A Further Investigation of the Source Stirred Chamber Method for Antenna Efficiency Measurements

Zhihao Tian, Yi Huang, and Qian Xu
Department of Electrical Engineering and Electronics
University of Liverpool
Liverpool, L69 3GJ, United Kingdom
zhihao.tian@liv.ac.uk, yi.huang@liv.ac.uk, qian.xu@liv.ac.uk

Abstract—**This paper presents a study of the radiation efficiency measurement of antennas using the source stirred chamber (SSC) method. The antenna under test (AUT) was a coplanar-line-fed monopole. By using the minimum value of the input resistance of the antenna in the chamber under different stirring configurations and introducing frequency stirring technique, the resonance effect can be greatly reduced. The efficiency of the antenna was also computed with Computer Simulation Technology (CST) package. The simulation result and the measurement result were compared and in good agreement.**

Keywords—radiation efficiency; source stirred chamber method; frequency stirring technique

I. INTRODUCTION

The radiation efficiency is an important figure of merit associated with antenna characterization. It is defined as the ratio of the total power radiated by the antenna to the total power accepted by the antenna at its input terminal. It is normally can be expressed as

$$\eta = \frac{P_r}{P_r + P_L} = \frac{R_r}{R_r + R_L} \tag{1}$$

Where P_r is the radiated power, P_L is the power loss on the antenna, R_r is the radiation resistance, and R_L is the loss resistance.

Traditionally, the antenna radiation efficiency is measured by using pattern integration method [1], which is based on integrating the radiation intensity over the whole spherical surface enclosing the antenna to get the radiated power. This method is usually time-consuming and the accuracy is not good. In 1959, wheeler introduced the radiansphere to remove the radiation resistance of a small antenna while retaining its other properties (loss resistance, capacitance, and inductance) [2]. This can be accomplished by enclosing the antenna in a perfect conducting sphere, and it is much easier to implement compared with other measurement methods [3]. Thereafter, many other methods have been proposed based on the original wheeler cap method [4-6].

Recently, a source stirred chamber (SSC) method has been proposed in [7]. It is based on the concept of the "source stirred chamber" [8] by placing the antenna at various strategic locations and orientations to alter the resonant modes. By using the peak values of the efficiencies measured at different locations and orientations, the resonance effect can be eliminated and the real efficiency can be extracted. In the original SSC method, Huynh's equation [6] which, actually, is only valid for electrically large chamber was adopted to calculate the efficiency. This may cause inaccuracy for an antenna whose operational wavelength is comparable with the dimension of the chamber. Besides, S11 parameter without resonance effect elimination was used in Huynh's equation, which can give meaningless complex efficiency.

In this paper, a further investigation of the SSC method is presented. The antenna efficiency was calculated using the definition formula (1) which is general for antenna efficiency calculation. By using the minimum values of input resistance of the antenna measured at different locations and orientations in the chamber, the resonance effect can be greatly reduced. Frequency stirring technique [9] is adopted to further alleviate the residual resonance effect.

II. ANTENNA EFFICIENCY MEASUREMENT

The antenna under test (AUT) selected for this study is an Ultra-Wideband (UWB) coplanar-fed monopole antenna while the approach can be applied to other frequencies, including millimeters. It is matched below -10 dB from 3 GHz to 12 GHz. It consists of a dome-toped, bowl-shaped patch with a 50 Ω coplanar waveguide [10]. To ensure the accuracy of the measurement, 10001 points was sampled in 4-5 GHz frequency span and its S11 parameter in 4-5 GHz is shown in Fig. 1.

