Issues on Calibration of Direct Feed Biconical Antenna In a Semi-Anechoic Chamber Using Standard Antenna Method

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Abstract—**Antenna calibration is crucial to ensure the accuracy of Electromagnetic Compatibility (EMC) measurement results. Standard Antenna Method (SAM) is one of the methods widely used in antenna calibration which requires reference antenna with known Antenna Factor (*AF*) in a free space environment. The work presented in this paper is on the calibration of the *AF* of a direct-feed biconical antenna in a semi-anechoic chamber (SAC) with considerations given to the effects of ground plane, antenna height, reference antenna type and effects of phase center. The frequency range for the analysis is from 200MHz to 2GHz. It is found that antenna located 1.5 m from ground provides the best result compared to modeling. In addition, the phase centers of the reference and test antenna must be at the same positions during the measurements.**

Keywords-Standard Antenna Method, Antenna Calibration, Biconical Antenna, Semi-Anechoic Chamber, Antenna Factor

I. INTRODUCTION

Antenna calibrations are required for EMC measurements to determine the radiated disturbance of communication's product as well as household electronics and automotive equipment in order to achieve highly accurate result. The standard for antenna calibration is published by American National Standard Institute (ANSI) C63.5 "Radiated Emission Measurements in Electromagnetic Interference (EMI) Control – calibration of antennas (9KHz – 40GHz)" [1] and CISPR 16-1-6. The most important parameter to be calibrated for EMC measurements is Antenna Factor (AF). AF is the ratio of the magnitude of incident electric field E at the surface of the measurement antenna to the magnitude of received voltage V at the antenna terminals, as given in equation (1).

$$|E| = |V|.AF \tag{1}$$

Calibration of EMC antennas to determine the AF is usually accomplished by using one of the three methods:

- Standard Antenna Method (SAM)
- Standard Site Method (SSM)
- Standard Field Method (SFM)

The SAM requires a reference antenna with calibrated AF to determine the incident electric field with known uncertainties. Meanwhile, SSM method builds upon the far field Friss transmission equation, and adds a ray tracing component from the ground bounce of the wave over the conducting ground plane. For SFM, a known field is created at a specified location and is picked up by the antenna. The received voltage is measured by the test receiver, and the antenna factor is determined by expressing the values of field strength in $dB\mu V/m$.

Numerous works from previous researchers [2-4] had analyzed the effects of compact chamber for antenna calibration, focusing on the suitability of the chamber to be used as the site to calibrate biconical antenna due to its broadband characteristic.

G. Betta et. al studied the suitability of semi-anechoic chamber for reliable AF evaluation using SAM [2]. Biconical antenna had been analyzed for various frequencies together with its uncertainty. A good agreement had been presented from the experimental AF with the manufacturer's data. However, the details in terms of effects for each arrangement were not stated.

Suzuki et. al. analyzed the practical antenna arrangement suitable for calibration of EMI biconical antenna using SAM [3]. They believed for different frequencies, antenna arrangement is needed to perform high accurate result. In addition, Gyoda et. al. concluded that different antenna arrangement give extraordinary result for AF [4].

Z. Chen et. al focused on ground plane effect to evaluate the AF using numerical analysis [5]. The authors concluded that the effects of ground plane coupling will affect the AF measurements.

This paper focuses on configuration and suitability of the use of a 3-meter semi-anechoic chamber to calibrate novel direct-feed biconical antenna using standard antenna method (SAM) from 200MHz to 2GHz. The evaluation includes the effects of ground plane, semi-anechoic chamber size, antenna position, and reference antenna type on AF. The results are compared with simulation by using CST MICROWAVE STUDIO®.

II. STANDARD ANTENNA METHOD

The standard antenna method of antenna calibration uses a reference antenna with known AF. The antenna factor of any other antenna (Antenna Under Test (AUT)), may be derived by substitution with the reference antenna. The AF measurement can be carried out on an OATS or certified calibrated anechoic chamber by keeping the distance of 3 meters between the transmitting antenna and the receiving antenna. The transmitting antenna is kept at a height of 2 meters [1], and the receiving antenna is kept at a height between 2.5 meters and 4 meters as shown in Fig.1.

