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Total Radiated Power Measurement in an Uncalibrated Reverberation Chamber

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ABSTRACT

With the increased use of wireless communication in recent years, the use of reverberation chamber (RC) has increased to a great extent. Reverberation chambers have been eminently used for EMC testing and shielding effectiveness. The environment it provides is very similar to the reverberant surroundings that antenna undergoes in real life use. An experiment to measure total radiated power of antenna, antenna efficiency and quality factor of chamber in indoor environment is proposed. This will make the measurement very simple and inexpensive as designing and calibration of chamber will not be needed. In this paper, we have used three different techniques to compare total radiated power, quality factor, Rician K factor and efficiency of a patch antenna measured in indoor environment with RC data. The three method used include plate stirring method and two time domain methods. The time domain methods use modulated pulse and Gaussian pulse respectively for the measurement. The antenna and chamber parameters are measured in the real time and the data matched well with the RC data for different techniques.

Keywords: Reverberation chamber; Total radiated power; Antenna efficiency; Quality factor; Rician distribution

1. INTRODUCTION

Anechoic chambers are closed rooms made up of metallic walls with absorbers inside the room. From past many years, anechoic chamber have been used for shielding effectiveness, antenna measurements and EMC testing. Due to the high cost of absorbers used inside the anechoic chamber and with the advent of reverberation chamber (RC) is now being widely used for EMC testing and radiated power measurements. RC has the advantage that once it is calibrated, it gives similar multipath environment if same transmitting and receiving antennas are used every time for measurements. The use of RC has reduced the measurement time and has MIMO capacity as well. Moreover, in a RC, the two antennae are kept in Non-Line-of-Sight (NLOS) manner to avoid coupling of power being transmitted and is thus better in comparison to LOS arrangement wherein unstirred power becomes dominant. Unlike anechoic chamber, RC is a closed reverberant room with metallic walls that leads to scattered environment inside the chamber thus being identical to the real world scenario. This reverberant environment leads to uniformity in the electric field inside the chamber. This uniformity of electric field can be improved by either changing the frequency, or the boundary condition, or size of the chamber. The change in boundary conditions, which we have used in this paper, leads to large number of resonant modes and can be achieved by using different mode stirring approaches, viz. mechanical stirring, polarisation stirring, or frequency stirring. For the measurement of different parameters of antenna and RC, several measurement techniques have been proposed in both frequency domain[1-7] as well as in the time domain[8-9]. Frequency domain techniques use different mode stirring methods for parameters evaluation while time domain measurements use pulse modulated signal and the measurements are carried out with respect to time.

In this paper, we have replaced the uncalibrated RC measurement system with an indoor environment consisting of RF sources like mobile phones and wifi routers etc. A small section in the room is specified by placing four metallic sheets of dimension 1.98 m × 1.9 m × 1.05 m which have been placed in a cuboidal manner in a small portion inside the room and no plates are used to cover the top and bottom surface. The four plates provide multiple reflections which is required to have uniformity of electric field. For both the frequency and time domain techniques used, a z-shaped stirrer is placed inside the area specified by the four sheets. For the first technique, the stirrer is rotated at different angles inside the area specified by the sheets. In the second and third method, a stirrer is rotated at few angles and pulse modulated signal and Gaussian signal is provided as input respectively. In second case, received power is measured at zero span mode of the spectrum analyser (receiver) while in third method, filter bandwidth of 12MHz and 99 per cent windowing is selected in time domain mode of VNA.

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2. FORMULATIONS

The most important parameter of a RC is its quality factor which is determined as the ratio of the power stored inside the chamber to the power exhausted with time. The most commonly used measurement approach to obtain Q factor is expressed as[10]

$$\langle Q \rangle = \frac{16\pi^2 V}{\lambda^3}\frac{P_r}{P_t} \tag{1}$$

where

$$\frac{P_r}{P_t} = \frac{|S_{21}|^2}{\left(1-|S_{11}|^2\right)\left(1-|S_{22}|^2\right)} \tag{2}$$

and, $\langle . \rangle$ denotes the averaged value over different stirrer positions.

In time domain, Q factor is given by[3]

$$\langle Q \rangle = \frac{20\pi f\,\Delta t}{\ln(10)\Delta P_r\,|_{dB}} \tag{3}$$

Another important parameter of a RC is the rician K factor which is the ratio of unstirred to stirred power inside the chamber and can be expressed as[1]

$$K = \frac{|\langle S_{21}\rangle|^2}{\left\langle \left|S_{21} - \langle S_{21}\rangle\right|^2 \right\rangle} \tag{4}$$

