The Application of Wire Mesh Ground Plane in Open Area Test Site for Radiated Emission Measurement

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Abstract—**Nowadays, the manufacturers apply the radiated emission test for all of their electrical or electronic products in order to avoid disturbance to other electrical or electronic products and to fulfil national or international standards. An Open Area Test Site (OATS) is one of the facilities used in the radiated emission measurement which requires the equipment under test (EUT), a receiving antenna with the antenna mast, the ground plane, and the radiated emission measurement device. The focus of this research is mainly about the ground plane of the OATS which can reflect the emission from the EUT to the receiving antenna. The perfect ground plane is very expensive; therefore the wire mesh ground plane can be used to cut the cost. The investigation of the ground plane could lead to an applicable radiated emission test and the accuracy of the measurement by using the mesh ground plane in OATS. In solving the problems related to the ground plane, the measurement of Normalized Site Attenuation (NSA) will be compared with the theoretical NSA. NSA is measured by transmitting signal from the frequency of 30 Mega Hertz (MHz) until 1000 MHz, assuming only two waves propagation which are direct wave and reflected wave.**

Keywords-EMC; OATS; ground plane; radiated emission

I. INTRODUCTION

A. Radiated Emission Testing

In radiated emission testing, electronic or electrical devices are tested for their electromagnetic radiation in order to comply with regulations and standards. There are four widely accepted facilities for measuring emission levels of the antenna which are OATS, Semi-Anechoic Chamber (SAC), Mode Stirred Chamber (MSC), and Gigahertz Transverse Electromagnetic (GTEM) Cell. The Federal Communication Commission (FCC) and European Norms (EN) suggested that the test should be conducted by using OATS for measurements in order to achieve the expected measurement with reduced error rate [2].

B. Open Area Test Site

The test site for measurement of radio disturbance field strength for the frequency range of 30 MHz to 1000 MHz requires a characteristic of cleared level terrain. According to [1], the test site shall be void of buildings, electric lines, fences, trees, etc. and free from underground cables, pipelines, etc., except as required to supply and operate the EUT. In other words, an obstruction-free area surrounding the EUT and field-strength measuring antenna is required. The obstruction-free area should be free from significant scatterers of electromagnetic fields, and should be large enough so that scatterers outside the obstruction-free area will have little effect on the fields measured by the field-strength measuring antenna.

C. Ground Plane

Ground plane is one of the important parts in the OATS facilities as it would reflect the emission from EUT to the receiving antenna. Therefore the ground plane should be made of electrically conductive material in order to reflect the emission in the OATS in measuring the radiated emission. The ground plane may be composed of a wide range of material from earth to highly conductive, metallic material as specified by CISPR 16-1-4 [1]. A metal ground plane is preferred, but for certain equipment and applications, it may not be recommended by certain product publications. Furthermore, such sites generally give different site attenuation characteristics compared to those with metallic surfaces. According to [3], the ground plane should preferably be solid metal sheets welded together, but this may be impractical. As a low cost alternative, wire mesh ground plane can be used.

D. Normalized Site Attenuation

NSA is a procedure that requires two different measurement of V_R which is the voltage received. According to CISPR 16-1-4 [1], the first reading of V_R is taken by connecting two coaxial cables using an adapter. The second reading of V_R is taken by connecting the coaxial cables to the transmitting and receiving antennas and the maximum signal measured when the receiving antenna is scanned in height of 1 to 4 meters (m) for this case of 3 m test distance. The free space antenna factors of the transmitting and receiving antenna are required for this procedure. The measured NSA (NSA_m) is calculated in dB according to (1)

$$NSA_m = M0 - M1 - AF_T - AF_R \qquad (1)$$

Where $M0$ is the reference level measured by the receiver with the cables connected together, $M1$ is the level measured by the receiver with the antennas installed, while AF_T and AF_R

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are free space antenna factors in dB/m. The deviation ΔNSA is calculated in dB according to (2)

$$\Delta NSA = NSA_m - NSA_{calc} \quad (2)$$

NSA_m is calculated using (1) and NSA_{calc} is calculated using (3)

$$NSA_{calc} = 20\log_{10}\left[\left(\frac{5Z_0 d}{2\pi}\right)\left(\frac{d}{\sqrt{1-\frac{1}{(\beta d)^2}+\frac{1}{(\beta d)^4}}}\right)\right] - 20\log_{10} f_m \quad (3)$$

where Z_0 is the reference impedance, d is the distance between the phase centres of both antennas in meters, β is defined as $2\pi/\lambda$, and f_m is the frequency in MHz.

