A Single Port Scanning Free Space Measurement Technique to Investigate Reflection Loss Characteristics of the Curved Structure at X-band

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ABSTRACT

Free space measurement (FSM) is a technique to investigate the electromagnetic characteristics of the microwave structures. The aim of this study was to develop a single port scanning free space measurement (SFSM) to measure reflection loss of the curved structure at X-band. Proposed calibration is GRL (gated-reflect-line), which is more convenient and accurate than other calibration because only use a sample holder and a metal plate as the antennas are fixed. The position of the metal plate was about 49.5ns in time domain, so the gating range was from 49 to 50.5 ns. Removing cable errors, test starting pointing was about 43ns. After finishing calibration, the developed SFSM software was connected with the PNA and N1500A software. The SFSM software could measure from one point to scan area and visualize results about scan area. In the curved structure, the reflection loss was much lower because electromagnetic waves had an incident and reflection angle. The curved structure was symmetric; the visualization result of the scan area was also symmetric. This indicates that it is possible to measure the electromagnetic characteristics in the whole specimen of both planar and curved structures. In future work, two port SFSM will be conducted to investigate the electromagnetic characteristics about planar and curved structures such as permittivity, permeability, loss tangent, and reflection & transmission loss.

1 INTRODUCTION

Microwave absorbers are well known for their superior anti-radar characteristics in terms of their wideband microwave absorption. The measurement techniques play a significant role for measuring the microwave absorption of materials about electromagnetic characteristics. Still, it is a very tedious job to identify a suitable measurement approach, which can be utilized for performance evaluation of absorbers in an open environment, i.e., free-space.

Microwave evaluation methods are generally classified into contact and non-contact techniques. Contact techniques include waveguide or co-axial methods, but there are limitations due to the requirement of a specified sample size. It is very difficult to use waveguide/co-axial techniques for arbitrary surfaces. However, the use of the free space measurement (FSM) technique may be adopted to solve such a problem. The FSM has no tolerance requirements for fitting the samples in a waveguide and does not limit the sample size and shape. In addition, FSM methods are nondestructive and contactless; hence, they are especially suitable for measurement of the electromagnetic characteristics [1]. Inaccuracies in dielectric measurement using free space methods are mainly due to 1) diffraction effects at the edges of a sample and 2) multiple reflections between the antennas via the surface of the sample [2]. FSM usually uses focused horn antennas to reduce the inaccuracies. However, focused horn antennas transmit the electromagnetic wave only the small spot size. They do not measure the scattering parameters in all sample areas.

Therefore, in this work, scanning FSM (SFSM) technique has been introduced for measuring the reflection loss of materials in terms of scattering parameters. Hence, it can be concluded that a single port SFSM is an efficient technique to measure the electromagnetic characteristics of the curved structure in the full field without any contact and damage to the sample. The adopted measurement technique may play an active and vital role in order to evaluate the electromagnetic structures for various other practical applications.

2 MEASUREMENT SETUP

2.1 Free space measurement (FSM)

In this study, the 3D scanning free space measurement (SFSM) performed to measure the stealth & radome electromagnetic characteristics. Before the 3D SFSM, the FSM was conducted in Figure 1.

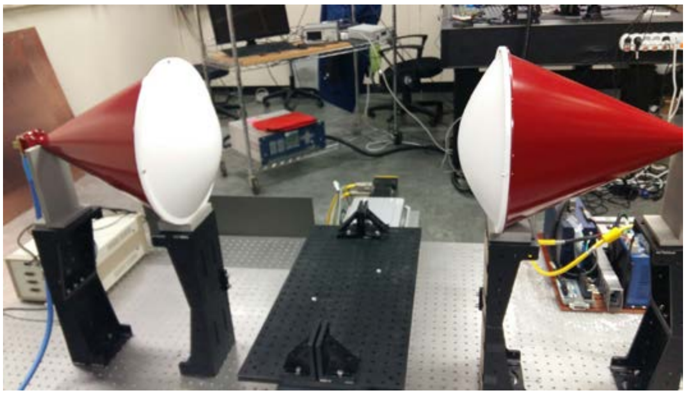

Figure 1: Free space measurement setup

The FSM components include two focused horn antennas, vector network analyzer (VNA), coaxial cables, and sample holder. Two focused horn antennas prevent electromagnetic waves propagation and make the plane waves at the focal length. The spot diameter is about 60mm, and the focal length is about 430mm. The frequency range is X-band (8.2 ~ 12.4 GHz), which most of the stealth & radome structures are using. The VNA is PNA N5222A including N1500A software. In this study, reflection loss (S_{11}) is focused on the electromagnetic characteristics because the stealth & radome structures do not detect a radar and all electromagnetic waves must be absorbed. The cable is connected between VNA and antenna to transmit electromagnetic waves. The sample holder is placed between two antennas. It is important to match the spot point with two antennas to increase an accuracy.