In order to evaluate the variation of total radiated power of a probe under test inside the chamber following expression is used[3]

$$\begin{aligned}\langle P_t \rangle|_{dBm} &= -10\log(\eta_r) + 10\log(V|_{m^2}) - \\ &10\log(\Delta t|_{\mu s}) + 20\log(f|_{MHz}) - 66.68 + \\ &10\log(\Delta P_{dB}) + \langle P_r \rangle|_{dBm}\end{aligned} \tag{5}$$

The efficiency of antenna under test (AUT) can be evaluated using the time domain measurement method as well as by frequency domain techniques. In this paper we have used time domain signal processing technique to evaluate efficiency of the antenna. The ratio between power received and power transmitted by the antenna is measured for different frequencies which indicates the relative efficiency of the antenna. The ratio is calculated by averaging for different stirrer positions. For the validation of new setup used, the three measurement techniques are also performed inside the RC of dimension height 3.4 m, width 1.89 m and length 2.1 m.

3. RESULTS

The experimental setup used in this paper is as shown in Fig. 1. The area we have used inside the room for experiment has dimensions 1.98 m × 1.9 m × 1.05 m with a z shaped stirrer placed inside it. The transmitting and receiving antennas are placed in NLOS manner 1.3 m apart from each other. A horn antenna is used as transmitter and a patch antenna is used as receiver operating in frequency range of 6 to 8 GHz.

The Q factor for indoor environment is computed by plate stirring method using Eqn (1). To compare the obtained results, the measurements are repeated in a RC of dimension 2.1 m × 1.89 m × 3.4 m. Fig. 2(a) represents the comparison of the two measurements. One can notice that the graph from this method in indoor environment is in close proximity with that of measurement results in RC. Similar graphs are obtained when measurements are performed using time domain method using (3) in indoor environment and inside RC as well as shown in Fig. 2(b).

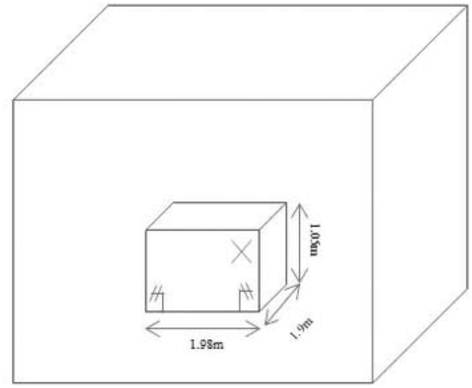

Figure 1. Experimental Setup in an indoor environment.

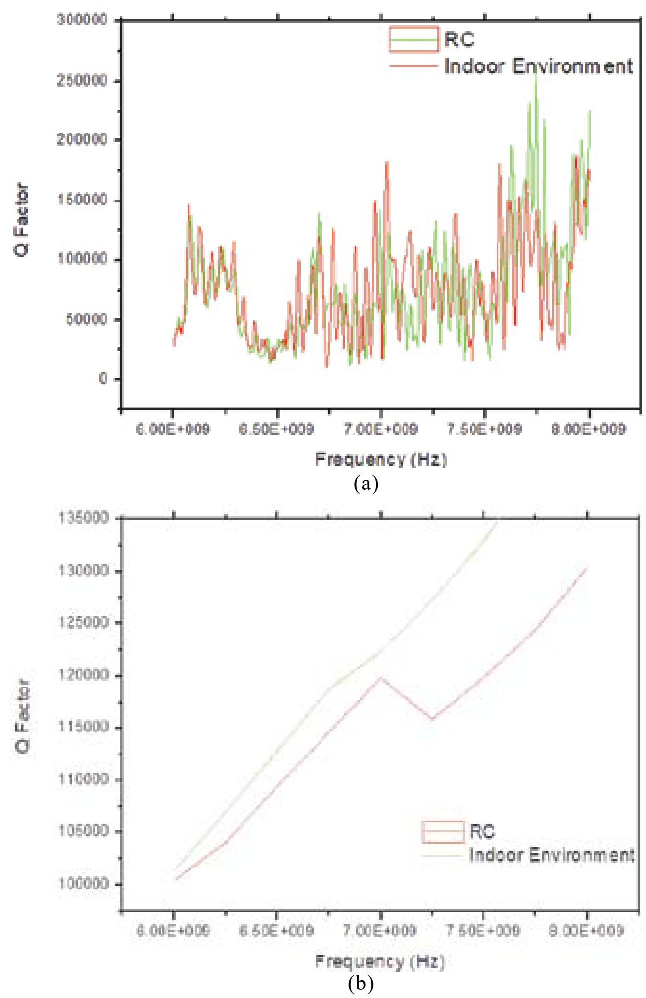

Figure 2. Two (averaged) graph of Quality factor of new setup and the reverberation chamber from two different measurement techniques. (a) Q factor calculated using plate stirring method. Graph shown with green solid line represents Q factor of the RC at different frequencies while red solid line shows Q factor of the new setup used. (b) Q factor measured in time domain using pulse modulated input.

