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# Antenna Characterization in Reverberation Chamber at Frequencies Close to the Lowest Usable Frequency

W. Krouka, F. Sarrazin, E. Richalot  
ESYCOM Laboratory (UMR 9007), Univ Gustave Eiffel, CNRS,  
77454 Marne-la-Vallée Cedex 2, France  
Email: wafa.krouka@u-pem.fr

**Abstract**—Research works done in the last years have shown a growing interest for antenna characterization measurements within Reverberation Chambers (RCs). Several studies on antenna characterization within RCs have led to interesting results for gain, radiation pattern and efficiency. In this work, a similar study is conducted at frequencies close to the Lowest Usable Frequency (LUF) of an RC. This study aims at obtaining a better understanding of the limitations of antenna characterization methods as well as the accuracy of the obtained results when measurements are conducted close to the LUF.

## I. INTRODUCTION

In addition to their universal characteristics, each reverberation chamber (RC) has some intrinsic properties that tightly depend on the losses inside the chamber, the dimensions of the chamber and the efficiency of the used stirring technique. The Lowest Usable Frequency (LUF) is one of these main properties, representing the frequency above which we consider that the RC presents an ideal behaviour (homogeneous and isotropic field within the working volume). Thus, in order to have accurate antenna characterization, measurements need to be conducted at frequencies far enough from the LUF as presented in [1] where measurements frequency range is above 1 GHz for an RC LUF around 400 MHz. In [2], measurements are also conducted at frequencies higher than the LUF estimated at 200 MHz. In this paper, we present radiation efficiency results of a patch antenna obtained from measurements conducted in two different RCs using a non-reference antenna measurement technique [1], [3]. The patch is a miniature antenna inspired from [4] combining different miniaturization techniques. It consists on a circularly-shaped monopole with an IFA-like short circuit and terminated by a capacitive load. It is printed on an Arlon 25N substrate, and designed to resonate at 400 MHz. The second antenna used to measure a transmission coefficient is a classical log-periodic antenna working in the frequency range [340 MHz - 4 GHz]. Picture of both antennas are presented in Fig. 1. In Fig. 2, we present both RCs used for measurements. The IETR RC is characterized by a volume of 93.35 m<sup>3</sup>, a LUF around 200 MHz and a large metallic mechanical stirrer. As a well-operation of this environment is expected with 56 uncorrelated stirrer positions at 400 MHz, only one configuration of the measurement setup (antenna location) is considered in this

RC. On the other hand, the ESYCOM RC is characterized with a volume of 19.11 m<sup>3</sup>, a LUF around 400 MHz and is equipped with a vertical metallic stirrer. To overcome the lack of measurement accuracy close to the RC LUF (only 16 uncorrelated stirrer positions around 400 MHz), both antennas are displaced within the RC working volume (where the fields are expected to be uniform) so that measurements are collected at 5 different locations of the antennas. This process allows having a comparable number of uncorrelated states in both RCs.

## II. MEASUREMENTS

Measurements are conducted over the same frequency range [300 MHz - 500 MHz] and 1001 equally spaced frequency samples in both RCs. The frequency range is carefully chosen to be around the LUF of the ESYCOM RC and far enough from the LUF of the IETR RC in order to compare the impact of RC characteristics on antenna radiation efficiency

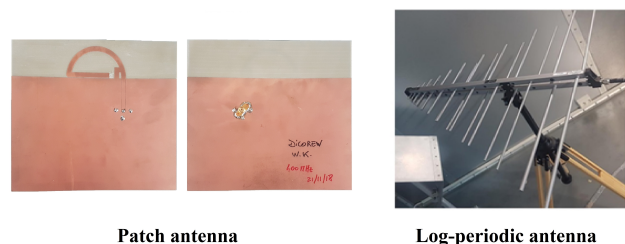


Fig. 1. Measurement antennas.



Fig. 2. Measurement environments.