The cap used to eliminate the radiation resistance was an aluminum sphere with diameter of 25 centimeters (comparable with the operation wavelength of the AUT) and thickness of 2 millimeters. The input resistance of the antenna inside and outside the cap was measured as in the original wheeler cap method. If a cavity mode appeared near the operation frequency at which the measurement was taken, the cavity resonance was tuned away by changing the position or the orientation of the antenna. It is easy to understand, the more positions and orientations, the better the modes in the cap will be stirred, *i.e.*, the resonance effect will be more greatly

978-1-4673-7434-7/15/$31.00 ©2015 IEEE

reduced. In our measurement procedure, 3 antenna orientations was chosen with 10 positions for each orientation. The measurement setup is shown in Fig. 2.

The input resistance in the cap was calculated from S11 in the cap, as shown in Fig. 3. It can be seen that, in the vicinity of the resonant frequencies the input resistance is abnormal. This phenomenon has been identified in [11] which advocates that the input resistance of the antenna enclosed by the chamber includes two terms, namely the loss resistance of the antenna and the coupling resistance between the antenna and the chamber. The input resistance of the antenna attains values two or three orders of magnitude higher at resonant frequencies than that at frequencies away from resonance because of the coupling resistance. The coupling resistance is negligibly small if no cavity resonance is encountered at the antenna operation frequency. Therefore, the minimum value of the input resistance was picked at each frequency point. It should be least affected by the resonance.

Since we had 3 antenna orientations with 10 positions for

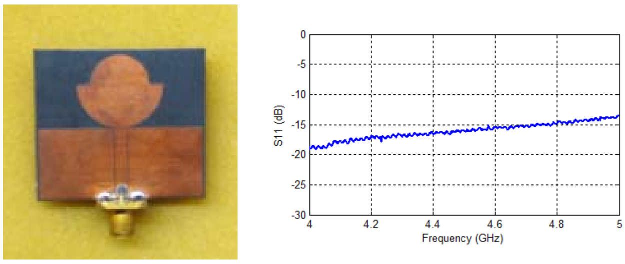

Fig. 1. Coplanar-fed Ultra-Wideband monopole antenna and its S11 in free space.

Fig. 2. The measurement setup of the SSC method.

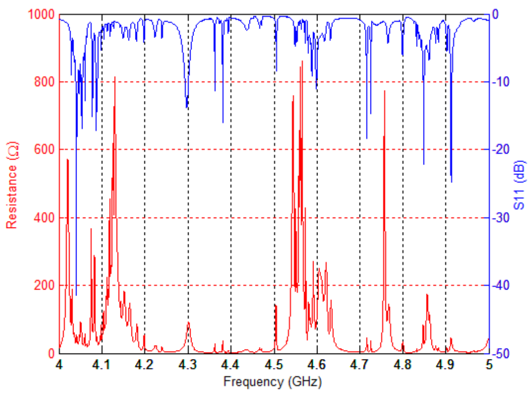

Fig. 3. S11 and the input resistance of the antenna in the cap.

each orientation, thus 30 stirring configurations were performed totally. The minimum value of the input resistance under the 30 configurations was picked for each frequency point. The result is shown in Fig. 4. To make it more readable, the longitudinal axis was set from -40 to 40. The thick black curve is the link of the minimum value of the input resistance. The antenna radiation efficiency was calculated according to equation (1), the result is shown in Fig. 5.

It can be seen clearly from Fig. 5 that the radiation efficiency seems to be reasonable, but there are still some spikes contaminating the results. This is caused by the residual resonance effect, which means the modes inside the cap were not stirred well enough by merely source stirring. To further eliminate the residual resonance effect, frequency stirring technique was introduced. The results are shown in Fig. 6 and Fig. 7.

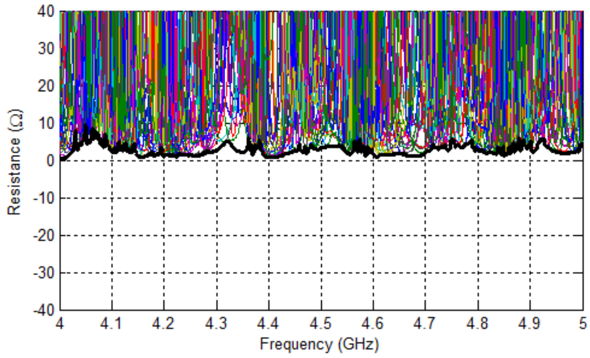

Fig. 4. The input resistance under different stirring configurations and the link of their minimum values at each frequency point.

