio-frequency radiation.

| Level | Intensity of testing field V/m |
|---|---|
| 1 | 1 |
| 2 | 3 |
| 3 | 10 |
| 4 | 30 |
| X | Special |

"X" represents the unlimited testing level and its associated field intensity can acquire whatever value. This testing level can be given in the product standard.

The intensity of the testing field is represents as a value of a non-modulated signal. This signal is modulated by sinus wave 1 kHz with 80% modulation depth when testing of electromagnetic susceptibility. The real threat when radio-frequency fields radiating is simulated for the equipment under test (EUT) by this modulation. [5]

## 3.2 Environmental classes

The selection of the appropriate level for EUT is made according to environmental class selection based on the followings:

- Class 1: The environment with the low levels of the electromagnetic radiation – typical environment for the local radio stations or television stations that are further than 1 km each other and low power transmitters/receivers.
- Class 2: The environment with the moderate levels of the electromagnetic radiation – typical for business environment in which the low power transmitters are used (less than 1 W) but with close-to-device-usage limitation.

- Class 3: Then environment with the demanding levels of the electromagnetic radiation – typical for the industry environment where are transfer receivers with the higher power than 2 W, which are used in the close field of the device (up to 1 m). There is also the environment, where the radio transmitters, industry, scientific or medical devices are used.
- Class 4: Transfer systems transmitter/receiver and significant sources of interference are situated at the distance of less than 1 m from the EUT.
- Class X: The unlimited level which is defined in a standard for particular product or in a device specification. [5, 6]

### 3.3 Frequency range

Testing of electromagnetic susceptibility on the general purposes is mostly done in frequency range from 80 MHz up to 2 GHz. In case, when testing levels involve safety against radio-frequency radiation from digital radiotelephones and other devices which emit radio-frequency fields, the immunity tests are done in frequency range from 800 MHz up to 960 MHz and 1.4 GHz up to 6.0 GHz.

## 4 Workplace for EMS testing

The basic principle of testing of susceptibility against the radio-frequency electromagnetic field is the use of appropriate antennas for irradiation EUT by specific levels of the electromagnetic field. This testing should be done inside absorption places (in an anechoic chamber or semi-anechoic chamber with additional absorbers).

Workplace for EMS testing consists of technical and other equipment such as the high-frequency signal generator with amplitude modulation sinus wave 1 kHz with 80% modulation depth. The output of the generator can have a filter at the bottom sluice band for harmonic features suppression of the generated signal.

Other equipment which is needed for susceptibility testing of electronic devices is broadband powerful amplifier (for signal amplification), the transmission directional antenna which emits testing electromagnetic wave (generates electromagnetic fields), for example, biconical (double-cone) antenna, logarithmic-periodic antenna, funnel antenna or antenna with double waveguide or another linear polarized antenna system which is appropriated for frequency requirements. In all inputs and outputs of cables and conducting to the testing chamber must be plugged the electric filters EMI (the filter must not to produce additional resonance on the plugged conducting). The isotropic sensor of the field with appropriate susceptibility and auxiliary device for recording power levels, for checking and for continuous functional evaluating EUT and other equipment for ensuring specific function when testing, are needed. [5, 6, 7]

In the tests of susceptibility to radio-frequency fields, most of the EUTs are placed in an absorption chamber on an 80 cm high table, or on a floor on a non-conductive pad 5-15 cm high. According to standards preferred distance of the antenna from the EUT is 3 m. If this distance is can not be met, it may be shorter, but not less than 1 m. Also, the distance of the EUT from the walls of the chamber should be greater than 1 m. The EUT should be irradiated by a homogeneous field of known and constant intensity. The area of this field is usually 1.5 x 1.5 m in height of 0.8 m above the floor. In case of testing smaller devices, the area of the field may be smaller, but it must not fall below 0.5 x 0.5 m.

The calibration of the surface of homogeneous field (Figure 3) in the (semi) anechoic chamber is carried out using the non-modulated harmonic signal before the immunity tests of the selected device begins. Desired surface is irradiated by the transmitting antenna in the direction of the receiving antenna or the sensors. Subsequently, field strength is measured at 16 measurement points of the area. If the measured intensity varies less than ± 3 dB on 75% of the area, the field may be considered homogeneous.