3.2 GRL (gated-reflect-line) calibration

In the FSM set up, calibration is the most important part to remove some errors. Two port network analyzer has twelve errors in Figure 2.

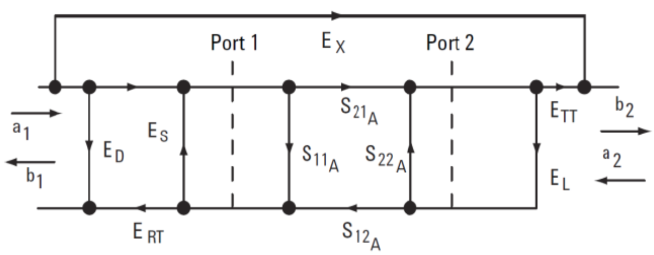

Figure 2: Signal flow of two port forward error terms [3]

Once known, the measurement errors caused by these system imperfections can be accounted for Classical methods for calibrating a free-space fixture are the GRL, TRL (thru-reflect-line), and the

TRM (thru-reflect-match) techniques [3]. The TRL and TRM calibration are difficult: 1)TRL is moving the antenna in 1/4 wavelength at line procedure, 2)TRM is not moving, but prepare some complex specimen to match calibration. However, GRL calibration is not moving the antennas, and only preparing the metal plate and sample. In previous, for calibrating, a SOLT (short, open, load, and thru) calibration needs to be performed at the end of the cables first [4]. SOLT calibration removes errors of cables. However, calibration for the one tier method is more convenient. This method is only using GRL calibration to remove errors of cables, antennas, and air. Before GRL calibration, we check the gating range using time domain.

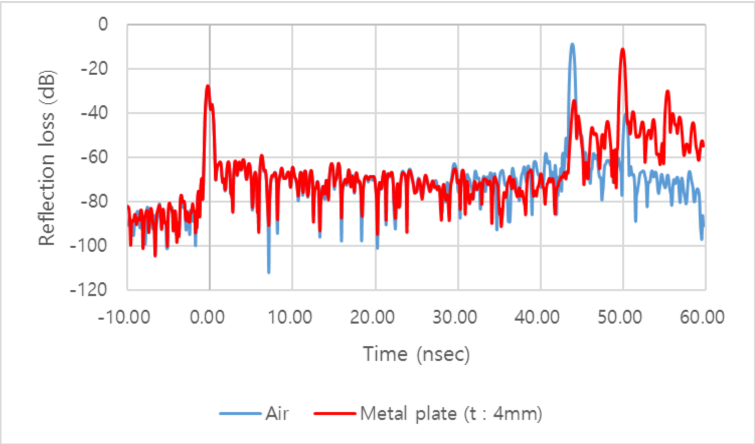

Figure 3: Reflection loss in the air and metal plate at the time domain

Figure 3 is the time domain in the air and metal plate. The metal plate was 4mm thickness aluminum. In the metal plate, reflection loss was the highest at 49.5 ns, so the gating range was from 49 to 50.5 ns. The test starting point was the starting point to the cable: the magnitude was about -80Db, and about 43ns was starting point of cable.

3.3 Scanning free space measurement (SFSM)

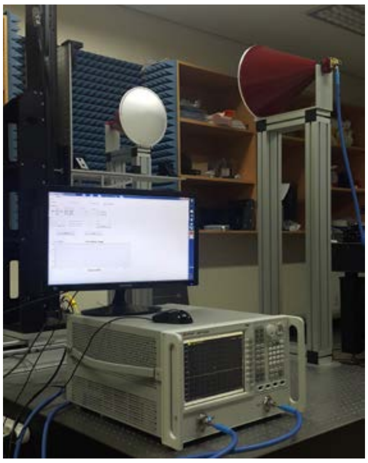

Figure 4: SFSM set up

Figure 4 is developed SFSM set up. After calibration, we only use one antenna to investigate the reflection loss. The cable only connect port 1, port 2 disconnect the cable. The SFSM is using x-y linear stage. The interface measures electromagnetic characteristics automatically. The interface is Qt program, which is open source program based on C language. The interface connects PNA and N1500A software to measure the s-parameters, calculate the electromagnetic properties, and conduct the GRL calibration.

