Electromagnetic Compatibility Analysis for Space Environments

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***Abstract*—An analysis of Electromagnetic Compatibility (EMC) for space environments is described and performed by the EMC area of the Testing and Calibration Laboratory (LEC) from ANACOM. This analysis focuses on a feasibility study of EMC testing for space objects at this facility, taking into account the ECSS standard for EMC, and the ISTSat-1 CubeSat from the IST as a case study. Therefore, a study of the EMC area capabilities is done concerning its normative references, equipment facility, frequency ranges, test levels and experience, which are essential for EMC test campaigns applied to space objects and, in particular, to the ISTsat-1 CubeSat.**

Keywords—Electromagnetic Compatibility, Electromagnetic Interference, Electromagnetic Susceptibility, ECSS standard, IEC Standard, CISPR Standard, MIL Standard.

I. Introduction

A demanding EMC analysis must be performed on satellite systems during their testing phase, to ensure not only their autoimmunity in orbit, but also their susceptibility to other systems during their launch and space deployment phases.

In this paper, an analysis of Electromagnetic Compatibility (EMC) for space environments is described, focusing on a feasibility study of EMC testing for space objects at the EMC area of the Testing and Calibration Laboratory (LEC) from *Autoridade Nacional de Comunicações* (ANACOM). This analysis considers the requirements from the ECSS standard for EMC described in [1], in order to develop an EMC test campaign at these facilities, being applied to the ISTSat-1 CubeSat from Instituto Superior Técnico. The results of this test campaign are described in "Results of Electromagnetic Compatibility Analysis of the ISTSat-1" [2], which followed the test planning and procedures described in this paper.

II. General EMC Applied to Spacecraft

A. The requirement

In order to fulfil the Electromagnetic Compatibility (EMC) requirement, a device must satisfy the equation

$$EMC = EMI + EMS. \quad (1)$$

Electromagnetic Interference (EMI) is the capability of the device to operate in its electromagnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment. On the other hand, Electromagnetic Susceptibility (EMS) is the ability of the device to perform as intended without degradation in the presence of an electromagnetic disturbance.

To achieve EMC, standard levels of EMI must be established and coordinated with the levels of EMS to provide adequate EMC margins for a device operating in its environment in cause. Considering a space environment, this coordination may be done by the ECSS standard for EMC [1] as in the case of ISTSat-1.

B. The approach

The proper procedures for an EMC test campaign are defined with a preceding EMC analysis, which may be done in a port by port approach, analysing the satellite ports like its enclosure port, the mains power port or the data communications port, or in a phenomena by phenomena approach, studying the, for example, the radiated emissions of a device or its immunity to an external radiated electromagnetic field.

C. Device Under Test

Special attention should be taken to characterize the DUT. According to the ECSS standard for EMC, the DUT is a spacecraft that must operate in its normal operating mode simulating its flight operation. Furthermore, the satellite integrates communication antennas and solar panels and must not have any external cables connected to it during the test. Therefore, any of the aforementioned EMC analysis approaches focuses only on the enclosure port of a space object, since no external cables exist connected to it.

Care should be taken with the selected radiated EMC phenomena and the existence of communication antennas on space objects. Shielded radiofrequency loads in the antenna ports may be used as well as exclusion bands on the test, around the transmission and reception carrier frequencies. This is important for transmission antennas during EMI tests and reception antennas for EMS tests.

D. EMC Test Monitoring

For the EMS test, a clear and objective minimum performance criteria or permissible loss of performance must be defined as the pass/fail criteria. For monitoring purposes, the assessment of the DUT performance may be done during the test in two ways:

- In real time assessment, for example, by observing an indicator of the good working state of the DUT, like a blinking LED, or by observing a galvanometer indicating his expected voltage level and current consumption.
- At the end of each test run, by accessing the monitoring results recorded during the test, either by the DUT itself or by external monitoring equipment.

Special care is required when choosing the monitoring equipment. This shall have a high level of immunity to avoid itself from being affected by the radiated electromagnetic field and cause false positives. One example of such highly immune monitoring equipment is the galvanometer.