II. Research Methodology

A. Measurement Equipment

The instruments used in the test are listed in Table I.

B. Ground Plane Implementation

The ground plane was made from bonded wire mesh of steel with the mesh area of ±2 mm^2 and was shaped into Special Plane I [4] for 3 m test distance. The test site was covered with the ground plane which was stretched and nailed to the ground. The ground plane was earthed at every edge of it.

C. NSA Measurements

NSA measurements were taken with the implementation of the bonded wire mesh ground plane. First, a measurement of voltage received by connecting the cable of the transmitter and receiver was taken. The location of the transmitting and receiving antennas are specified in Special Plane I [4]. Signal was transmitted via transmitting antenna to the receiving antenna which was scanned between 1 m to 3.5 m and the data was recorded by the spectrum analyzer. The measurements were then calculated by using (1) for the frequency range of 30 MHz to 1000 MHz and compared to the theoretical value of the NSA with ±4 dB (decibels) acceptability criterion. The configuration of the site for NSA measurements is shown in Fig. 1. It should be noted that the position of the cable roller next to the receiving antenna mast, although quite disturbing, was unavoidable due to the length of the antenna mast cable. Furthermore, the effect of the electromagnetic energy used in this experiment to the operator was considered negligible because the power generated by the signal generator was only 1 mW and the operator had to be stay far away from the test site.

TABLE I. NSA Measurement Equipment

No.	Instrument	Brand & model
1.	Antenna Mast	ETS-EMCO 2075
2.	BiConiLog Antenna (receiving antenna, f =30-1000MHz)	ETS-EMCO 3142B
3.	Antenna Positioning Controller	ETS-EMCO 2090
4.	Spectrum Analyzer	Rohde & Schwarz ESCS30
5.	Log Periodic Antenna (transmitting antenna, f=300-1000MHz)	ETS-EMCO 3146
6.	Biconical Antenna (transmitting antenna, f=30-300MHz)	ETS-EMCO 3110
7.	Signal Generator	Marconi IFR 2032

D. Shift of Measurement Axis

The method of shifting the measurement axis is to move the antennas away from the focal points [5]. In this case, the transmitting antenna was moved from the focal point of the receiving antenna. The transmitting antenna was shifted 0.5 m to the left and right hand side of the receiving antenna focal point. The shifted antenna was then directed towards to the antenna for direct measurement and the shifted antenna was facing parallel against the receiving antenna for indirect measurement. There were four measurements taken using this method.

E. Height Scanning

The transmitting antenna should be 1 m above the ground plane. The receiving antenna, Biconilog antenna which has the operation range from the frequency of 30 MHz to 1000 MHz was placed onto the antenna mast that could reach the peak of 3.5 m in height. The NSA measurement requires the receiving antenna to scan between 1 m and 4 m as being specified by CISPR 16-1-4 [1].

Figure 1. NSA measurement in the test site

III. RESULTS

The data collected are presented in the form of NSA against frequencies graphs as shown in Figure 2 to Figure 6.