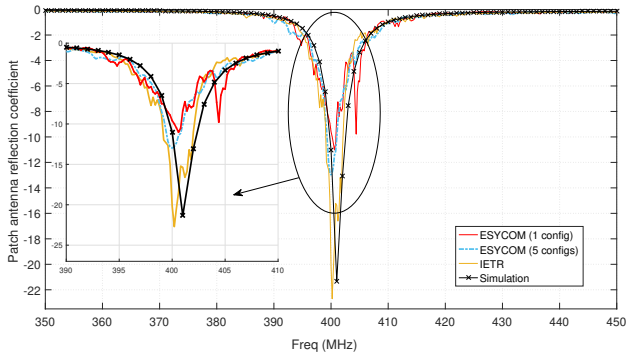


Fig. 3. Patch antenna reflection coefficient.

measurements. As detailed in [1], [3], the patch antenna radiation efficiency  $\eta_{\text{rad}}$  is calculated using the equation below

$$\eta_{\text{rad}} = \sqrt{\frac{\langle |S_{11,s}|^2 \rangle}{(1 - \langle |S_{11}|^2 \rangle)^2}} \frac{C_{\text{RC}}}{\omega \cdot \tau_{\text{RC}} \cdot e_b} \quad (1)$$

with

$$e_b = \frac{\sqrt{\langle |S_{11,s}|^2 \rangle \langle |S_{22,s}|^2 \rangle}}{\langle |S_{21,s}|^2 \rangle} \quad (2)$$

and  $C_{\text{RC}} = 16\pi^2 V / \lambda^3$ ,  $S_{ij,s} = S_{ij} - \langle S_{ij} \rangle$  is the stirred component of  $S_{ij}$ ,  $S_{11}$  is the patch antenna reflection coefficient,  $\langle \cdot \rangle$  is the average over measurement configurations and/or stirrer positions,  $e_b$  is the enhanced backscattering coefficient,  $V$  is the chamber volume and  $\lambda$  is the wavelength.

### III. EXPERIMENTAL RESULTS

Fig. 3 presents the reflection coefficient of the patch antenna measured in both RCs. The obtained results are compared to simulated ones. When only one antenna configuration is considered in ESYCOM RC, we notice important fluctuations compared to IETR RC measurements which are closer to simulation results. When the average is calculated over the 5 setup configurations in ESYCOM RC (source stirring), the resulting curve presents less fluctuations and is in better agreement to IETR RC (TABLE I). It shows that, when measurements are conducted higher than the LUF (IETR RC), mechanical stirring is enough to accurately estimate the reflection coefficient. On the other hand, a source stirring is necessary in addition to the mechanical stirring for measurements close to the LUF (ESYCOM RC) to increase the accuracy.

TABLE I  
RELATIVE DIFFERENCES BETWEEN MEASUREMENT RESULTS IN  
ESYCOM AND IETR RCS.

Reverberation chamber	Reflection coefficient	Radiation efficiency
ESYCOM RC (1 config)	6.04 % in linear	30.88 %
ESYCOM RC (5 configs)	4.56 % in linear	12.72 %

We evaluate the patch antenna radiation efficiency using (1) in both RCs. Results are presented in Fig. 4 and are compared

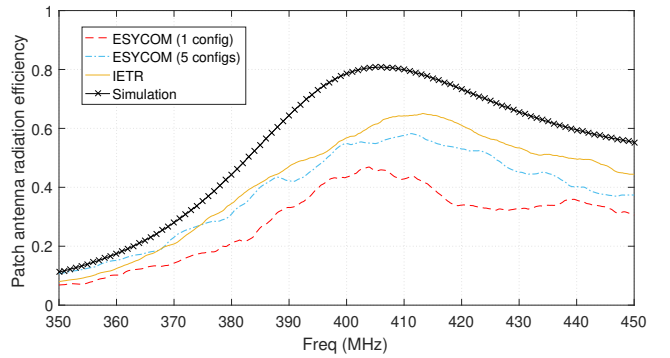


Fig. 4. Patch antenna radiation efficiency.

to simulation ones. The simulated efficiency reaches 80 % at 400 MHz while it remains below 60 % for the IETR result. Simulated radiation efficiency of miniature antenna is usually overestimated which may explain this difference. However, we highlight that the result obtained at ESYCOM with only one antenna configuration leads to only 45 % efficiency. Combining source stirring and mechanical stirring in ESYCOM RC measurements allows obtaining an efficiency very similar to the one obtained in IETR RC. Relative differences between the efficiencies obtained on both RCs are presented in TABLE I.

### IV. CONCLUSION

In order to underline the impact of the RC characteristics on measurement accuracy, we compare in this paper radiation efficiency measurements of a patch antenna obtained in two different RCs. Measurement frequency range is chosen to be close to the LUF of one RC and far enough from the second one. When measurements are conducted close to the LUF, important fluctuations of the reflection coefficient and an underestimation of the radiation efficiency are obtained. To overcome this lack of accuracy, a source stirring is proposed; with 5 different measurement configurations combined to the mechanical stirring, the obtained results become similar to the ones obtained in the larger RC.

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