Figure 3 represents the total power radiated by the antenna when a pulse modulated signal is provided as input at several plate positions in the indoor environment and inside the RC. The received power is averaged for the complete time duration and its change is observed for small time interval. The graph in the Fig. 3 shows that total radiated power by the patch antenna inside the new setup is in close proximity of the power radiated inside the RC. Next, the Rician K factor is calculated using plate stirring technique in the new setup and in the RC and is compared in Fig. 4. It is apparent from the graph that measurement data of the new setup match well with the RC data except for the mismatch of results between 6 GHz and 6.5 GHz. This disagreement in result is because of the VSWR of the transmitting antenna which is above the standard -10 dB for these frequencies. To increase the number of modes generated inside the chamber, plate and polarisation stirring can be used at the same time. The use of polarisation stirring alongside plate stirring avoids any particular polarisation to become dominant which further increases electric uniformity inside the area. Moreover, the results can be further improved by using frequency stirring method during processing of measurement results. But in such a case, there will be a trade-off between result accuracy and resolution bandwidth.

Next the average transfer function between horn antenna and patch antenna is computed for 15 stirrer positions. The efficiency of patch antenna obtained using third technique is plotted against frequency in Fig. 5. The graph shows good agreement of values in the new setup with the values calculated inside a RC. However, there is a mismatch in the efficiency values from 6 GHz to 6.5 GHz because the VSWR values of transmitting antenna are below standard -10 dB in this frequency range. For validation of result, efficiency can also be calculated using mechanical stirring inside a RC or by using an anechoic chamber.

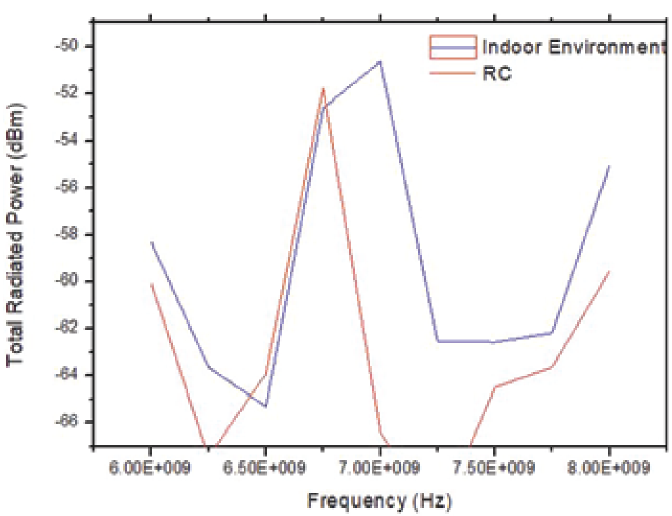

Figure 3. Total radiated power of antenna using pulse modulated signal obtained from both reverberation chamber and new setup in the indoor environment. Data is averaged over 10 different stirrer positions and change in the received power is observed for 8 μs interval of time.

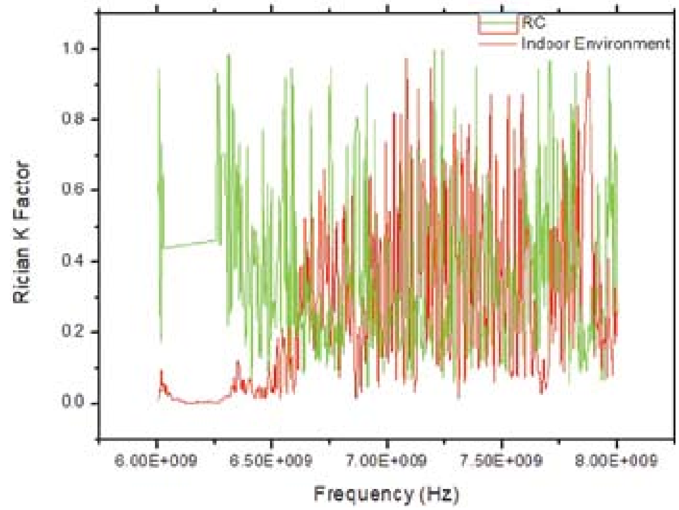

Figure 4. Ideally, the em waves inside the chamber should be Rayleigh distributed when NLOS antenna arrangement is present. But, due to coupling of energy between transmitting and receiving antenna, some portion of energy remains unstirred and so Rician distribution exist. Rician distribution inside new setup in the indoor room and reverberation chamber is measured using plate stirring technique. Rician K factor which is the measure of Rician distribution inside a closed system is plotted against frequency for both RC and indoor setup.

