Electromagnetic Measurement Activities at CRC of OIT

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1. INTRODUCTION

Usually, the antenna and electromagnetic performances can be simulated by various commercial available software (HFSS, CST, GEMS, FDTD.,etc.). Unfortunately, the implementation of hardware for these devices may have error during manufacturing. Electrical performance testing is required even for pilot run or mass production of these devices. Usually, the passive electrical performances, such as impedance, VSWR, return loss, power gain, power patterns, axial ratio, antenna overall efficiency, can be measured by the vector network analyzer inside anechoic chamber. Except for the passive electrical performances, the active electrical performances, TRP (total radiation power) and TIS (total isotropic sensitivity) are required for wireless communication system. The uncertainty of passive and active measurements not only depends on the experience of operator but also the signal to noise ratio. In this paper, overview the activities of passive and active measurement at CRC (Communication Research Center) of OIT (Oriental Institute of Technology) are presented at this paper. Various kinds of antenna measurement systems and TRP and TIS communication measurement system are presented.

2. SCATTERING MATRIX AND PASSIVE MEASUREMENT

The important parameters are from the S-parameter as shown in Eq.1.

$$\begin{aligned} b_1 &= s_{11}a_1 + s_{12}a_2 \\ b_2 &= s_{21}a_1 + s_{22}a_2 \end{aligned} \tag{1}$$

Where a_1, b_1 are the input and reflect voltage at port 1, a_2, b_2 are the input and reflect voltage at port 2. S_{11}, S_{22} are the input reflection coefficient at port 1 and port 2 respectively. S_{12}, S_{21} are the transmission reflection coefficient at port 1 and port 2 respectively. If the electromagnetic device is reciprocal, then $S_{11} = S_{22}$, $S_{12} = S_{21}$. The impedance and power pattern are from these parameters.

2.1 Impedance

Usually the complex reflection coefficient of device is interesting as shown in Eq.2 for port 1. From the reflection coefficient, the complex input impedance, VSWR can be calculated by Eq.3.

$$\begin{aligned} \Gamma &= S_{11} \\ &= \frac{Z_L - Z_0}{Z_L + Z_0} \end{aligned} \tag{2}$$

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{3}$$

Where Γ is the complex reflection coefficient, Z_0 is the characteristic impedance of transmission, Z_L is the complex input impedance. The Smith Chart is simplified from Eq.2. The simple way for the relationship of these parameters can be viewed from Smith Chart as shown in Fig.1. Fig.1 is the example of dipole with frequency range from 0.94 GHz to 1.06 GHz. The red dot line is with 2 of VSWR curve. The solid red curve is the complex impedance with impedance matching. The green solid curve is the matching complex impedance. The complex reflection coefficient at each frequency is easier to measure from the Smith Chart. Most of the laboratories in Taiwan will have the vector network analyzer to measure the complex impedance.

2.2 Power pattern

The power pattern is calculated by either S_{12} or S_{21}. The field intensity of antenna at (θ,ϕ) direction with fixed polarization , frequency can be expressed as

$$S_{12}(\theta,\phi) = S_{21}(\theta,\phi) = \left|S_{21}(\theta,\phi)\right| e^{j\tan^{-1}\left(\frac{imag(S_{21}(\theta,\phi))}{real(S_{21}(\theta,\phi))}\right)} \tag{3}$$

The radiation power pattern (watt per solid angle) can be expressed as

$$U(\theta,\phi) \propto \left|S_{21}(\theta,\phi)\right|^2 \tag{4}$$

The power pattern in decibel scale is expressed as

$$20\log_{10}\left|S_{21}(\theta,\phi)\right|^2$$

3. VARIOUS KINDS OF PASSIVE MEASUREMENT SYSTEM

There are far field range, compact range, and near field range for antenna measurement.

3.1 Far field range

Usually, the quadratic phase error is smaller than 22.5°, the minimum range between transmit antenna and antenna under test is

$$R \geq 2D^2 / \lambda \tag{5}$$

Fig.2 is the 7m x 4m x 3m far field range. It can not only for far field antenna measurement, but also for active radiation emission measurement.

3.2 Compact range

The compact antenna test range will also generate the planar wave for antenna testing. Usually, part of paraboloid will be used as the prime reflector. The feed is located at the focus of paraboloid. The spherical wave from the feed source will be reflected by the paraboloid and the reflected wave is plane wave. Due to the stray wave from feed spillover and edge diffraction, the performance of quiet zone will be degraded. Absorber fence will be used for the reduction for feed spillover. The edge treatment along the edge of reflector can reduce the diffraction field. The types of edge treatment will include serrated edge, rolled edge, and R-card. These edge treatments are frequency dependent. The lower the frequency the larger the size of edge treatment will be. Fig.3 is the serrated compact range. Fig.4 is the compact range with serrated edge.

The edge treatment will not only increase the cost but also the size of compact range. In order to reduce the edge diffraction field without edge diffraction, impulse time domain vector network analyzer with time gating can be used. Fig.5 is the compact range without edge treatment.

3.3 Near field range

The traditional far field range will have more space to reduce the quadratic phase error. Although the compact range will have small anechoic chamber, the edge treatment and high precision reflector is the major cost of compact range. The far field range or compact range will only measure the radiation performance of far field. If the amplitude and phase of field distribution on or near the antenna are interesting, the near field range is a powerful tool not only to get the far field performance but also the near field information.