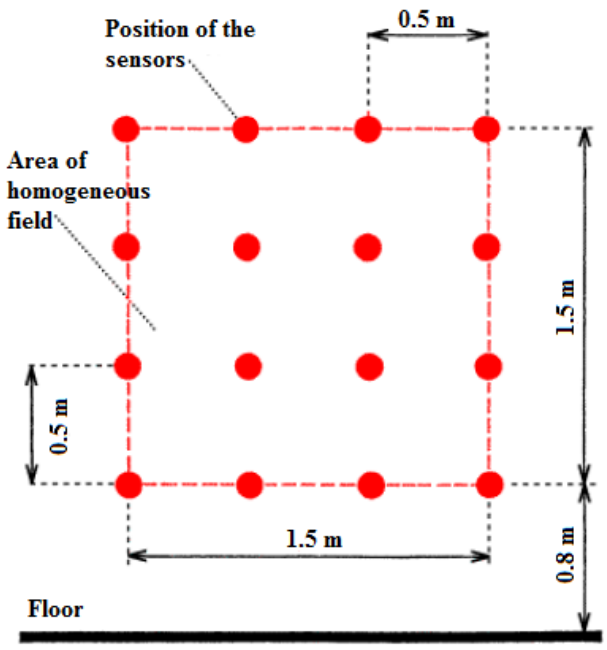

**Fig. 3.** Area of homogeneous field with 16 measuring points

The test procedure includes four points:

a) Verification of laboratory reference conditions.
b) Verification of the proper operation of the EUT.
c) Performing the test.
d) Evaluation of test results. [5, 6, 7]

### 4.1 Equipment under test

Figure 4 shows the basic set of intrusion and hold-up alarm systems, which was tested for resistance against radio-frequency interference. For this type of equipment it is necessary to comply not only the basic standard IEC 61000-4-3, but also the next specialized standard EN 50130-4 Alarm systems – Part 4: Electromagnetic compatibility – Product family standard: Immunity requirements for components of fire, intruder, hold up, CCTV, access control and social alarm systems. [8]

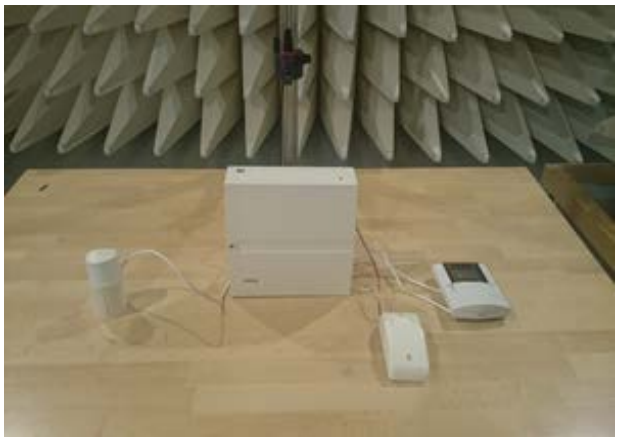

**Fig. 4.** The basic set of I&HAS.

The set was powered from the mains 240V/50Hz. The control panel, accumulator and mains power module were closed in the plastic box which is usually supplied with the control panel. All components belong to the product lines Oasis. Figure 4 shows the location of the components of I&HAS on the table which was placed on the turntable in the semi-anechoic chamber.

The set included the following components:

- Control panel JA 82-K.
- Accumulator 12V, 2.4Ah.
- Mains power module.
- Keypad JA-81E.
- PIR detector JS-20.
- Siren SA-913TM.

### 4.2 Measuring equipment

The measurements of electromagnetic susceptibility were performed in the semi-anechoic chamber in the EMC laboratory at the Tomas Bata University in Zlin. The semi-anechoic chamber creates a shielded space in which all inappropriate electro-magnetic interferences from the environment that could distort the measurement results are eliminated. [9]

Used semi-anechoic chamber from manufacturer FRANCONIA was equipped with the logarithmic-periodic antenna HL046 (Rohde&Schwarz) (Figure 5) which operates in the frequency range from 80MHz to 1.3 GHz. The distance of the antenna from the equipment under test is adjustable according to the requirements of standards.

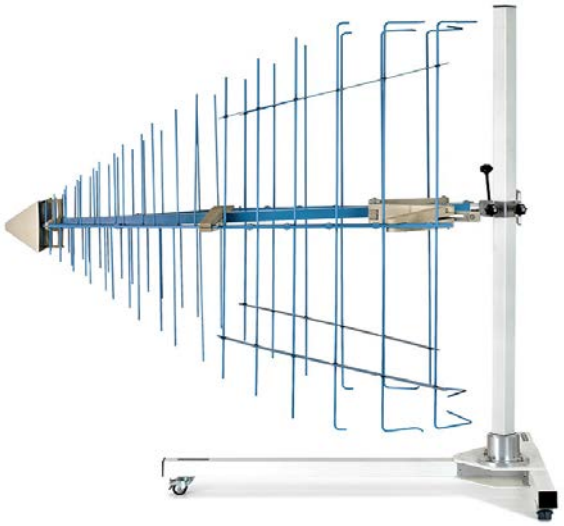

**Fig. 5.** Logarithmic-periodic antenna HL046.

Another device in a semi-anechoic chamber was electric field probe HI-6015 (ETS-Lindgren) which operates in the frequency range from 100 kHz to 6 GHz.