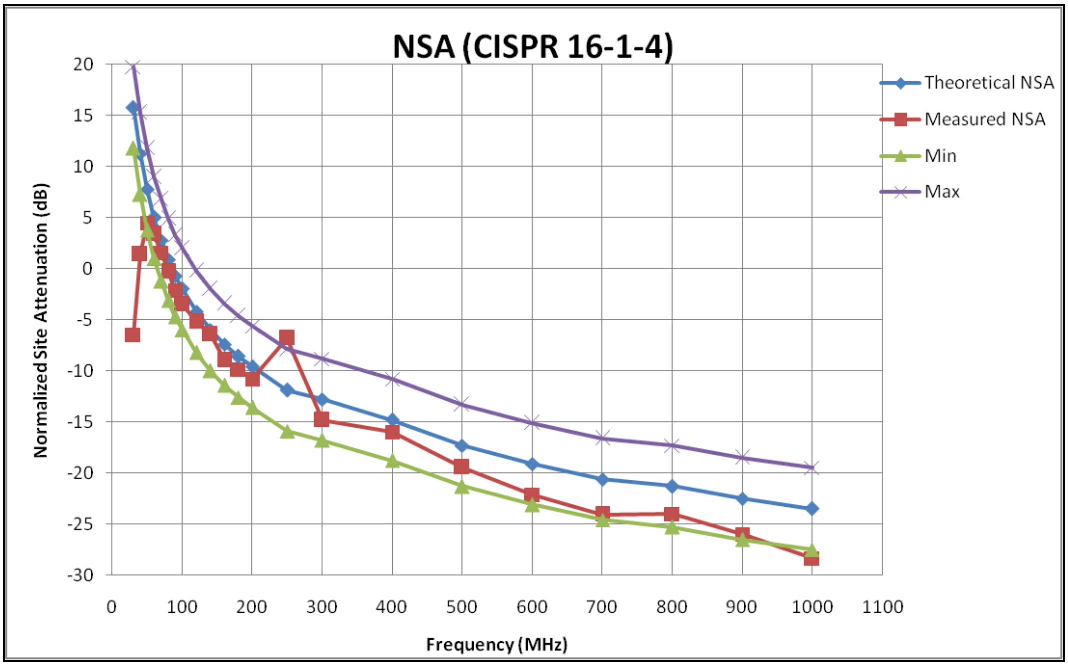

Figure 2. Graph of NSA measurement according to CISPR 16-1-4 procedure

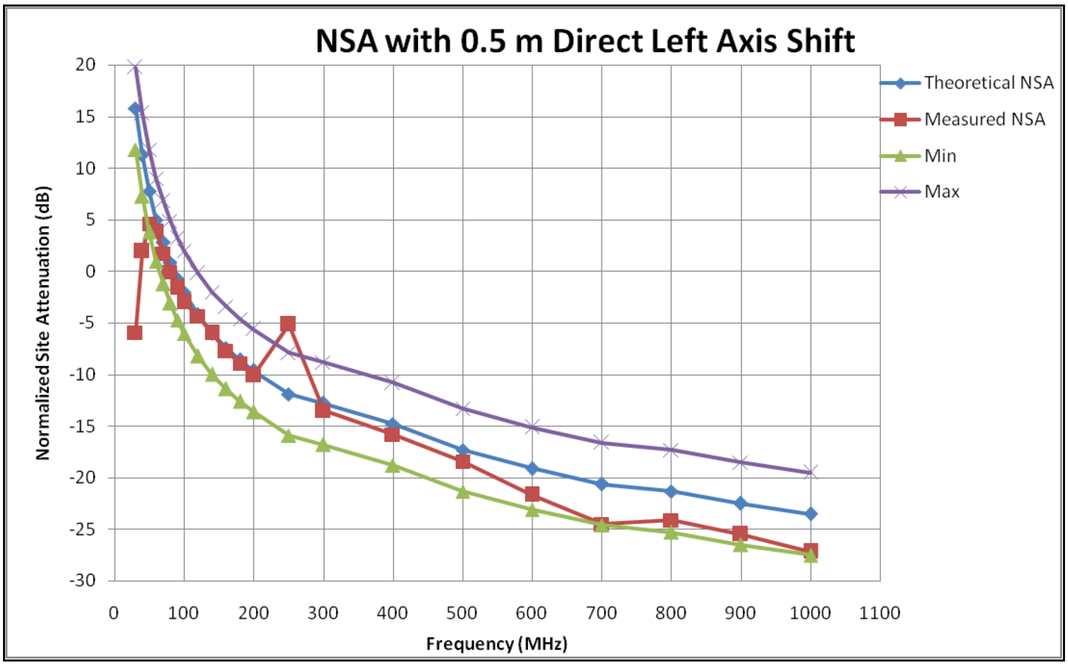

Figure 3. Graph of NSA with 0.5 m direct left axis shift

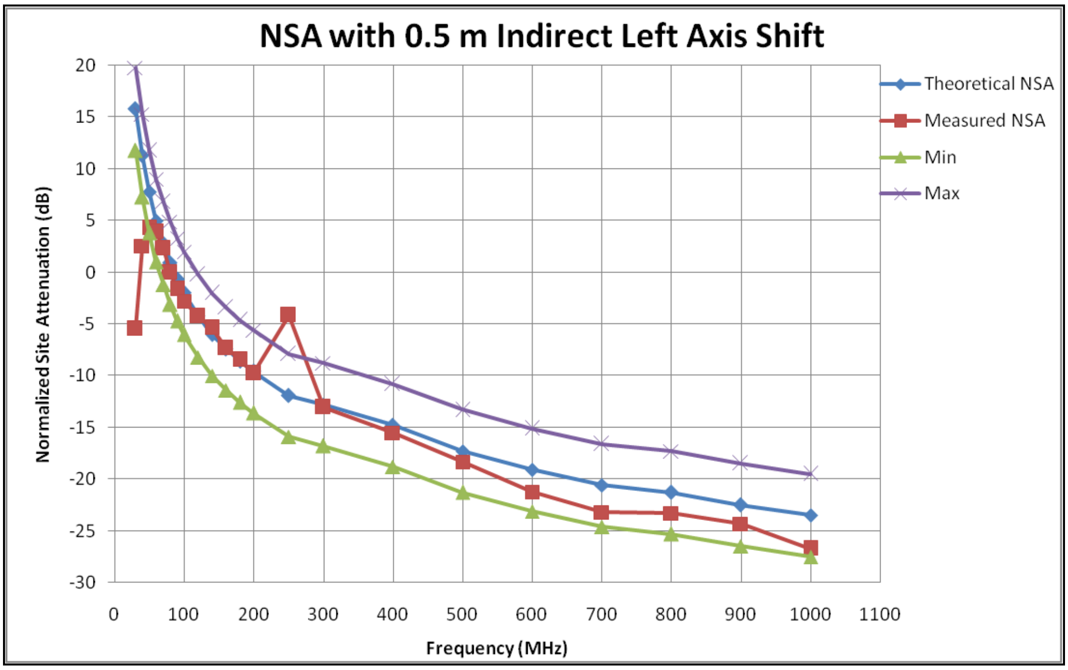

Figure 4. Graph of NSA with 0.5 m indirect left axis shift

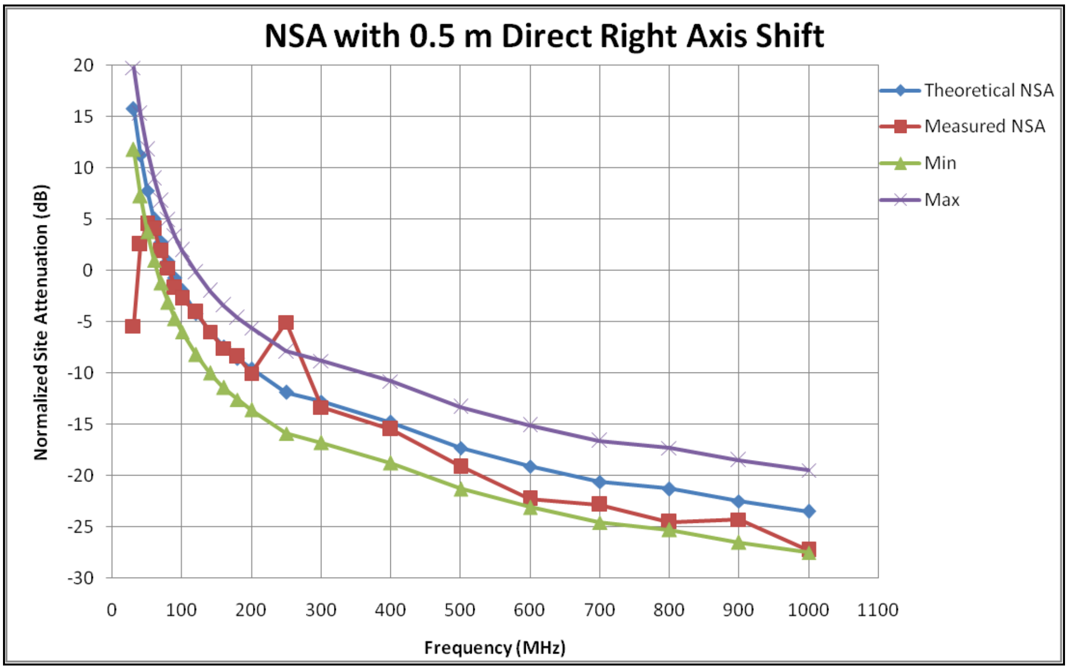

Figure 5. Graph of NSA with 0.5 m direct right axis shift

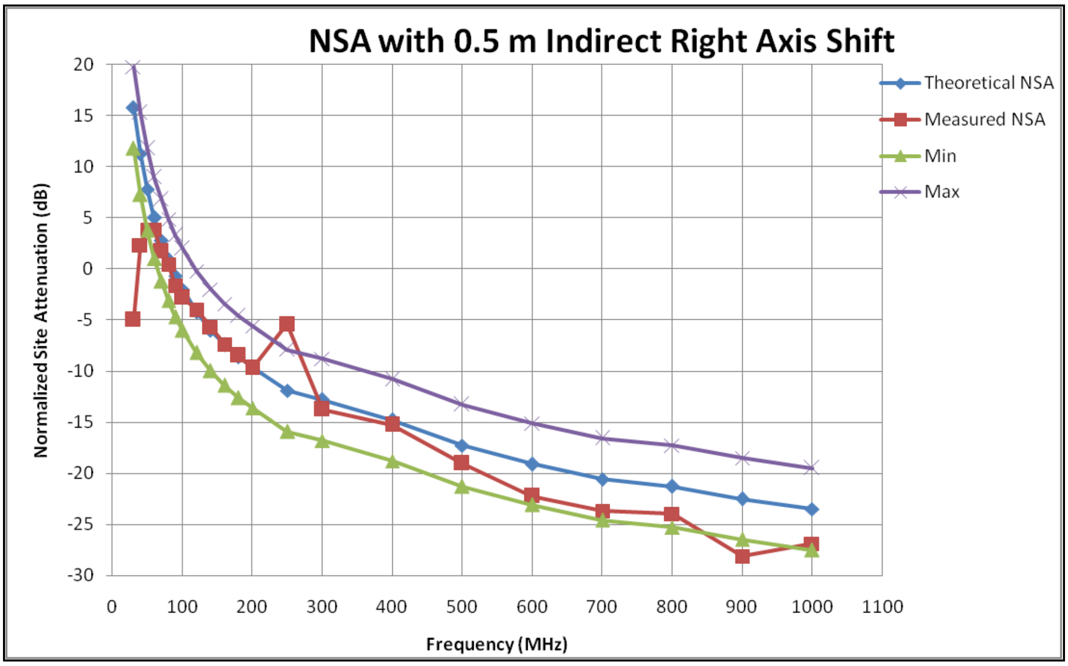

Figure 6. Graph of NSA with 0.5 m indirect right axis shift

IV. Analysis and Discussion

A. NSA Measurement (CISPR 16-1-4)

The graph from Fig. 2 shows that there are 4 frequencies measured exceed the ±4 dB acceptable criterion [1]. The frequencies are 30, 40, and 250 MHz measured by applying the Biconical antenna (30 MHz to 300 MHz). For the use of the Log Periodic antenna (300 MHz to 1000 MHz), the data is in the range of the maximum and minimum value allowed for NSA measurement of OATS except for 1000 MHz which is 4.84 dB lower than the theoretical NSA measurement exceeds the acceptable criterion. The problem exists at the initial frequencies and at the end of the Biconical antenna frequency specification. This mislead of signal received might be caused by the radiation pattern characteristic of the Biconical antenna which have less radiation at 30, 40, and 250 MHz. Furthermore, there also might be some errors regarding to the elements of the Biconical antenna such as unexpected increment of the antenna factor at 30MHz and 40MHz, or unexpected decrement of the antenna factor at 250MHz. The part of using the Log Periodic antenna shows that the NSA measurement value is still in ±4 dB except for 1000 MHz which might be caused by low radiation transmitted by the antenna or the ground plane is incapable of reflecting the wave with shorter wavelength. For 300 MHz to 900 MHz, the measurement can still be accepted although the measurement did not exactly match with the theoretical value but they are still in the acceptability criterion.