III. EMC AREA OF THE LEC

The battery of EMC tests required by the ECSS standard, which is a combination of commercial and military standards, involves a huge amount of experience and skills. The EMC area of the current Testing and Calibration Laboratory (LEC) is active since 1992. Its capabilities were firstly recognized in 1995 with accredited EMI tests up to 1 GHz, according to standardized test methods of both electric and electronic equipment in the framework of a Quality System according to EN 45001. In 1996, the facility was equipped with a shielded semi anechoic chamber, which extended its field of activity to EMS up to 1 GHz and improved his EMI test performances. In 2010, the EMC area accepted the responsibility to manage the list of accredited EMC test standards in the framework of a flexible accreditation under the scope of EN 17025, with the extension of his scope to EMC of radio equipment. Finally, the frequency range was extended up to 6 GHz for EMI in 2015, and for EMS in 2019.

The EMC area of the LEC offers a wide range of 12 flexible qualified tests as detailed in [3], which are:

- CEM.01: Radiated disturbance – Electric field (dBµV/m).
- CEM.02: Electrostatic discharges immunity test - ESD (kV).
- CEM.03: Radiated, radio-frequency, electromagnetic field immunity test (V/m).
- CEM.04: Electrical fast transient/burst immunity test (kV).
- CEM.05: Surge immunity test (kV).
- CEM.06: Immunity to conducted disturbances, induced by radio-frequency fields (V).
- CEM.07: Conducted disturbance at mains terminals (dBµV).
- CEM.08: Conducted disturbance at mains terminals – Discontinuous disturbance (dBµV).
- CEM.09: Disturbance power (dBpW).
- CEM.10: Electromagnetic radiation disturbance – Magnetic field (dBµA/m).
- CEM.11: Radiated electromagnetic disturbances – Loop diameter at 2 m (dBµA).
- CEM.12: Insertion loss (dB).

IV. ISTSAT-1 TEST PLANNING AND PROCEDURES

The analysis of the ECSS standard for EMC shows some similarities when compared to the equivalent EMC area skills, particularly with the MIL, IEC, CISPR standards described in [4], [5], [6] and [7]. Nevertheless, the ECSS standard establishes the EMI and EMS limit test levels necessary to guarantee the required EMC margins of spacecraft, establishing the corresponding measurement procedures, considered the phenomena and the ports to be assessed.

Therefore, there was the need to adapt the operating procedures of the EMC area for the ISTSat-1 case, being decided by the ISTnanosat team to apply both **CEM.01** test for EMI and the **CEM.03** test for EMS to its enclosure port.

Although the ECSS standard requires the satellite operating in its normal operational mode, and since the only solar panels and antennas available for the ISTSat-1 were the flight ones, which could not be handle outside a clean room area, these components were not used during the EMC tests so that they would not become contaminated due to anechoic chamber located outside a clean room, as shown in Figure 1.

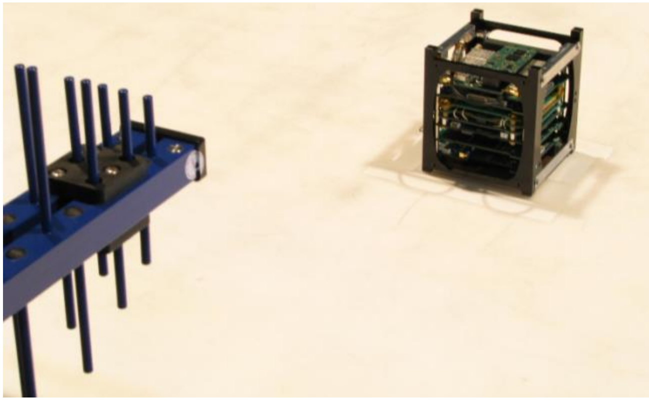

Fig. 1. ISTSat-1 at the LEC EMC area during an EMI test.

A. *Immunity Test (EMS)*

The mode of operation of the EMS test system CEM.03 was in open loop, meaning that a pre-established Uniform Field Area (UFA) was necessary. According to the ECSS standard, a record of this field strength is also required throughout the tests to ensure a stable UFA during the frequency sweep, meaning that test system was changed to operate in a closed loop mode, with real time feedback from a calibrated sensor placed near the DUT to maintain the field measured at the correct intensity level [1].

