Equipment and Methodology for Destructive High-Power Microwave Testing

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***Abstract*— FOI is establishing a facility for destructive HPM testing and is developing an envisaged test methodology for such tests. The methodology consists of two test phases: (1) Determine the lowest power density required to destroy an object within a frequency range, using a reverberation chamber. (2) At this frequency, determine the most sensitive direction of attack using an HPM generator. A reverberation chamber and an HPM-generator adequate for such tests are also presented.**

Keywords- Destructive testing, High-Power Microwave (HPM), Reverberation chamber, Vircator

I. INTRODUCTION

High-power electromagnetic radiation has not only the potential to upset electronics; it may also be used for physically destroying electronic components. The development of HPEM devices has reached a sufficient maturity to form a real threat in this respect, at least in the military context [1]. General mitigation techniques include low-level tests, which can be performed since the system responses are linear. However, when studying destructive effects, the system response becomes non-linear and scaling from low-level tests will not be possible. To be able to perform tests in the destructive, non-linear regime, FOI is developing a relevant test methodology and appropriate facilities.

II. TEST METHODOLOGY

In general, susceptibility testing of electronic equipment is demanding since the electromagnetic coupling into an object is strongly dependent on frequency, polarization and direction of incidence [2]. Thus, during an HPM test, the device under test (DUT) must be irradiated in a broad frequency interval (at least the S-band, 2-4 GHz), in many directions and with at least two polarizations. Destructive HPM testing of electronic equipment requires that the DUT is subjected to very high power densities, usually on the order of several 100 kW/m^2, or over 10 kV/m [3].

The proposed test method consists of the following two test phases:

- First, the DUT is tested in a reverberating chamber (RC) where the minimum power density required to destroy the DUT is established and at which frequency this occur.
- Second, the DUT is tested for its most sensitive direction of attack and polarization using a frequency-tuned HPM generator.

To realize this test method a designated RC and HPM generator must be developed. These are described in the following two sections.

III. DESCRIPTION OF SYSTEM

A. Reverberation Chamber

The RC was designed and delivered by Siepel and has a working volume of 0.72 x 0.56 x 0.4 m^3 and a lowest usable frequency (LUF) of 1 GHz. The time constant of the chamber is below 400 ns and the normalized E-field according to DO-160 varies between 300 V/m and 400 V/m in the frequency range between 1 GHz and 6 GHz [4]. At the time of writing the chamber is powered by a 5 kW pulsed S-band amplifier enabling electric field strengths up to about 25 kV/m in an empty chamber. The 400 ns time constant enables pulsed testing down to about 2 µs according to DO-160, shorter pulses requires loading of the chamber to reduce the time constant.

B. High-Power Microwave Generator

The HPM-source is a modified version of a coaxial virtual cathode oscillator, vircator that will generate a TE_{11} mode in a cylindrical waveguide connected to a medium gain horn antenna [5]. This system can produce a power density on the order of 10 MW/m^2 over an area of a few square decimeters where the far field of the antenna begins. For testing at a lower power density objects are simply moved further away from the antenna. The polarization is changed by rotating the cathode so that the direction of electron emission and hence the polarization of the TE_{11} mode is changed. This simplifies testing of large objects that can be difficult to rotate around the axis of the propagation vector of the radiation in order to facilitate testing at different polarizations.

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