Preliminary Design and Development of Open Field Antenna Test Site

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Abstract

An open area test site (OATS) for electromagnetic compatibility (EMC) antennas calibration will be built at the campus of Universiti Tun Hussein Onn Malaysia (UTHM) in Batu Pahat, Johor, Malaysia. The calibration of the EMC antenna mainly is to determine the antenna factor (AF). The development of the test site will be through modeling, simulation, selection of test site location, test site construction, and evaluation phases. The location of the test site will be selected so that it will have low ambient noise. The test site will be constructed based on the specification obtained from the model and simulation. Site attenuation measurements will be performed to evaluate the quality of the test site. This paper discusses a preliminary design and development of the test site includes feasibility study, design of the site construction, and measurements on site attenuation for site validation.

Keywords: Electromagnetic compatibility, antenna, open field test site, measurement.

1. INTRODUCTION

The rapid development of domestic and commercial electrical and electronic equipments increased the demand for electromagnetic compatibility (EMC) test to comply radiated emission requirements from governing body. EMC testing can be in the form of conducted and radiated emissions measurements. For radiated emissions the most commonly used measurement techniques are antenna-based measurements in screened rooms, anechoic chambers, open area test sites (OATS), and gigahertz transverse electromagnetic (GTEM) cells.

An OATS often becomes a choice for EMC testing because it is fast, efficient and low cost compared to the other techniques. The OATS should be located in an area of low RF ambient. It must be far away from above ground or underground electromagnetic reflecting objects.

In the OATS, the electromagnetic field emanating from the equipment under test (EUT) is measured using an antenna. To obtain valid measurements, the antenna must be precisely calibrated. The calibration of the EMC antenna is to determine the antenna factor (AF) [3]. In general, AFs provided with the antenna usually are not adequate for valid measurement. AF is a parameter of an antenna which relates the value of the incident electromagnetic field to the voltage at the output of the antenna.

An OATS can be classified as a calibration test site (CALTS) or compliant test site (COMTS). A CALTS is an OATS that complies with the tightly specified site attenuation specifications. A CALTS is used for determining the parameters of an EMC antenna. A COMTS is an OATS that has less stringent specifications than a CALTS. A COMTS is used for performing radiated emission measurement [1].

The validation of a test site is performed using site attenuation (SA) measurement. Site attenuation is defined as the minimum site insertion loss measured between two polarization-matched antennas located on a test site when one antenna is moved vertically over a specified height range and the other is set at a fixed height. Normalized site attenuation (NSA) is the site attenuation which is divided by the product of the antenna factors for the two antennas used. For a COMTS, NSA must be within ±4 dB while for a CALTS, NSA must be within ±1 dB of the theoretical NSA in the frequency range of 30–1000 MHz [1].

Basically there are two calibration methods i.e. the standard site method (SSM) and the reference antenna method (RAM). The SSM requires a standard antenna calibration site. There must be three SA measurements under identical geometries using three different antennas taken in pairs. The antenna factors for each antenna are then calculated. The RAM uses a tuned half-wave dipole antenna as a reference to derive the AF of the unknown antenna. In this method a field is generated using any type of antenna. The field is then measured using he reference antenna and the unknown antenna. The difference in the measured field strength is the difference in AFs between the reference antenna and the unknown antenna [3].

2. FEASIBILITY STUDY

A feasibility study has to be done to evaluate the candidate location for the test site. Ambient noise must be the fist to be considered in the feasibility study. If the ambient noise in a location is too excessive then the test site can not be built in that place. CISPR 16-1 uses 6 dB measurement signal level above the ambient noise to categorize the quality of a test site. The best one if the measurement signals are 6 dB above the ambient noise for the entire measurement range [1].

An ambient noise measurement has been performed at the candidate location of the test site in UTHM campus area using a log periodic antenna EMCO 3146 in the frequency 200 – 1000 MHz [6]. The result is shown in Fig. 1. Significant amount of noise appears at the frequencies of 390, 462, 633, 921, 930, 939, 948, and 957 MHz with the peak value ranges from 42.51 to 70 dBμV. These are broadcast and GSM signals, which are considered normal and found almost everywhere nowadays. In addition the measurement in this site will not be in those frequencies. Therefore the location is considered feasible to build a test site.

3. Test Site Construction

The test site which will be built is a 10 m CALTS, therefore the size of the minimum required site will be the obstruction free ellipse, i.e. 20 m length by 17.3 m width [1][2].