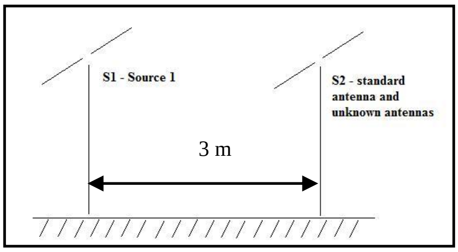

Fig.1 Geometry for calibration of antennas against the reference antennas

The reference antenna (with known Antenna Factor, AF_1) is initially used to measure the received voltage (V_1) and subsequently signal strength (E) from the source S1. Then, the reference antenna is substituted by the AUT, maintaining the height and position of both antennas. The Antenna Factor AF_2 for the AUT is calculated as follows (all in logarithmic units):

$$V_1 + AF_1 = E \quad (2)$$

$$E - V_2 = AF_2 \quad (3)$$

The accuracy of AF_2 depends upon the standard antenna used, the construction or geometry of the AUT, test site and accuracy of the test instrumentation. Ideally an Open area test site (OATS) is preferable according to ANSI C63.5 / CISPR 16-1-6. It is interesting to perform the calibration in semi-anechoic chamber to provide better understanding on the impact of test site to the accuracy of the AF.

III. DIRECT FEED BICONICAL ANTENNA

In this paper, the AF of a direct-feed biconical antenna measured using SAM and modeling will be presented. Biconical antenna is fundamentally based on the conical antenna proposed by Papas and Kings [6]. For infinite biconical (very large a), the input impedance depends only on the flare angle, θ as shown in Fig. 2. However, for finite biconical antenna, the input impedance is determined by considering the antenna height, a and flare angle, θ [7]. The antenna used has flare angle is optimized to 65 degrees for 50 Ω systems and h = 400 mm for lowest operating frequency = 200MHz.

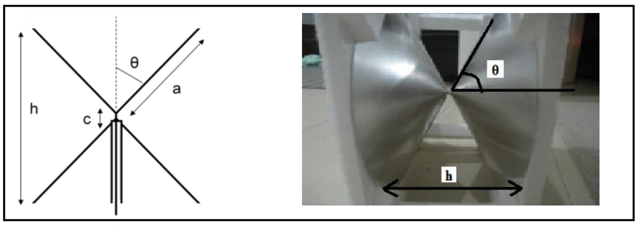

Fig.2 Direct feed biconical antenna

IV. CALIBRATION ARRANGEMENT

Standard Antenna Method is highly dependent on high accurate reference antenna and the site measurement must have uniform field within the measurement range. Therefore, to achieve high accurate results, site measurement should be analyzed because semi-anechoic chamber has been used. This is due to the chamber and equipment limitation if compared to the standard calibration laboratory.

Three important criteria for AF evaluation are the site configuration, antenna height, and reference antenna.

All measurements were conducted in Semi-Anechoic Chamber and Log-periodic antenna was used as transmitting antenna .

A. *Site Configuration*

A 3 meter semi anechoic chamber with dimensions 9680mm x 6530mm x 6000mm (l,w,h) was used as the test site. The chamber fulfiled the NSA requirement in accordance to CISPR 16-1-6 and ANSI C 63.5.

The first analysis is the consideration to use absorbers between two antennas. Hybrid absorbers consisting of ferrite tiles and pyramidal absorber were used to cover 9 m² of the ground plane as shown in Fig. 3. Similar measurement had also been conducted for ground plane without absorbers.

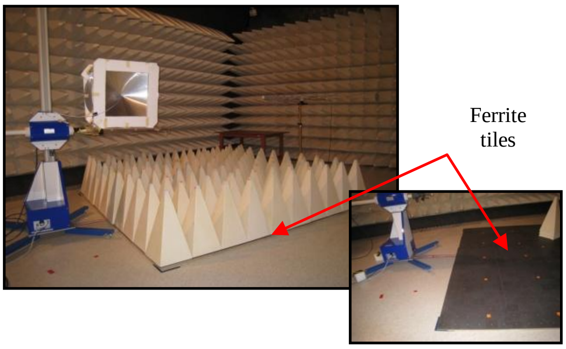

Fig.3 Absorbers on ground plane between two antennas

It can be seen in Fig. 4 that the AF of the direct-feed biconical antenna measured with absorbers on ground plane has better agreement with simulation compared to the case of without absorbers. It is therefore suggested that for all SAM measurements using semi anechoic chamber, absorbers must be placed between the two antennas to avoid ground reflection.

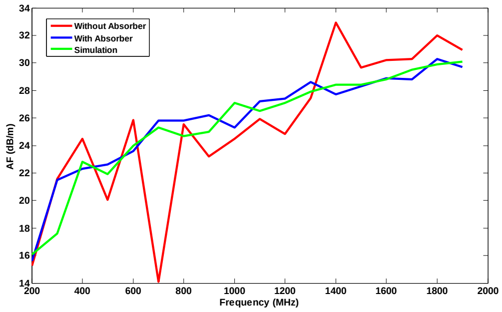

Fig. 4 AF with and without absorbers compared with simulation data

B. *Antenna Height*

It is also of interest to explore the effects of varying the height of the reference antenna and AUT on the *AF*. This also indirectly reflects the importance of antenna and ground floor coupling.

