Introduction

Before introducing the motivation and the content of this book, we will carry out a brief retrospective of the advent of reverberation chambers in electromagnetism.

The first experiments recounting the confinement of electromagnetic waves in a reverberation chamber probably date back to 1976. We will find the details of these experiments in a publication by P. Corona from the Naval Academic Institute of Naples (Italy). The objective of these precursory works was above all the measurement of the radio source emissions. It was then demonstrated that the wave confinement led to a direct evaluation of the total power radiated by the object. At this moment there are two competing theories: one considers that the electromagnetic power in the chamber is mainly governed by the resonance mechanisms and the second considers the emission as the radiation of the blackbody, imported from the statistic thermodynamics [COR 76a, COR 76b, COR 02].

Together with the research led and carried out by P. Corona, reverberation chambers were already being developed in the United States. Around 1980, we may mention the building of a chamber at the National Institute of Standard and Technologies (formerly called the National Bureau of Standards), where the theory of the stirred modes was founded, borrowed from the statistical analyses. We find this approach in many publications, notably written by M. Crawford, G. Koepke, T. Lehman. The physical-statistical analysis was then continued by works published 20 years later by D.A. Hill, J. Ladbury, L. Arnaut, L. Jansson, M. Bäkström and by many other scientists working on and increasingly discussing this subject [ARN 02, CRA 74, CRA 86, HIL 94, JAN 99, LEH 91, LEH 97].

Reverberation chambers have been designed in this context and devoted to the measurements of the electromagnetic compatibility. Indeed, as of this time, the demand turns first to the measurements of the attenuation of the connectors and cable shields. The concerned frequencies are then extended from hundreds of MHz to tens of GHz. Knowing that the reduction of the wavelength comes with a decrease in the antenna size, it was decided to favor the confinement techniques in the reverberant environment. We could add the advantage of producing oversized cavities compared to the wavelength to these primary properties. We thus managed to generate fields of random amplitude, amplitudes coordinated by a mode stirring. Contrary to measurements in free space, the method gave, to the objects under test, insensitivity to the criteria of directivity and wave polarization. These factors, combined with the emergence of high amplitude fields, stimulated by resonances, will immediately extend the reverberation chambers to immunity and susceptibility tests [WAR 96].

At the same time and with the efforts of M. Hatfield of the Naval Surface Warfare Center in the United States, test methods using a reverberation chamber enter the international standards with texts currently recognized by the International Electrotechnical Commission (IEC) and the aeronautics standardization [HAT 00].

Nowadays, the use of reverberation chambers, in France as well as in other European countries, intensifies with the need for the tests, but also in order to extend their scope in a very significant scientific research effort. In France, we can count several chambers distributed in some universities and other installations devoted to military activities, the automobile industry and aeronautics, without forgetting their interest for the study of the expected biological effects of radio waves. The use of reverberation chambers also concerns applications other than electromagnetic compatibility, since they simulate the propagation environments generating multiple reflections and, because of that fact, are very disruptive for modern telecommunication techniques [LIE 04].

To this day, there are many articles produced by the scientific community on the subject of reverberation chamber, and thus this book does not have the objective being added as a contribution to these high level works. The authors preferred a conventional physical approach, hoping it will help engineers, technicians or beginner students to understand the basics.

The eight chapters of this book, by a gradual description, bring the reader from the analysis of the mode stirring and the properties of field distribution, to the applications illustrated by measurement examples found in various installations.

The book is made up of three topics that we will briefly summarize.

Chapters 1, 2, 3 and 4 discuss the physics of the chamber's operation. From the analysis of other test means, we can show that a test in reverberation chamber integrates measurement errors. We will try to quantize their amplitude and stationary behavior. Resorting to the 1D model will facilitate an understanding of the generation of eigenmodes, whose identity will then be specified for a rectangular chamber. The concepts of the modal cells and of the plane wave spectrum will be used to introduce the principle of mode stirring, and then indirectly (Chapter 3) the link that we can establish between the disordered distribution of the fields and the estimate of the error margins of their average amplitudes. This part will largely use the results and demonstrations from the articles published by D.A. Hill [HIL 94]. The statistical tests concluding Chapter 3 will supply the tools able to confront the experiment on idealized field or power distributions stated by the probability density function of Rayleigh distribution or exponential distribution, respectively. Chapter 4 is mainly devoted to the characterization of the chambers, tackling the evaluation of the mode stirring procedures, as well as a few demonstrations relative to the application of statistical theories, in preparation for the calibration of the field's amplitude.

Chapters 5, 6 and 7 discuss the questions of the chambers' use. Their aim is not to do a detailed description of the standard documents. On the contrary, the authors wanted to extract from the official methodology the protocols forming the strongest links with the physical and theoretical analyses undertaken in the previous chapters. These in-depth explanations of the phenomena will be followed by results of experiments carried out on electronic equipments or on components tested in several reverberation chambers installed in France. This is how we will find, in Chapter 5, immunity and susceptibility tests performed on electronic on-board car equipment. Chapter 6, devoted to the emission measurements, will be illustrated by an experiment coming from a radiation constituted of spectrum lines spreading on more than 1 GHz. The analysis will insist on the confrontation of measurements done on chambers of different volumes. Chapter 7 exclusively turned on the shield effectiveness, discusses the problem of the evaluation of the attenuations brought by shielded cables or connectors, by shielded enclosures, and then by materials offering a certain opacity to the radio waves. This chapter will be illustrated by results of experiments successively practiced on a coaxial test tube, comprising a small aperture on a shielded box, with a slit and on a polymer conductor material, deposited against a plane substratum in fiberglass.

To conclude this book, Chapter 8 begins the link with some recent research works accomplished on the reverberation chamber. This part is not exhaustive and the authors propose a discussion on the physical limits of some approaches described in the previous chapters. It is obvious that for purely didactic reasons, the phenomena have often been reduced to ideal situations. Such is the case for field distribution, whose reality is found between the purely periodic model of the standing waves and the perfect disorder established on the hypothesis of the maximal entropy. We will find in this last chapter the results of the measurements, proving that a reverberation chamber does not rigorously follow the model of the disordered field, notably when we get close to the minimal frequency of use of the chamber. This analysis will lead to the probability density function of Weibull. In this part of the book, the subject of the capture of statistically independent field or power data, will also be taken and improved by the search for a correlation estimator more appropriate to the context of the reverberation chamber.

In the presentation of the text, the authors have deliberately repeated formulas that they judge important, or in other cases, some demonstrations. We notably find this process at the end of Chapter 3, where we have the calculations leading to the determination of the radiated power by an object tested in reverberation chamber. This reasoning will partially be repeated, and then detailed in Chapter 6, which is entirely devoted to the emission measurements. We think that this practice limits the constant returns to the zones anterior to the text and that it facilitates in the same time the merger of the different chapters.

Knowing that the reverberation chambers are still prone to in-depth studies, the authors have replaced the conventional conclusions of Chapter 8 with open discussions on questions mainly related to the physical functioning.

To complete the main text, five appendices detail physical concepts or auxiliary calculations. Moreover, after each chapter, the reader will find bibliographical references.

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