Other measuring equipment were placed outside the semi-anechoic chamber:

- Signal generator - SMB 100A (Rohde&Schwarz) - frequency range from 9 kHz to 6 GHz.
- EMI test receiver - ESU (Rohde&Schwarz) - frequency range from 20 Hz to 8 GHz.
- Amplifier No.1 - 150A250 (Amplifier Research) - frequency range from 100 kHz to 250 MHz.
- Amplifier No.2 - 150W1000 (Amplifier Research) - frequency range from 80 MHz to 1 GHz.
- Amplifier No.3 - 80S1G4 (Amplifier Research) - frequency range from 0.7 GHz to 4.2 GHz.
- Switch and control unit - OSP 130 (Rohde&Schwarz).

- Switch and control unit - OSP 150 (Rohde&Schwarz).
- EMC measurement software - EMC32 (Rohde&Schwarz). [10]

## 5 The results of selected measurements

The EUT, on which was measured the electromagnetic susceptibility to radiated electromagnetic fields, was tested in the semi-anechoic chamber in the EMC laboratory at the Tomas Bata University in Zlin. The set of I&HAS was measured in the mode where the whole set was in the ON state (state of guarding) or when the alarm was induced. The distance of the antenna from the EUT was 2.5 m, in order to ensure the required strength of an electromagnetic field. The testing was performed using a Peak detector which indicates the maximum value of the electromagnetic field for each measured frequency.

The selected measurements from the semi-anechoic chamber are shown in Figures 3, 4, 5 and 6. A harmonic non-modulated signal (which corresponds to the values of field strength) is amplitude modulated to a depth of 80% by the low-frequency harmonic voltage of 1 kHz. The strength of the electric field should be set to a value of 10 V/m.

Each test run is shown using two images that are outputs from the EMC32 control and display software. The x-axis shows the frequency in Hz from 80 MHz to 3 GHz. The y-axis shows either the degree of the radiated electromagnetic field (Imm Level) in V/m (volt per meter) or the level of the currently used amplifier (Amp Out Fwd) in W (watt).

According to standard IEC 61000-4-3 the frequency range from 80 MHz to 2 GHz is the most often to used, but we have set the frequency value up to 3 GHz, since standard EN 50130-4 recommends testing EMS frequencies up to 2.7 GHz.

In the first EMS test, I&HAS test set was in the ON state (state of guarding). During the test in the prescribed frequency range (80 MHz to 2 GHz - according to IEC 61000-4-3), the assembly resisted the action of a radio-frequency field of level 3, which corresponding to the intensity of the field of radiation of 10 V/m. After exceeding the 1.988 GHz frequency, the status of the EUT has changed, the system detected an error and proclaimed an alarm (the siren was activated).

In Figure 6 the intensity of the test field at individual frequencies is shown where deviations from the required 10 V/m are usually minimal. At 175 MHz and 810 MHz the deviation was greater (-1.25 V/m). Figure 7 shows the power of the amplifiers during the test.

In the next test, I&HAS test set was in the alarm state (when the alarm was induced and the siren has been activated). During the entire test (from 80 MHz to 3 GHz), the status of the EUT has not changed and the system did not report no errors after the test was completed. The intensity of the test field at individual frequencies and the power of the amplifiers during the second test are shown in Figure 8 and Figure 9.

