U.R.S.I. FRANCE JS 20 FUTURE NETWORKS: 5G AND BEYOND

On the use of ERCs for 5G measurements
De l'utilisation des chambres réverbérantes électromagnétiques pour les mesures 5G

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Keywords ; mots-clés: 5G Networks, Electromagnetic Reverberation Chamber, Susceptibilty Tests; réseaux 5G, chambre réverbérante électromagnétique, tests de susceptibilité.

Abstract/Résumé

Electromagnetic reverberation chambers (ERCs) have demonstrated their cost-effectiveness over the years as a viable alternative to classical electromagnetic compatibility (EMC) environments. Their ability to deal with EMC, safety-, or security risk analysis connected with 5G applications is just limited by the lack of knowledge and control of transient fields. The technological spectrum of ERCs will be extended to examine effects of life-like electromagnetic transient fields, targeting EMC risk assessment and mitigation (reliable and safe communication). This paper will outline the usability of ERCs for various areas.

1 Introduction

The increasing degree of interconnectedness of all kinds of electrical devices is currently modifying the challenges on safe and secure technical engineering. This requires the establishment of new engineering procedures and tools that enable an integrated and simultaneous analysis of risks inherent to the massive use of electronic devices and facilities. Especially the introduction of 5G networks requires re-validation of EMC properties and biological compatibility because of a much larger parameter space (e.g. frequency range and power density), and particularly, transient effects.

2 ERCs for Susceptibility and Dosimetry Tests

Due to their cost-effectiveness and simple usability, ERCs have become a viable alternative to classical EMC environments such as Open Area Test Sides and Anechoic Chambers. This development has become possible by research carried out during the last 20 years leading to an understanding how the electrical fields are distributed in these resonators with a moving geometry and how characteristic data of a device under test can be derived via suitable measurement procedures including hardness tests, emissivity tests, and the measurement of a device's shield damping capacity. For a comprehensive introduction to the field, see [1].

Measurements in ERCs become increasingly interesting for wireless applications: These environments came into the focus of research some years ago due to their advantages, comprising the suitability for fully automated measurements, the capacity to provide complicated field patterns, or the possibility to generate a high field intensity with relatively inexpensive amplifiers. Additionally, their easy handling makes ERCs an area of interest for various applications. Consequently, the biological community is continuing to use **ERCs** for exposure test (the topic was discussed at BioEM 2017 conference, June 2017, Hangzhou, China) e.g. [2, 3]**. In particular,** many questions arising within the spectrum of future 5G applications can be examined by ERCs, including biological and electromagnetic compatibility issues due to field patterns resulting from massive MIMO, beamforming, and the enormous density (co-location) of devices, such as the expected high background noise power and unneglectable interference problems The requirement of a statistical analysis to assess these new technologies has been pointed out, e.g., in [4]. EMC research groups are hence exploring their behavior both with deterministic, statistical, stochastic, and “chaotic” approaches [5, 6, 7, 8, 9].

The relevant international standard IEC 61000-4-21 [IEC11] unfortunately recommends a minimum volume of 70 m^3 for an ERC, which exceeds the space available in most EMC laboratories and consequently restricts their applicability (see Fig. 1 for a typical example of a “small” ERC). Additional research on small scale ERCs will therefore provide smaller companies with an affordable test method. Numerical simulations of the electric fields in a small ERC are presented in [10].

Fig.1: Small size ERC used for testing.

2.1 Susceptibility tests

Any relevant investigation on the susceptibility of DUTs to interference from external electromagnetic fields must include a test that delivers information on the coupling frequencies, i.e. frequencies at which the DUT can receive power from the signal environment as a function of frequency. To facilitate this, we use a method which allows for the identification of critical coupling frequencies of an unknown electronic device by nondestructive measurement based on an electromagnetic reverberation chamber (ERC), which is in accordance with the appropriate standard IEC 61000-4-21 in terms of size, calibration, and stirrer efficiency. Basically, the idea of microwave spectroscopy is transferred to detect possible resonances of electronic devices. For this method, the use of an ERC is highly favorable, since other test environments cannot guarantee that every combination of field direction and polarization is included. This kind of spectroscopic applications of ERCs have been initialized by L. O. Fichte et al. [11] and since then further developed [12, 13]. A simulation-based assessment of the suitability of small ERCs has been presented, e.g., in [10] by analysis of their field statistics.

The spectroscopic method is based on the power consumption (i.e. absorbing cross section, ACS) of a device in an ERC, monitored as a function of the applied frequency. Hardware improvements to reduce noise and to increase the signal to noise ratio as well as procedures to reconstruct the signal from the measured data in high quality had to be considered. Currently, the limits of the method are analyzed, e.g., by a comparison of the coherence time of the eigenmodes of an ERC to the coherence time of a device under test. Another area, the power spectroscopy method will be extended to, are testing methods showing whether a system is susceptible to data security issues for certain types of disturbances. Such techniques are of paramount importance, especially regarding 5G framework for TRP (Tx/Rx point) characterization in realistic environments. The complete power budget (including both scattered and absorbed power in an ERC) provides reliable information considering functional safety of next generation electronics devices. Moreover, newest and next generation of electronic devices rely on very high frequencies; in that way, the ambiance seen by the components or the PCB is statistical in nature. Indeed, their respective containers (boxes, bays or shelters) act by themselves as ERCs.