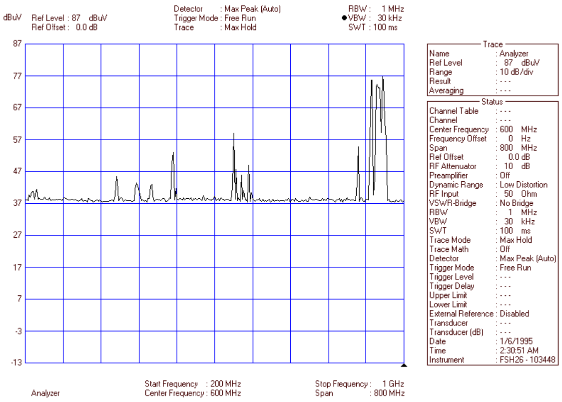

Fig. 1 Ambient electromagnetic noise around proposed CALTS location

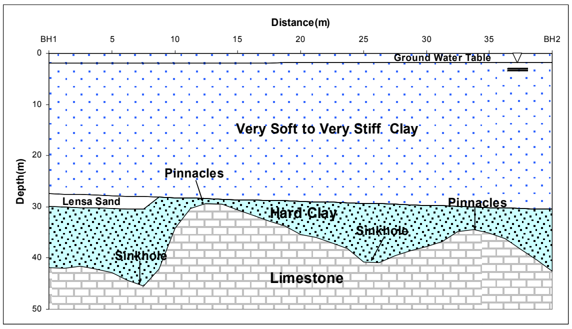

Fig. 2 Geological structure at UTHM campus area

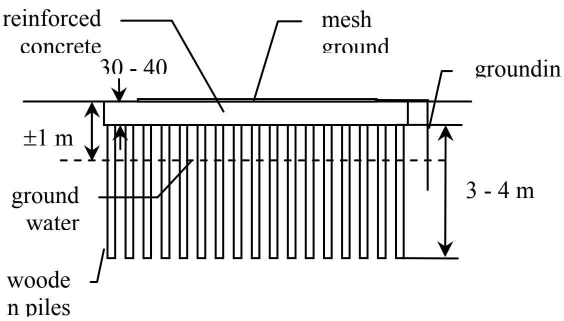

Fig. 3 Conceptual design of the site construction

The concrete base will be designed using soil quality data (boring log) and geological structure data as depicted in Fig. 2.

Since the soil is very soft, the concrete must be supported using wooden piles to avoid it from cracking and slow dropping. The ground water table is found to be very shallow (±1 m) which makes easier for grounding of the ground plane. Fig. 3 shows the conceptual design of the site construction.

4. Site Attenuation Measurement

SA measurement for 3 m separation antenna distance has been performed to evaluate the quality of the site [7]. The measurement setup is shown in Fig. 4.

The measurements were performed with two antennas oriented horizontally with respect to the ground. Mesh ground plane with the geometry known as Special Plane I [5] as illustrated in Fig. 5 was used in this measurement.

A waveform produced by a signal generator was fed to the transmit antenna to create an electromagnetic field. The height of the transmit antenna was kept constant while the receive antenna scanned the field emanating from the transmit antenna from 1 m up to 4 m. The process was done repeatedly from frequency 30 MHz to 1000 MHz. The maximum peak was then recorded by a spectrum analyzer which measured the field strength received by the receive antenna.

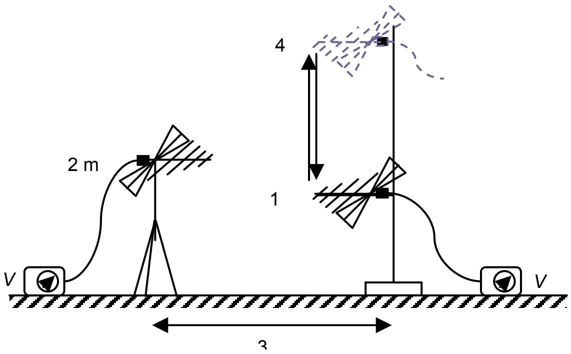

Fig. 4 Antenna configuration for NSA measurement

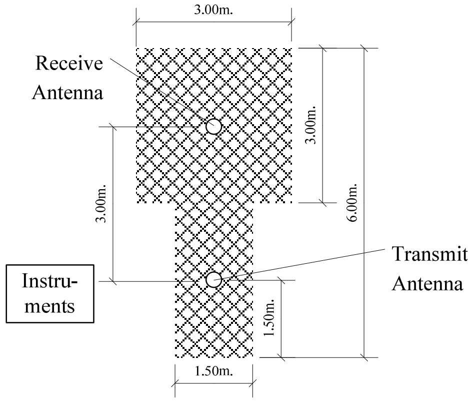

Fig. 5 Mesh ground plane geometry

The theoretical SA is related to the antenna factors of the receive and transmit antennas as given by the following formula [4]:

$$A = \frac{279.1 AF_R AF_T}{f_M E_D^{\max}} \tag{1}$$

where

f_M : frequency (MHz)

AF_R : antenna factor of receiving antenna (dB/m)

AF_T : antenna factor of transmitting antenna (dB/m)

E_D^{max} : maximum electric field in receiving-antenna height-scan range from a theoretical half wave dipole with 1pW of radiated power.