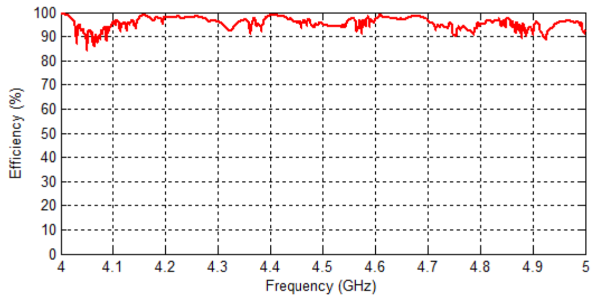

Fig. 5. The radiation efficiency calculated from equation (1) by picking the minimum value of the input resistance.

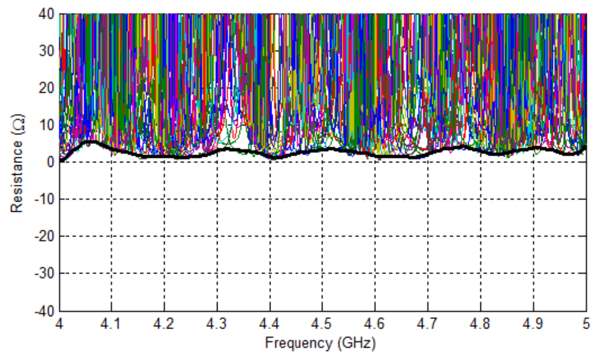

Fig. 6. The input resistance under different stirring configurations and the link of their minimum values with 50MHz frequency stirring at each frequency point.

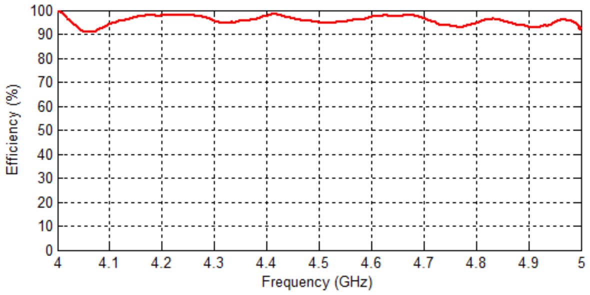

Fig. 7. The radiation efficiency calculated from equation (1) by picking the minimum value of the input resistance with 50MHz frequency stirring.

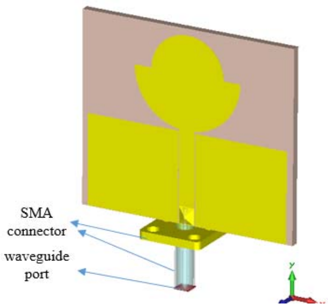

Fig. 8. The antenna model used for CST simulation.

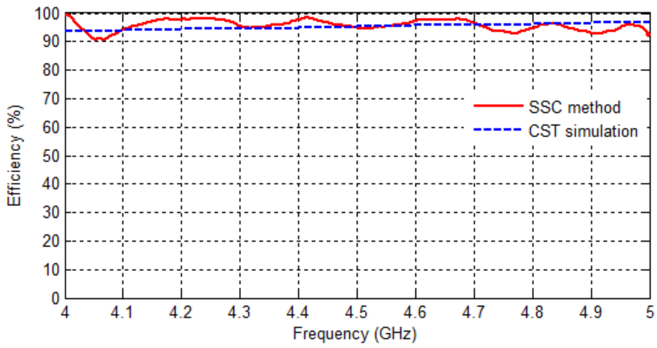

Fig. 9. Comparison of the SSC method and CST simulation.