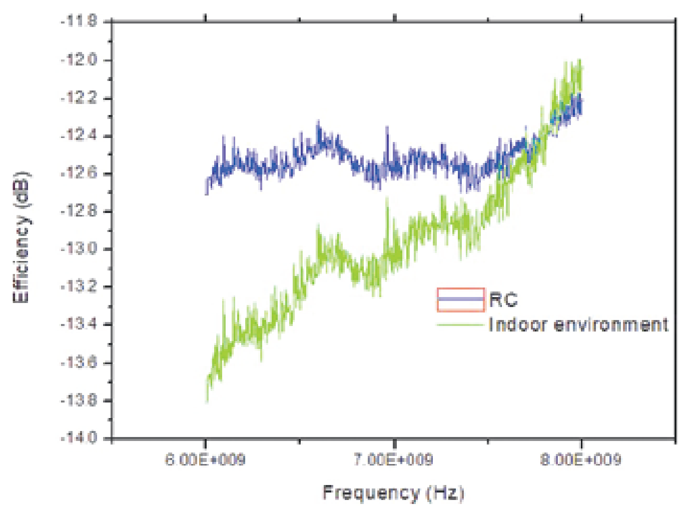

Figure 5. The efficiency of antenna describes how antenna will perform in real world use at certain operating frequency. Plot of Efficiency of the patch antenna vs frequency using time domain method with Gaussian pulse as input.

4. CONCLUSIONS

A new measurement setup has been introduced in this paper to measure the antenna and chamber parameters. The measurements performed inside the new setup considers all the electromagnetic processes that exist inside the RC. The advantage of new setup is that calibration is not needed for any measurement and the designing cost is reduced but there is a small trade-off with measurement accuracy. A small change in the value is evident as two sides of the setup are non-conducting (not closed by any metallic plate) implying loss of waves. But, the measurement setup is still advantageous because the setup can be arranged anywhere at any point of time and yet it provide results in close proximity of standard values calculated inside RC. The accuracy of data can be further improved by frequency stirring the data while processing it.

REFERENCES

1. Boyes, S.J. & Huang, Y. Reverberation chambers: Theory and applications to EMC and antenna measurements. John Wiley & Sons, Ltd., New Jersey, 2015, pp. 10-56. doi: 10.1002/9781118906279
2. Holloway, C.L.; Shah, H.A.; Pirkl, R.J.; Young, W.F.; Hill, D.A. & Ladbury, J. Reverberation chamber techniques for determining the radiation and total efficiency of antennas. *IEEE Trans. Antennas Propag.*, 2012, **60**(4), 1758-1770. doi: 10.1109/TAP.2012.2186263
3. Arnaut, L.R. Effect of size, orientation, and eccentricity of mode stirrers on their performance in reverberation chambers. *IEEE IEEE Trans. Electromagn. Compat.*, 2006, **48**(3), 600-602. doi: 10.1109/TEMC.2006.879256
4. Clegg, J.; Marvin, A.C.; Dawson, J.F. & Porter, S.J. Optimization of stirrer designs in a reverberation chamber. *IEEE Trans. Electromagn. Compat.*, 2005, **47**(4), 824-832. doi: 10.1109/TEMC.2005.860561
5. Hill, D. A. Electromagnetic fields in cavities: Deterministic and statistical theories. *In* IEEE Press Series on Electromagnetic Wave Theory, John Wiley & Sons, Inc., (Hoboken), New Jersey, 2009, pp. 91-147.
6. Bamba, A.; Joseph, W.; Andersen, J.B.; Tanghe, E.; Vermeeren, G.; Plets, D.; Nielsen, J.O. & Martens, L. Experimental assessment of specific absorption rate using room electromagnetics. *IEEE Trans. Electromagn. Compat.*, 2012, **54**(4), 747-757. doi: 10.1109/TEMC.2012.2189572
7. Remley, K.A.; Pirkl, R.J.; Wang, C.M.; Senić, D.; Homer, A.C.; North, M.V.; Becker, M.G.; Horansky, R.D. & Holloway, C.L. Estimating and correcting the device-under-test transfer function in loaded reverberation chambers for over-the-air tests. *IEEE Trans. Electromagn. Compat.*, 2017, **59**(6), 1724-1734. doi: 10.1109/TEMC.2017.2708985
8. Krauthäuser, H. G. On the measurement of total radiated power in uncalibrated reverberation chambers. *IEEE Trans. Electromagn. Compat.*, 2007, **49**(2), 270-279. doi: 10.1109/TEMC.2007.897122
9. Khaleghi, A. Time-domain measurement of antenna efficiency in reverberation chamber. *IEEE Trans. Antennas Propag.*, 2009, **57**(3), 817-821. doi: 10.1109/TAP.2009.2013445
10. Hill, D.A.; Ma, M.T.; Ondrejka, A.R.; Riddle, B.F.; Crawford, M.L. & Johnk, R.T. Aperture excitation of electrically large, lossy cavities. *IEEE Trans. Electromagn. Compat.*, 1994, **36**(3), 169-178. doi: 10.1109./15.305461

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