The theoretical NSAs (NSA_t) for each frequency were then calculated using the following formula:

$$NSA_t = \frac{A}{AF_R AF_T} \tag{2}$$

The measured NSAs (NSA_m) for each frequency were calculated from the measurement data using the following formula [1]:

$$NSA_m = V_{DIRECT} - V_{SITE} - AF_T - AF_R \tag{3}$$

where

V_{DIRECT} : received voltage measured at the spectrum analyzer when the cable from the signal generator and the cable to the spectrum analyzer are directly connected.

V_{SITE} : received voltage measured at the spectrum analyzer when the cables are connected to the respective antennas.

AF_T : the transmit antenna factor

AF_R : the receive antenna factor

The results of the measurements and calculations are listed in Table 1 and plotted as a graph as shown in Fig. 6. It can be seen that the measured NSA curve is quite close to the theoretical NSA curve. Around 70% measured NSAs are within ±1 dB band and only 2 are outside ±4 dB band. It means that the quality of the site is quite good although is not valid yet for antenna calibration. Some improvements have to be taken on the equipments and measurement method in order to get better result.

Table 1: NSA Measurement Data for Horizontal Polarization

f (MHz)	V_{DIRECT} (dBμV)	V_{SITE} (dBμV)	AF_T (dB/m)	AF_R (dB/m)	NSA_m (dB)	NSA_t (dB)
30	96.626	58.352	14.8	18.9	4.574	15.8
40	96.483	63.633	12	12.7	8.150	11.3
50	96.335	72.514	10.4	9	4.422	7.8
60	96.290	74.934	9.7	7.1	4.556	5
70	96.127	77.221	9.5	6.9	2.506	2.8
80	96.076	77.271	9.7	7.7	1.405	0.9
90	95.885	77.034	10.3	8.8	-0.248	-0.7
100	95.827	77.530	10.9	9.2	-1.803	-2
120	95.569	80.158	11.8	7.9	-4.289	-4.2
140	95.540	81.135	12.4	8.2	-6.194	-6
160	95.483	80.280	13	9.7	-7.497	-7.4
180	95.266	80.038	13.6	10.1	-8.472	-8.6
200	95.076	79.672	15	10.2	-9.795	-9.6
250	94.877	77.362	12.3	12.5	-7.285	-11.9
300	94.685	75.752	14.6	14.2	-9.867	-12.8
400	94.178	77.406	15.8	16.4	-15.428	-14.8
500	93.491	74.779	17.9	17.9	-17.088	-17.3
600	93.165	71.576	18.9	20.3	-17.611	-19.1
700	92.816	68.033	21.6	22	-18.817	-20.6
800	92.191	70.166	21.4	22.2	-21.575	-21.3
900	91.858	68.686	22.7	23.6	-23.128	-22.5
1000	91.798	66.726	24.5	24.1	-23.528	-23.5

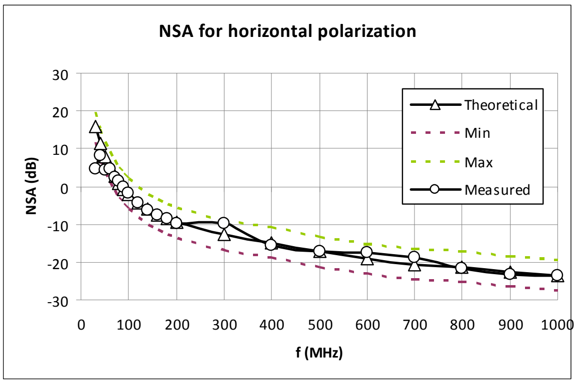

Fig. 6 Comparison between theoretical and measured NSA at candidate location

7. CONCLUSION

A preliminary study on the development of an antenna calibration open field test site has been presented. The feasibility study reveals that the test site is feasible to be built at the candidate location. A conceptual design of the site construction has been created. It can be developed further by the contractor of the test site construction. The preliminary measurements on the site attenuation have been performed and analysed. The results are promising and the development of an antenna calibration open field test site in UTHM can be continued.

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