The 4th International Conference on Electronic Information and Communication Technology (ICEICT), August 18-20, 2021, Xian, China

Measuring the Total Radiated Energy of Transient Signals in a Reverberation Chamber

Qian Xu, Kai Chen
College of Electronic and Information Engineering
Nanjing University of Aeronautics and Astronautics
Nanjing, China
emxu@foxmail.com

Xueqi Shen
Nanjing Rongce Testing Technology Ltd
Nanjing, China
george@emcdir.com

Tian-Hong Loh
Electromagnetic & Electrochemical Technologies Department
National Physical Laboratory
Teddington, United Kingdom
tian.loh@npl.co.uk

Yi Huang
Department of Electrical Engineering and Electronics
University of Liverpool
Liverpool, United Kingdom
yi.huang@liverpool.ac.uk

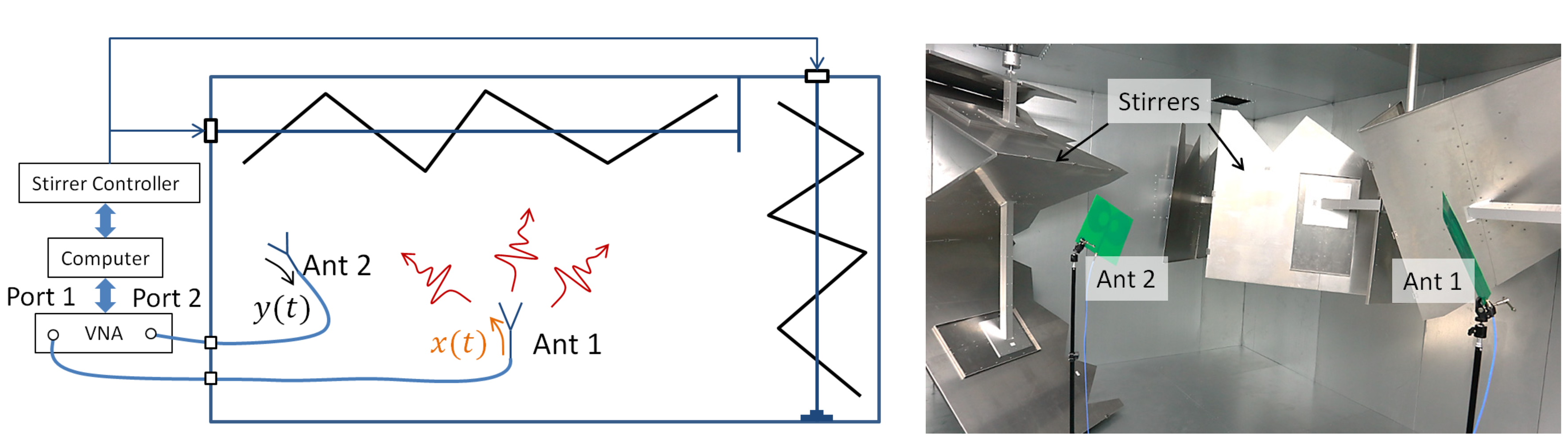
Introduction

- **Reverberation chambers** (RCs) are well suited for measuring system-level properties due to the **inherent statistical properties**.
- For a continuous wave (CW) signal, the electromagnetic (EM) fields in the RC can reach a steady state , and the total radiated power (TRP) can be measured in an RC.
- For **short-time non-sinusoidal pulse** signals, the power variation may vary too fast such that the EM fields in RC can not reach a steady state. In this case, the **power-time relationship** of the radiated signal in an RC **cannot be easily assessed**.
- We show that the **total radiated energy** (**TRE**) can also be measured in an RC for transient signals, and observe that the proposed method has **fast convergence speed** for wideband signals.

Measurement Setup

The measurement setup is shown in Fig. 1. Ant 1 and Ant 2 were connected to Port 1 and Port 2 respectively. Two stirrers in RC were rotated with 1º/step resulting in a total of 360 stirrer positions.

- Working principle: similar to the TRP measurement in RCs.
- Measurement setup: the **same** as TRP measurement **except** using different instruments.
- Application: useful for assessment of the TRE of high-power microwave devices.



(a) (b)

Fig. 1. Measurement setup: (a) schematic plot, (b) measurement in an RC at NUAA.

Theory

- The **TRE of Tx** (ransmitting antenna) can be defined and expressed as:

$$\mathrm{TRE} = \int_{-\infty}^{+\infty} \frac{x(t)^2}{50} dt$$

where $x(t)$ is the equivalent voltage in a 50 Ohm system of the radiated signal.