Measurements were conducted at 4 different heights. Transmitting antenna was fixed at 1.5m height from ground plane for all measurements, but the reference and AUT antennas were positioned at 1.5m, 2m, 3m and 4 m from the ground plane.

Fig. 5 shows the AF results at various heights compared with the simulation. It can be seen that good agreement with simulation data is observed at 1.5 m and the worst results is at 4m above the ground plane. It is obvious that both the reference and antenna under test should be positioned at same height from ground plane to achieve reliable data for *AF*.

The locations of ferrite tiles and pyramidal absorbers in the chamber are shown in Fig. 6 and 7. When the antenna is positioned higher from the ground plane at 4m, it is closer to the ceiling as shown in Fig.7. At this position, there is no high frequency absorber to prevent the reflection and coupling effect from the antenna and only low frequency ferrite absorber was placed on the top of the chamber. Therefore, there is a high reflection and coupling effect at frequency higher than 900MHz if the antenna is adjusted up to 4m.

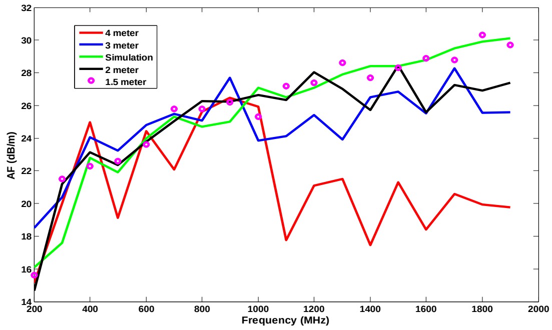

Fig. 5 AF for various heights compared with simulation

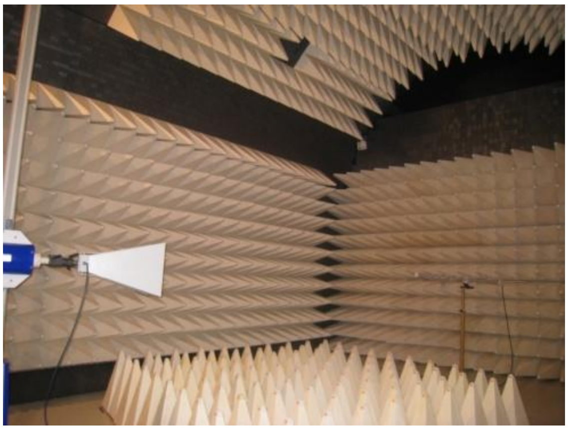

Fig.6 Absorber height around 3.5m

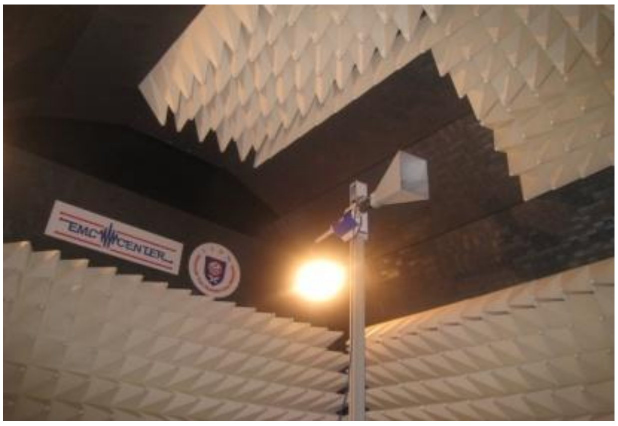

Fig.7 Reference antenna at 4m height from ground plane

C. *Phase Centers of Reference Antenna*

SAM emphasized that the reference antenna must be accurate and the AF is known. Therefore, several measurements using different reference antenna had been conducted. Three difference antennas namely Bi-log, Dipole and Horn antenna are used as a reference/standard antenna. For the first analysis, Bi-log antenna has been used as a reference antenna to cover from 200 MHz to 1GHz.

Fig. 8 shows the *AF* results by using Bi-log antenna as reference antenna. It indicates large differences compared to the simulation due to the variation of the phase centers. Position of the phase center provided by manufacturer is only a guideline since the phase center for Bi-log antenna varies with frequency. Since a Bi-log antenna consists of many dipoles, each resonating at different frequencies, the electric field should not be measured at a fixed distance. For example, when performing a 3m calibration for low frequency, the bow tie elements are active. Therefore, the active phase center is at the end of the Bi-log antenna. As an impact, the measurement is actually performed at 4m test instead of 3m. Therefore, Bi-log antenna is not suitable as reference/standard antenna in SAM measurement.