There are three types of near field ranges. They are spherical near field range, cylindrical near field range, and planar near field range. The planar near field range is suitable for high directivity antenna measurement The spherical near field range is suitable for low directivity antenna measurement. The cylindrical near field range is suitable for fan beam antenna measurement. Fig.5 is the hybrid near field ranges which includes the above three near field ranges.

4. ACTIVE MEASUREMENT SYSTEM

Antenna is part of communication system. It doesn’t matter how good the antenna performance will be, the end user is care about the communication performance, such as high efficiency antenna, high transmission data rate, low bit error rate, etc.,.. Usually the TRP and TIS are interested for communication engineers. Fig.6 is the TRP/TIS measurement for wireless communication system. It is very useful for the measurement of GSM, WCDMA, WiFi, and Bluetooth, etc.,.

5. CONCLUSIONS

The three anechoic chambers at CRC of OIT are used for passive antenna test ranges (hybrid near field ranges, far field ranges, compact range), active communication test range, and EMI radiation emission. The maximum operation frequency is 40 GHz. Except for the three different kinds of chambers, two powerful computer clusters equipped with GEMS general electromagnetic simulation software are also available. All these systems are for research, teaching, and industrial services.

References

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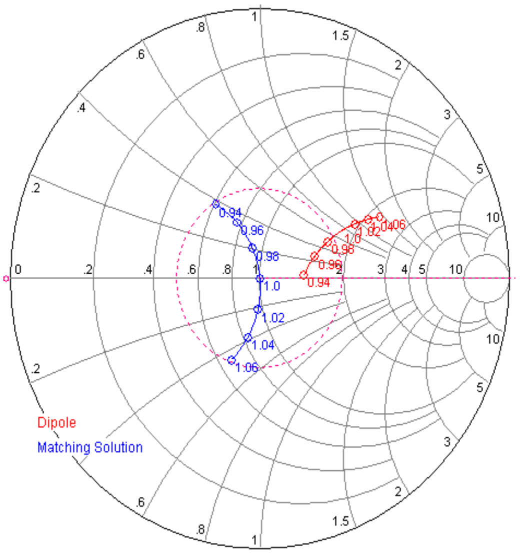

Fig.1. Smith Chart of half wave length dipole

Fig.2. 7m x 4m x 3m far field range for EMI measurement

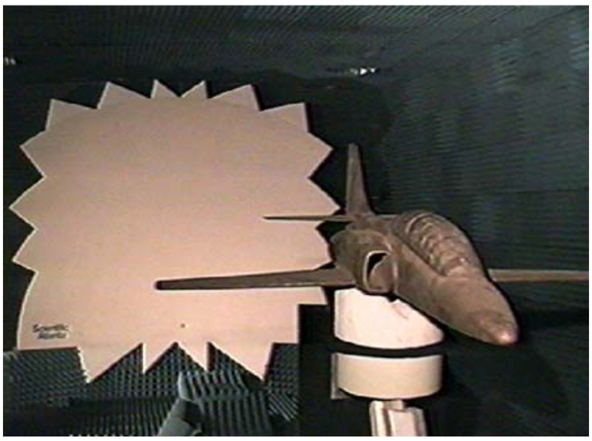

Fig.3 Serrated edge compact range

Fig.4 Compact range with impulse time domain vector network analyzer

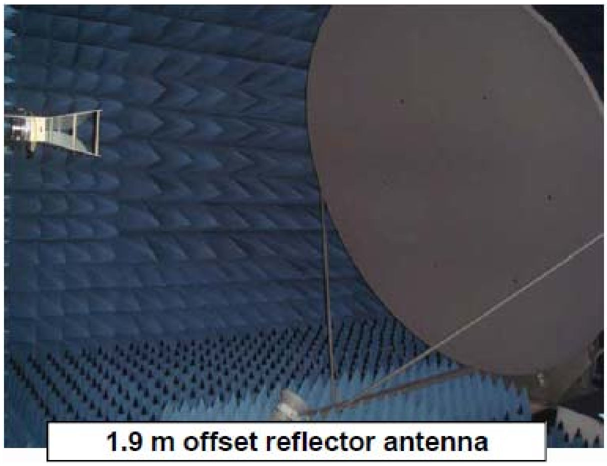

Fig.5 Hybrid near field range

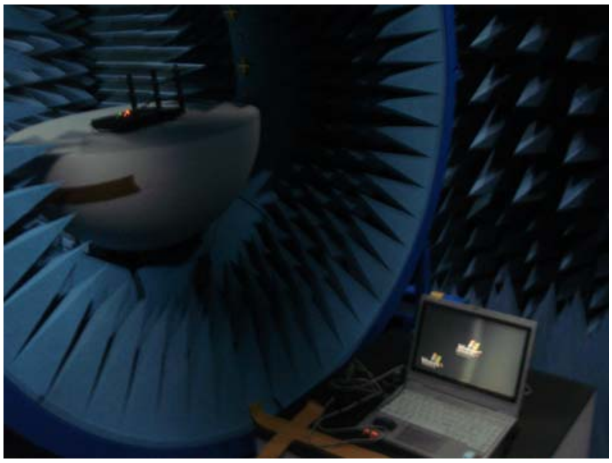

Fig.6 TRP and TIS measurement of WiFi MIMO