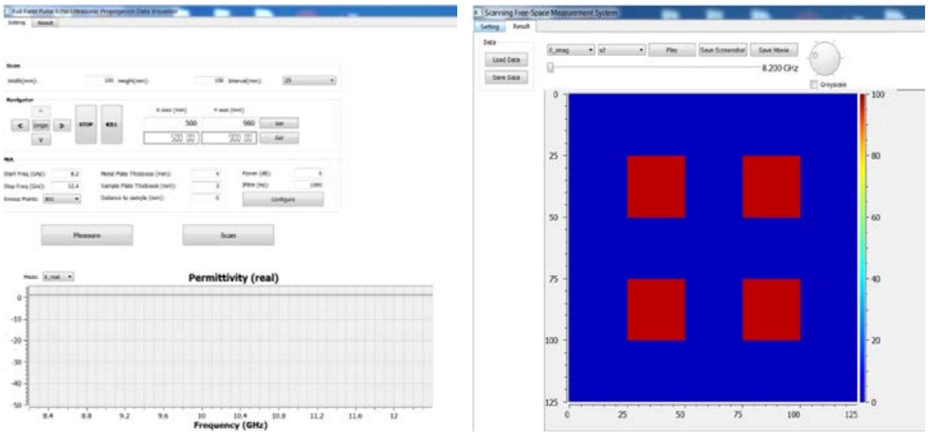

Figure 5: SFSM software

Figure 5 is the interface of SFSM. This interface conduct from one point to scan area. Before measure, we define the measurement condition such as frequency range, sweep point, IFBW, power, sample and metal plate thickness. The measurement result is displayed in the interface directly. If the interface is conducted the scanning at the scan area, the scanning results are visualized in real time. After finishing the scanning, all data can save in binary format and the visualization results can save the movie at the frequency. Anechoic chamber is back the sample to remove the propagated electromagnetic waves.

4 RESULTS

Using the SFSM set up, we measured the reflection loss at the curved structures.

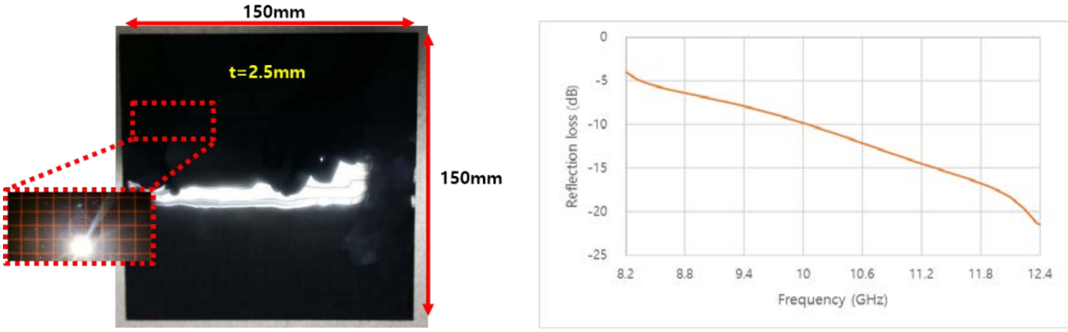

Figure 6: Radar absorbing structure (RAS) specimen and reflection loss at X-band

Figure 6 is the radar absorbing structure (RAS) specimen provided by the Agency of Defense Development (ADD). Copper is attached the specimen to avoid the transmission of electromagnetic waves. The specimen attached curved bracket is shown in figure 7 and scan area is shown in table 1.

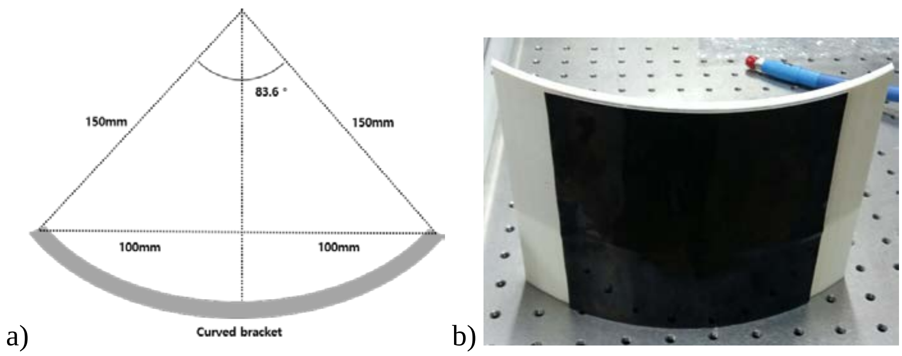

Figure 7: a) The Schematic of the curved bracket and b) the curved specimen

Specimen (Size : W x H x T)	Scan area (mm) (W x H x Interval)	Measurement
Curved RAS specimen (150 x 150 x 2.5mm)	125 x 125 x 25	Frequency : 8.2 ~ 12.4 GHz Sweep point : 401 Spot diameter : 50mm Focal length : 430mm