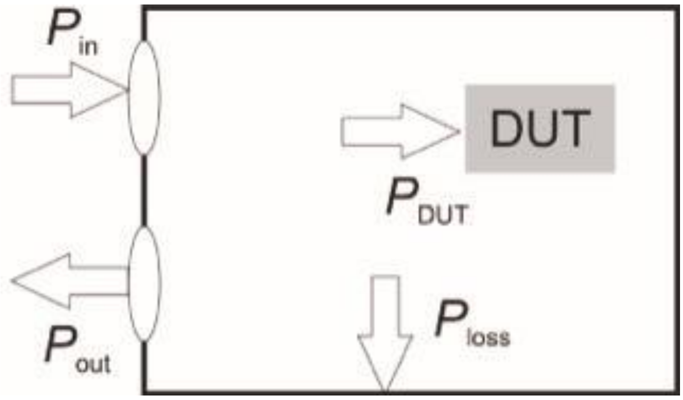

Fig.2: Power fluxes in a loaded ERC.

In detail the power absorption of the device (as a function of frequency) is determined from comparing the power losses of an empty ERC with the losses measured after loading the chamber with the DUT (see. Fig. 2 for power fluxes). The losses can be determined by subtracting output from input power, under the assumption that loss mechanisms are unchanged after loading the chamber with a DUT. The power measurement is performed with a (rather expensive) Vector Network Analyzer (VNA), but earlier experiments successfully employed power meters; the cost of the self-constructed ERC is negligible. Testing for critical coupling paths can therefore be executed with simple means, on the spot, and is even feasible for ammunition. With a correct implementation, we are able to fully automate the test procedure with the only exception of changing the DUT.

The method has been successfully validated with linear DUTs chosen for their known resonant frequencies, and with more complex devices. The precision of measurement is estimated below 5%, e.g. [13]. Note that the dimension of the DUT is only limited by the size of the ERC, so system level tests (e.g. for cars or trucks) are possible in larger ERCs.

2.2 Biological dosimetry

For biological reverberation chambers a dosimetry in terms of the specific absorption rate (SAR) has been developed, that has also been transferred to biological exposition experiments with open wave guides [14]. Consideration of pulsed fields and, more generally, of transient effects in ERCs is a completely new subject with promising perspectives and interesting scientific questions. Such new applications rely on a deepened insight into the statistical distribution of electromagnetic properties, as examined, e.g., in [15, 16].

In order to estimate the impact of emitting devices on biological tissue, a dosimetry for continuous and pulsed fields is required. In this context, figures that reflect the impact of such fields on the load of the chamber become relevant. One of the characteristic figures is the specific absorption rate (SAR), which indicates the mass related absorbed power. A dosimetry requires knowledge of how the chamber interacts with a load. This can be derived by measurements inside an ERC and can be validated by physical modelling.

Depending on their amplitude and duration, electromagnetic pulsed and continuous waves (CWs) may generate adverse health effects (i.e. heating of the tissues) or contribute to thermal and non-thermal therapeutic applications (i.e. electrochemotherapy or gene transfer). Thermal effects are well known and correctly documented in the safety standard. On the contrary, non-thermal effects are still studied and badly documented. Biologists are still expecting solutions from physicists to generated pulsed electromagnetic waves in biological samples. In that way, an ERC with a high confidence in the level and homogeneity of fields and of the SAR is highly appreciated [17].

3 Advantages of ERCs at higher frequencies

In addition to the obvious advantages of ERCs they face the same problems as conventional EMC test procedures (like semi-anechoic chambers or GTEM cells) with regard to being RF proof. Yet, ERCs do not require any absorbers and therefore avoid the installation of costly broadband absorbing devices; possibly they can cover the full frequency range of 5G tests. While time-gating can be applied in every test environment at very high frequencies to mitigate additional reflections at not perfectly absorbing boundaries, ERCs might be able to provide better results after being investigated for excitation with transient signals.

The minimum volume of 70 m^3 for an ERC recommended by IEC 61000-4-21 (as discussed above) applies also for chambers designed for 5G related test. Yet, since the size of an ERC – more precisely its volume – is defined by the lowest usable frequency (LUF), and ERCs intended for measurement at 5G frequencies will be a lot smaller than the conventional chambers recommended by IEC. As a consequence, it will be possible to design small ERCs – smaller than an average refrigerator or even as small as a desktop computer - for very cost-efficient EMC test. Last but not least, measurements based on ERCs can be easily automated, yielding a higher efficiency for performing the large number of tests required by the new wireless technologies expected.

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