The mode of operation of the EMS test system CEM.03 was in open loop, meaning that a pre-established Uniform Field Area (UFA) was necessary. According to the ECSS standard, a real-time recording of the field strength was also required during the tests, using a calibrated sensor near the DUT.

The other possibility was to operate in closed loop mode, with real time feedback to maintain the field measured by a calibrated sensor in a point in the vicinity of the DUT, although this method would introduce measurement errors due to the presence of the DUT.

Additionally, an adaptation of the UFA was required for the EMS tests. Normally, this field would be calibrated with 16 points inside a square grid of 1.5 m located 80 cm above the floor, considering the antenna placed 3 m away from the DUT, as shown in Figure 2. However, the ECSS standard required this field to be calibrated with 9 points inside a square grid of 1 m located 90 cm above the floor, being the antenna placed 1 m away from the DUT [1].

The EMS tests consisted of a frequency sweep from 30 MHz up to 1 GHz, where intensity fields of 1 V/m and 10 V/m were imposed to the DUT. Due to the high EMS intensity level required, two broadband antennas (a biconical and a log-periodical one) were used with adequate baluns, being able to support the power needed for the higher field strength level, specially at a low frequency range from 30 MHz to 80 MHz, where the power needed is higher due to the lower gain of the biconical antenna, requiring up to 100 W in the linear operating range of the power amplifier.

In the case of ISTSat-1, its enclosure port was the only port to be assessed from an EMS point of view, since there are no external cables connected to the satellite. Additionally, the satellite radio transceiver subsystem was not present in the DUT during these tests, meaning that no extra care was needed for the reception antenna port, like shielded RF loads or excluded frequency bands [2].

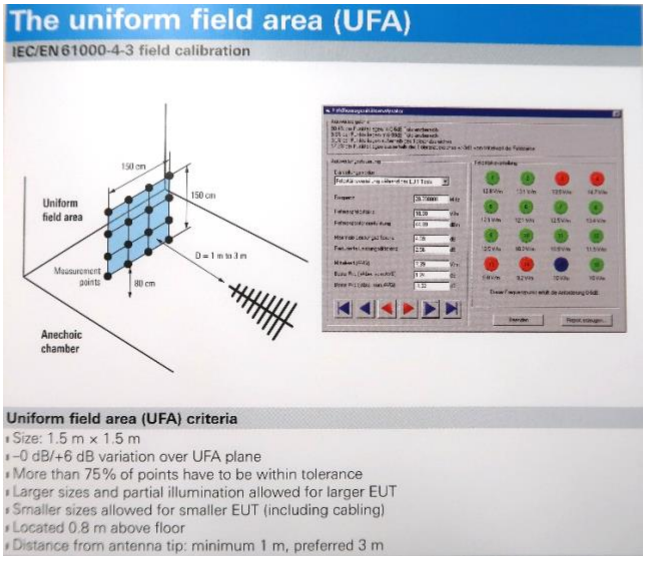

Fig. 2. Test setup configuration required for establishment of the UFA.

B. Disturbing Emissions Test (EMI)

During the CEM.01 EMI test, the distance between the antenna and the DUT was changed from 3 m to 1 m, according to the ECSS standard [1].

In the case of ISTSat-1, its enclosure port was the only port to be assessed from an EMI point of view, since there are no external cables connected to the satellite. However, since the satellite radio transceiver subsystem was present during these tests, the transmission antenna port was attenuated with a shielded RF load to reduce the influence of the high-power transmission signal on the EMI readings [2].

V. CONCLUSIONS

The presented EMC analysis for space environments allows to conclude that the EMC area of LEC is adequate to provide both radiated EMI and EMS tests campaigns for space objects. Nevertheless, some changes were needed on the EMC area standard operation modes in order to satisfy the ECSS standard requirements, namely regarding the creation of different UFAs applied to the DUT, with lower test frequency ranges and different distances between the radiating antenna and the DUT and its height.

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