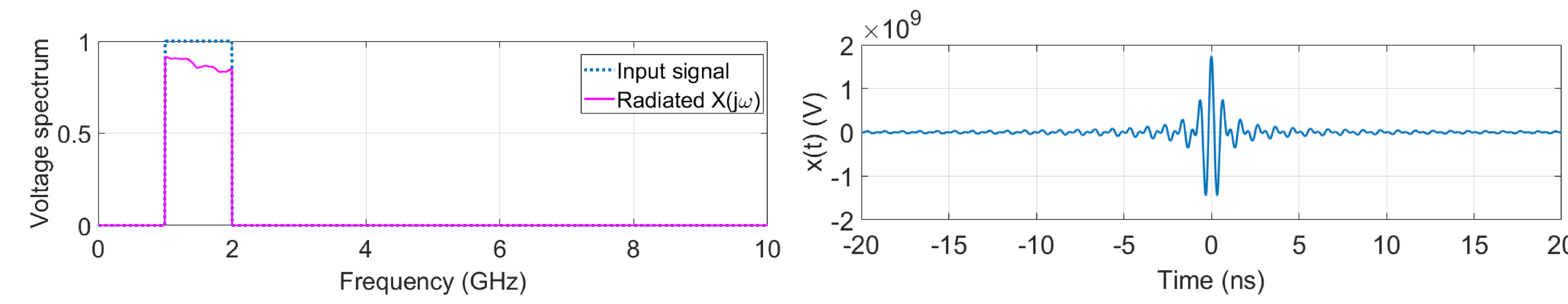
- From Parseval's theorem, **The TRE of Rx** (receiving antenna) can be expressed as:

$$\mathrm{TRE} = \int_{-\infty}^{+\infty} \frac{x(t)^2}{50} dt = \int_{-\infty}^{+\infty} \frac{|X(j\omega)|^2}{50} df = \int_{-\infty}^{+\infty} \frac{\langle |Y_i(j\omega)|^2 \rangle}{50 \langle |H_i(j\omega)|^2 \rangle} df$$

where i represents different stirrer position (i.e. position index), $X(j\omega)$ is the frequency transform (FT) of $x(t)$, $Y_i(j\omega)$ is the FT of $y_i(t)$ and $H_i(j\omega)$ is the transfer function of the measurement system at each stirrer position.

Results and Analysis

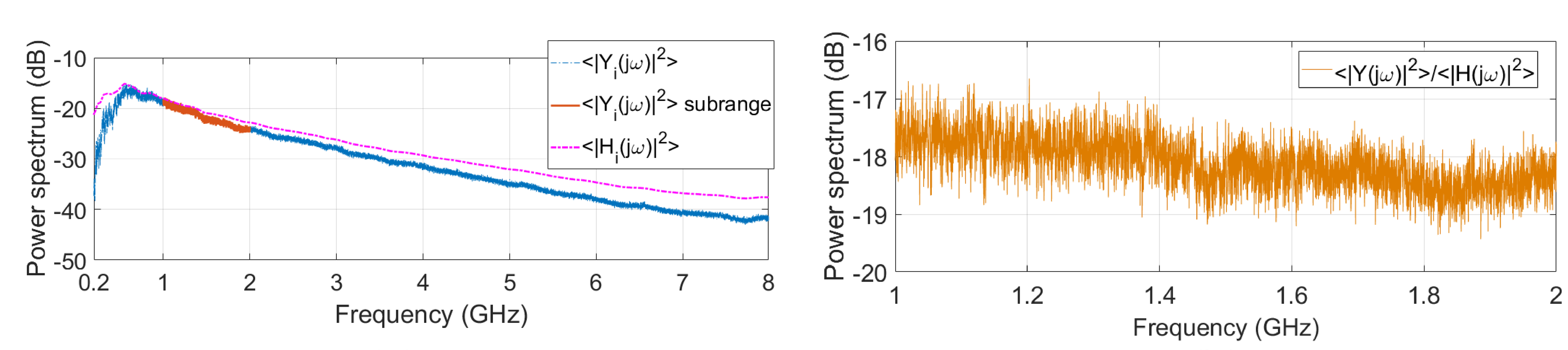
Fig. 2(a) shows the spectrum of the input signal which is ideally band-limited and we use Ant 1 as the radiation source. By applying IFT to $X(j\omega)$, the equivalent voltage $x(t)$ of the radiated signal can be obtained in Fig. 2(b).