From Fig. 6 and Fig. 7, we can see that the frequency stirring technique can effectively eliminate the residual resonance effect and make the curve of radiation efficiency smoother and more reasonable.

III. Antenna Efficiency Simulation

To make the results comparable, the present antenna was simulated in Computer Simulation Technology (CST) 2014 Microwave Studio using time-domain solver. The simulation domain was divided into 3,150,000 mesh cells. To make the simulation closer to actual condition, the SMA connector was also considered for simulation. The excitation was modeled by a waveguide port in the coaxial input of the SMA connector, as shown in Fig. 8.

The simulation result is shown by the blue dash curve in Fig. 9. As can be seen from Fig. 9, the radiation efficiencies from SSC method and CST simulation are coincident well, only approximately 3%-5% difference can be observed, which manifests the effectiveness of the SSC method.

IV. Discussion and Conclusions

The SSC method for antenna efficiency measurement has been further investigated in this paper. Resonance effect was greatly reduced by picking the minimum values of input resistance. A good result of antenna efficiency was achieved by the use of definition formula (1) and frequency stirring technique. In our work, in order to ensure the accuracy of the measurement, only 4 -5 GHz frequency band was considered because in the previous measurements, we found that the sampling number has great influence on the measurement accuracy. If the sampling number is not big enough, the measurement error caused by chamber resonance cannot be avoided. Actually, this method can extend to other frequencies as long as enough frequency points can be sampled. Or, as an alternative, the full frequency span can be split into several fractions and the measurement will be done for each fraction.

References

[1] E. H. Newman, P. Bohley, and C. H. Walter, "Two methods for the measurement of antenna efficiency," *Antennas and Propagation, IEEE Transactions on,* vol. 23, pp. 457-461, 1975.

[2] H. A. Wheeler, "The Radiansphere around a Small Antenna," *Proceedings of the IRE,* vol. 47, pp. 1325-1331, 1959.

[3] D. M. Pozar and B. Kaufman, "Comparison of three methods for the measurement of printed antenna efficiency," *Antennas and Propagation, IEEE Transactions on,* vol. 36, pp. 136-139, 1988.

[4] R. H. Johnston, L. P. Ager, and J. G. McRory, "A new small antenna efficiency measurement method," in *Antennas and Propagation Society International Symposium, 1996. AP-S. Digest*, 1996, pp. 176-179 vol.1.

[5] H. G. Schantz, "Measurement of UWB antenna efficiency," in *Vehicular Technology Conference, 2001. VTC 2001 Spring. IEEE VTS 53rd*, 2001, pp. 1189-1191 vol.2.

[6] M. C. Huynh, "Wideband compact antennas for wireless communication application," Ph.D. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, US, 2004.

[7] Y. Huang, Y. Lu, S. Boyes, H. T. Chattha, and N. Khiabani, "Wideband antenna efficiency measurements," in *Antenna Technology (iWAT), 2010 International Workshop on*, 2010, pp. 1-4.

[8] Y. Huang, "The investigation of chambers for electromagnetic system," Ph.D. dissertation, Department of Engineering Science, University of Oxford, Oxford, UK, 1993.

[9] Y. Shih-Pin and C. F. Bunting, "Statistical investigation of frequency-stirred reverberation chambers," in *Electromagnetic Compatibility, 2003 IEEE International Symposium on*, 2003, pp. 155-159 vol.1.

[10] N. Pires, C. Mendes, M. Koohestani, A. K. Skrierviky, and A. A. Moreira, "Radiation efficiency of a coplanar-fed ultra-wideband antenna," in *Antennas and Propagation Society International Symposium (APSURSI), 2012 IEEE*, 2012, pp. 1-2.

[11] Y. Huang, R. M. Narayanan, and G. R. Kadambi, "Electromagnetic Coupling Effects on the Cavity Measurement of Antenna Efficiency," 2003.