Table 1: Scan information of the curved specimen

Figure 8: Set up the curved specimen

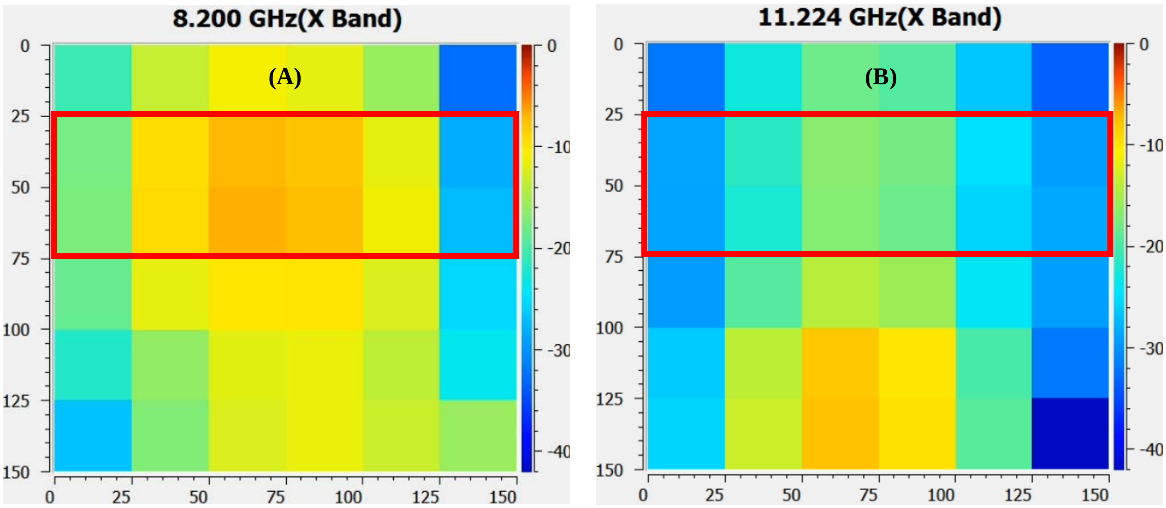

Figure 9: Scan visualization at 8.2 & 11.224 GHz

Figure 8 is the setup of the curved specimen and measure the reflection loss at the curved specimen at the scan area. In ADD, the specimen resonance frequency is about 15GHz at the planar specimen. In figure 6, the reflection loss is lower and decreases at the high frequency. In figure 9, the scan results are visualized at the scan area. At the curved specimen, the reflection loss is different in (A) & (B). In (A), reflection loss from 50 to 100mm area is similar to planar specimen, but reflection loss of other area is much lower. The incident angle at the curved surface has a reflection angle, so electromagnetic waves do not almost return at the single port. If the incident angle is much larger; the reflection loss is much lower. In (B), at the symmetric shape, the reflection loss result is symmetric at the scan area. Thus, the scan visualization of curved structure is clear in the scan area.

5 CONCLUSIONS

A technique for single port SFSM was presented. Before SFSM, many researchers have used the waveguide and FSM. However, these methods have some problems to measure curved structure of the whole specimen. At the GRL calibration, the gating area is selected using time domain. Reflection loss at the time domain checks the position of sample holder. Using x-y linear stage, FSM and stage are connected and set the software to conduct SFSM

The curved specimen has much lower reflection loss at the large curvature. The curved shape has the incident angle at the plane wave. Almost electromagnetic waves are reflected at the reflection angle, so the reflection loss of curved specimen is much lower at the single port SFSM. If the shape is arbitrary, the reflection loss is much lower and asymmetric at the scan area.

This is the first study to investigate the reflection loss at the whole specimen. Our results provide the electromagnetic characteristics at each point. This is an initial set up, so we have to revise and improve to increase the accuracy of the calibration and measurement results.

In the future, we will conduct two port SFSM at the planar and curved structures. In two port, we will conduct to measure the electromagnetic characteristics such as permittivity, permeability, and loss tangent. All electromagnetic characteristics will be visualized using SFSM.

ACKNOWLEDGEMENTS

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