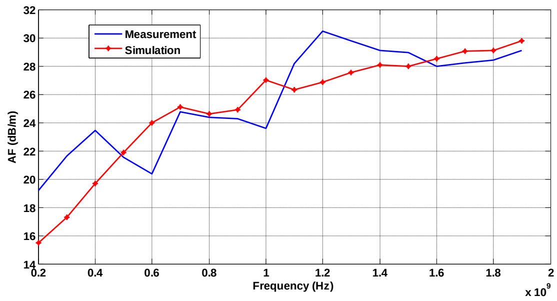

Fig.8 AF for Bi-log antenna as a reference antenna

The Bi-log antenna is then replaced with a tunable dipole antenna. Dipole antenna is a single wire antenna and the phase center is located exactly at the feeding point of the two wires. However, the frequency range for dipole antenna available for the measurements is from 30 MHz to 1GHz. Horn antenna is used for frequencies between 1.1 GHz to 2 GHz.

The horn antenna must be positioned exactly below the phase center to ensure the 3m measurement can be achieved accurately. Two different analyses regarding the phase center of the horn antenna have been done. For the first measurement, the 3m measurement is positioned at the edge of the horn antenna as shown in Fig. 9. Therefore, for this measurement, the exact distance between two cones for reference antenna is greater than 3m from the transmitter if compared with AUT position.

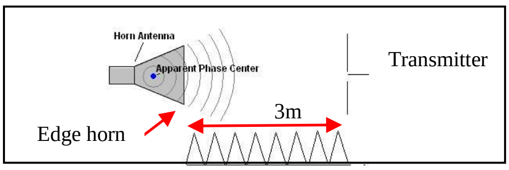

Fig.9 Horn antenna measurement without concerned on phase center position

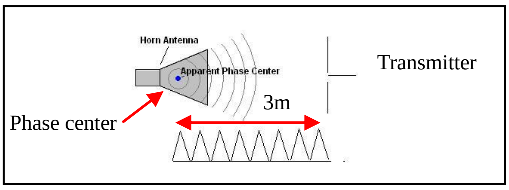

Fig.10 Horn antenna measurement with correct phase center position

For second measurement, the horn antenna is positioned exactly 3m at the phase center from the transmitter as shown in Fig. 10. As the results, horn antenna with exact phase center position shows better agreement with simulation results as shown in Fig. 11. Therefore, knowing the exact position of the phase center of the reference and AUT is important and must be taken into considerations because by referring to Fig.11, the deviation of the *AF* from the simulation can be as high as 3dB.

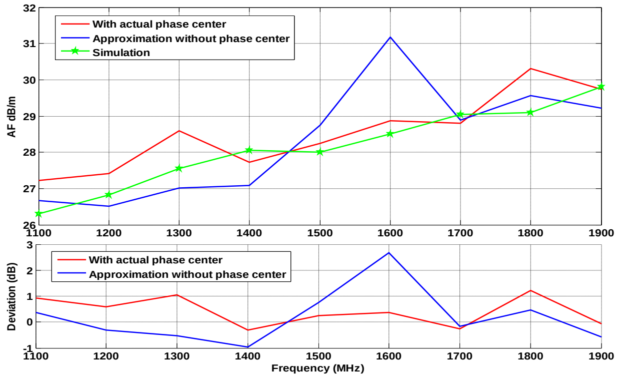

Fig.11 AF using Horn antenna as reference antenna with and without offset of phase center

V. CONCLUSIONS

Three factors that have impact on *AF* evaluation in a semi anechoic chamber for SAM measurement have been evaluated. These factors are ground plane, antenna height and phase centers. It was found that absorbers are important and must be placed between transmitting and receiving antennas to avoid the reflection and coupling between antenna and ground plane. In addition, reference antenna height must be taken into considerations during the measurement because of the limited volume in a semi-anechoic chamber. The antenna must be placed at suitable height preferably at the center of the chamber to avoid reflection and coupling with the surrounding walls.

Phase centers of reference antenna have been highlighted as a critical factor in calibration using SAM. Therefore, dipole and horn have been used for 200 MHz to 2 GHz measurement due to fix phase center and accurately known AF. Antennas with frequency dependent phase centers such as Bi-log antenna must be avoided to achieve reliable *AF* calibration.

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