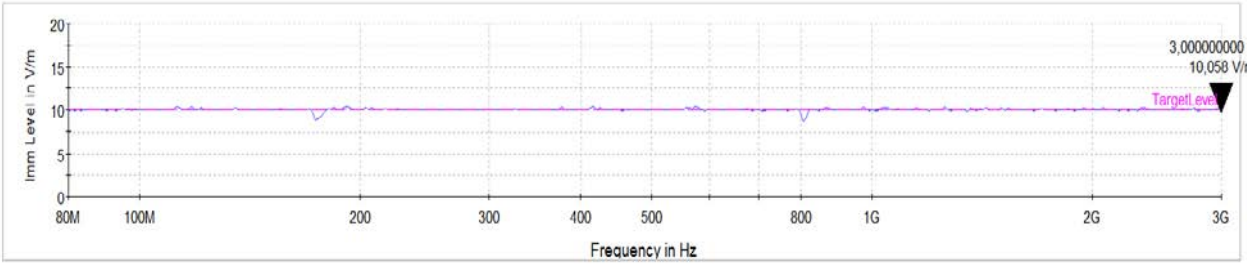


**Fig. 6.** Test 1 - Immunity level.

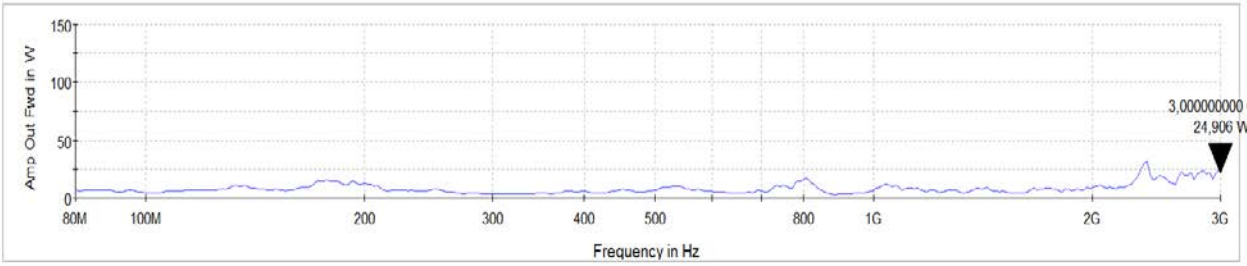


**Fig. 7.** Test 1 - Amp Out Fwd.

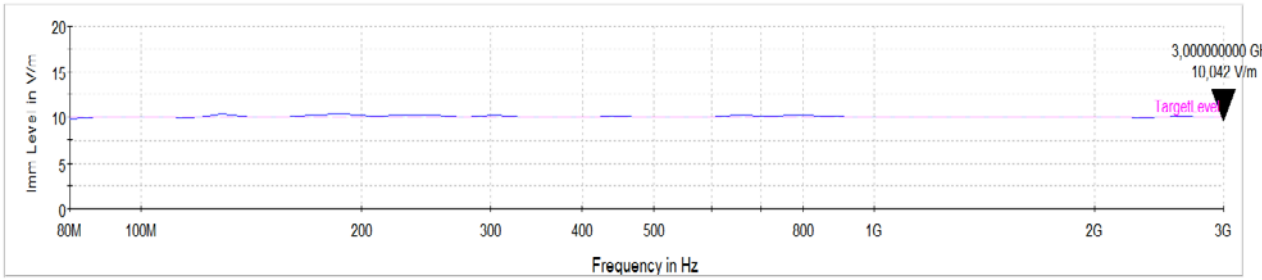


**Fig. 8.** Test 2 - Immunity level.

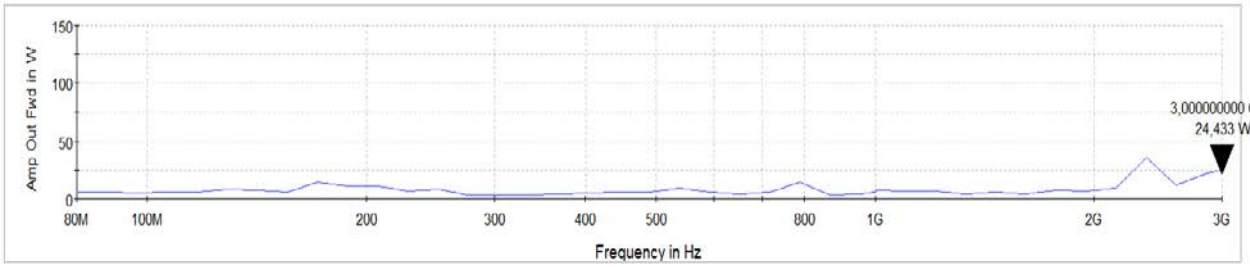


**Fig. 9.** Test 2 - Amp Out Fwd.

# 6 Conclusion

The article describes the requirements and the course of the test of electromagnetic susceptibility of electronic devices on radiated radio-frequency electromagnetic field. In our case the EUT was the basic set of the intrusion and hold-up alarm system in two basic states - ON state and state of alarm. For this type of equipment it is necessary to comply not only the basic standard IEC 61000-4-3, but also the next specialized standard EN 50130-4.

According to standard IEC 61000-4-3 the equipment under test are exposed to test electromagnetic fields with an intensity from 1 V/m to 30 V/m, the most often in the frequency range from 80 MHz to 2 GHz. Standard EN 50130-4 recommends testing EMS frequencies up to 2.7 GHz.

During our selected measurements I&HAS test set was exposed to radio-frequency fields at an intensity of 10 V/m and in the frequency range from 80 MHz to 3 GHz. During the immunity test when EUT was in the ON state, the status of the EUT has changed after exceeding the 1.988 GHz frequency - the system detected an error and proclaimed an alarm (the siren was activated). At the end of the test, it was necessary to turn off the alarm manually, but the system remained fully functional. During the immunity test when EUT was in the alarm state, no change was observed.

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