(a) (b)

Fig. 2. Measurement results: (a) voltage spectrum of the input signal and the radiated signal, (b) the equivalent voltage of the radiated signal in TD.

Fig. 3(a) illustrates the power spectrums of $\langle |H_i(j\omega)|^2 \rangle$and the received signal $\langle |Y_i(j\omega)|^2 \rangle$. Since the radiated TD signal is in the frequency range of 1GHz - 2 GHz, the measured $\langle |Y_i(j\omega)|^2 \rangle / \langle |H_i(j\omega)|^2 \rangle$ can be calculated and is shown in Fig. 3(b).



(a) (b)

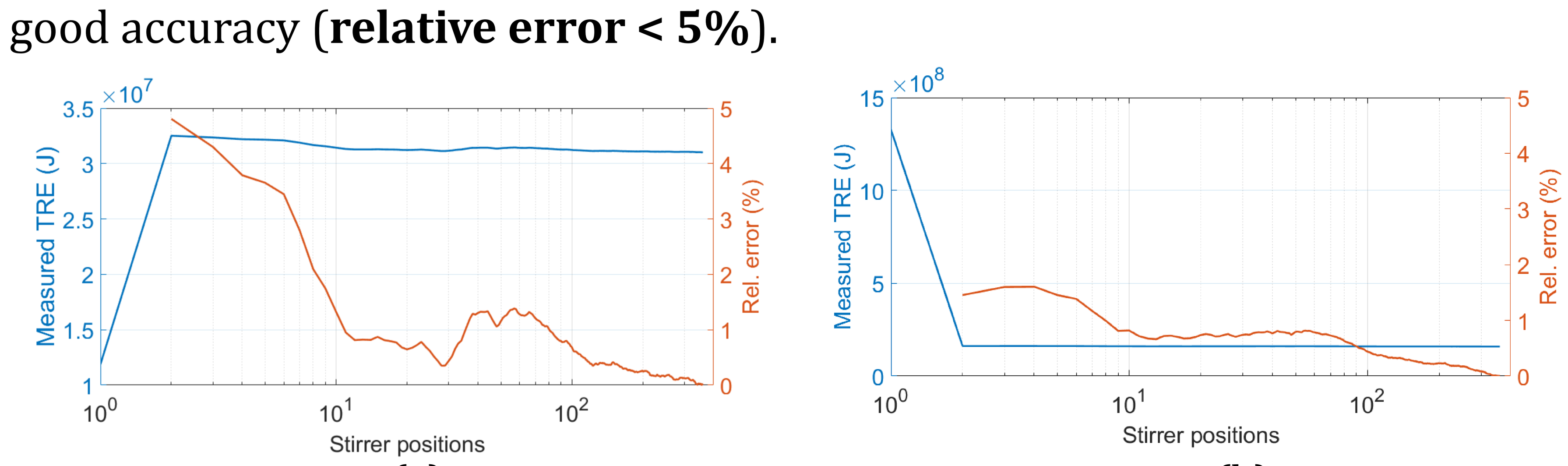
Fig. 3. Measurement results: (a) and (b) measured power spectrum.

The whole procedure was then repeated covering the frequency bandwidth of **1 GHz - 8 GHz**, and the results are summarized in Table I, which shows **very good agreements**.

TABLE I
MEASUREMENT RESULTS

Bandwidth	Tx TRE	Measured TRE
1 GHz – 2 GHz	3.05×10^7 J	3.10×10^7 J
1 GHz – 8 GHz	1.57×10^8 J	1.59×10^8 J

The analysis on the measured TRE convergence performance against the stirrer position number is presented in Fig. 4, we use the results from 360 stirrer positions as references and calculate the relative errors. It is interesting to note that **only two stirrer positions** could be enough to have good accuracy (**relative error < 5%**).



(a) (b)

Fig. 4. Convergence analysis of the stirrer position number: (a) Tx signal with spectrum in 1 GHz - 2 GHz, (b) Tx signal with spectrum in 1 GHz - 8 GHz.

Conclusions

- The validity of the measurement of TRE for transient signals in an RC has been demonstrated. Both **theoretical equations** and **measurement results** have been presented.
- The TRE method is very **similar** to the TRP measurement.
- The TRE measurement has very **fast convergence speed** because of the integral operator in the frequency domain.
- Only **two stirrer positions** are required for **wideband signals** to have a good accuracy.