B. Shift of Measurement Axis

The method produced four graphs which are from Fig. 3, 4, 5 and 6 according to the measurement procedures of this method [5]. All of the four graphs showed the same problem experienced by the NSA measurement in Fig. 2 at the frequency of 30, 40, and 250 MHz as being specified at IV.*A*. For the frequencies of 300 MHz to 1000 MHz which used the Log Periodic antenna, the problems exist starting at 600 MHz for left shift and 500 MHz for right shift. The difference that happens when shifting to the left or right may be caused by the metallic (electrically conductive) object near to the test site which is on the right hand side of the transmitting antenna. By shifting to the right, the measured NSA should be the same as shifting to the left if the boundary condition of the test site is the same for left and right. A deviation table of frequency 300 MHz to 1000 MHz is created as the frequency of 50 MHz to 200 MHz is acceptable when compared with theoretical NSA measurement. Table II shows the error between the measured NSA and theoretical NSA in the measurement procedures of this method which is calculated by using (2).

TABLE II. NSA Deviation In The Measurement Procedures

Frequency (MHz)	0.5 m direct left axis shift (dB)	0.5 m indirect left axis shift (dB)	0.5 m direct right axis shift (dB)	0.5 m indirect right axis shift (dB)
300	-0.663	-0.257	-0.531	-0.929
400	-1.017	-0.735	-0.655	-0.466
500	-1.144	-1.030	-1.832	-1.733
600	-2.526	-2.147	-3.152	-3.162
700	-3.904	-2.599	-2.228	-3.079
800	-2.832	-1.985	-3.238	-2.681
900	-2.952	-1.814	-1.814	-5.613
1000	-3.650	-3.226	-3.755	-3.412

According to [5], by shifting the transmitting antenna, the area of the receiving antenna would have smaller interference instead of without shifting the transmitting antenna. The theory proved to be right as there is an improvement according to the NSA measurement value between 300 MHz and 1000 MHz compared with the NSA measurement by applying the CISPR 16-1-4 method as can be seen from Figure 8. This is because by placing the transmitting and receiving antennas at the focal points of the elliptical area of the test site causes a superposition of reflections at both sides of the rim with an identical propagation path and a strong interference pattern. By considering ±1 dB of the NSA deviation, each measurement procedure has compatibility with certain frequencies. The most suitable measurement procedure can also be determined by using Table II as the reference for the frequencies of 300 MHz to 1000 MHz by choosing the lowest deviation and neglecting the negative sign. By shifting the axis of the transmitting antenna, the ground plane performance can be determined according to the location and direction of the transmitting antenna. The only NSA measured exceeds the acceptability criterion is at 900 MHz of 0.5 m indirect right axis shift. This might be caused by the radiation of the transmitting antenna reflecting on the ground plane suffered loss of directivity due to the interference from nearby metallic object which is on the right hand side of the transmitting antenna.

V. Conclusion & Recommendations

It has been shown in this paper that the application of the mesh ground plane can be evaluated by different method of measuring NSA. The ground plane could not perform well in the frequency of 30, 40, 250, and 1000 MHz for NSA measurement of normal and shift of measurement axis. With lack of radiation and the unexpected change of the antenna factor would contribute to this unacceptable NSA measurement. As for the method of shift of measurement axis, all of the measurement procedures are suitable for 300, 400, and 500 MHz as the measurement is about ±1 dB instead of other measurement frequencies according to Table II. The procedure of 0.5 m direct left axis shift is not suitable when compared to the other procedures regarding the NSA deviation values for each frequency. 0.5 m indirect left axis shift is suitable for the frequency of 300, 500, 600, 800, 900 and 1000 MHz. 0.5 m direct right axis shift is suitable for 700 MHz and 900 MHz. 0.5 m indirect right axis shift is suitable for 400 MHz. This suitability is measured according to the value of the NSA deviation which is near to zero value.

Acknowledgment

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