Reduction of Edge Diffraction Effects of MUT Holder Using EM Absorber in W-band Free-space Material Measurements

Jin-Seob Kang*, Jeong-Hwan Kim and Jeong-Il Park
Center for Electromagnetic Wave
Korea Research Institute of Standards and Science (KRISS)
267 Gajeong-ro, Yuseong-gu, Daejeon 34113, Republic of Korea

***Abstract* - In free-space material measurements, it is known that the minimum size of a planar MUT (Material Under Test) should be larger than three times the beam waist of the antenna to neglect diffraction effects at the edges of the MUT. To hold the MUT, its holder has the aperture size larger than the minimum MUT size. In the case of metal MUT holders, even though their aperture size is larger than three times the beam waist, their edge diffraction effects are not small and need to minimize. In this paper, EM absorbers with a circular hole on each side of the metal MUT holder are used to reduce edge diffraction effects of the MUT holder in W-band (75-110 GHz) free-space material measurement system.**

***Index Terms* — Free-space measurements, material parameters, material measurements, corrugated horn antennas.**

1. Introduction

For planar material characterization at millimeter waves, the quasi-optic based free-space material measurement system measures the free-space S-parameters of MUT located at the intermediate position between two Gaussian-forming corrugated horn antennas [1], [2], [3]. The measured S-parameters provide material parameters of MUT by means of material parameter extraction algorithm [4].

In general, the minimum size of a planar MUT should be larger than three times the beam waist of the antenna to neglect diffraction effects at the edges of the MUT. To hold the MUT, its holder has the aperture size larger than the minimum MUT size. In the case of metal MUT holders, even though their aperture size is larger than three times the beam waist, their edge diffraction effects are not small and need to minimize. In this paper, EM absorbers with a circular hole on each side of the metal MUT holder are used to reduce the edge diffraction effects of the metal MUT holder in W-band free-space material measurement system.

2. W-band Free-space Material Measurement System at KRISS

W-band free-space material measurement system consists of an mm-wave S-parameter measurement system and a quasi-optic based free-space measurement system, as shown in Fig. 1. The mm-wave measurement system for measuring S-parameters of MUT consists of a 67 GHz vector network analyzer used as a main frame and a frequency extender which is operating from 67 GHz to 110 GHz.

The quasi-optic based free-space measurement system, as shown in Fig. 1 and Table I, consists of two Gaussian-forming corrugated horn antennas (Antenna #1 and #2) of 26 dB gain, two ellipsoidal refocusing mirrors, a MUT holder with 110 mm aperture diameter, and a splitted-form bench for supporting TRL calibration, where all apparatus except the antennas are made of Aluminum.

In the free-space measurement system, the metal MUT holder has the aperture diameter (in this case 110 mm) larger than four times the beam waist (25 mm) of the antenna at the MUT holder. The two antennas of 26 dB gain compensate for the large insertion loss along the long signal path (in this case 1750 mm) between the feeding ports of the two antennas, where the measured insertion loss is smaller than 2 dB in W-band.

The W-band free-space material measurement system is calibrated by TRL method and S-parameters measured by the calibrated system provide material parameters of MUT by means of material parameter extraction algorithm such as NIST method [4].

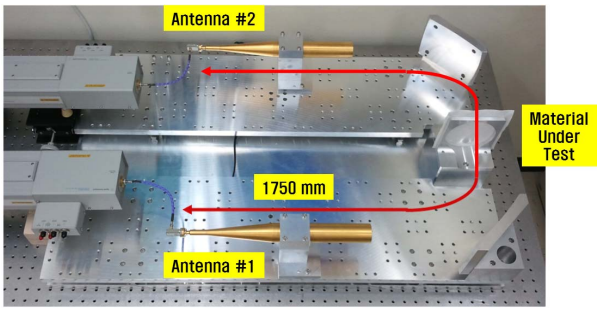

Fig. 1. W-band free-space material measurement system at KRISS.

3. Reduction of Edge Diffraction Effects of MUT Holder Using EM Absorber

To reduce edge diffraction effects of the metal MUT holder, one uses two EM absorbers with a circular hole of 75 mm diameter on each side of the MUT holder, as shown in

Fig. 2, whose diameter is equal to three times the beam waist of the antenna at the MUT holder.

Relative permittivity of an arystal plate of 1.1 mm thickness is obtained in the cases without and with the EM absorbers with a circular hole in W-band, as shown in Fig. 3. Fig. 3 shows that results in the case using the EM absorbers with the circular hole equal to three times the beam waist are superior to ones in the case using the MUT holder with the aperture diameter larger than four times the beam waist. It means that, even though a metal MUT holder has the aperture diameter larger than four times the beam waist, their edge diffraction effects are not small and need to minimize. Fig. 3 also shows that using the EM absorbers with a circular hole gives reduced ripples on material parameter results.

TABLE I Specifications of a quasi-optic based free-space measurement system at KRISS

Base plate	Operating frequency range	75 – 1100 GHz
	Size	1000 mm × 625 mm
MUT holder	Beam waist size (S) in W-band	25 mm (–8.6 dB@94 GHz)
	Aperture diameter	110 mm (> 4S)
Mirror	Type	Ellipsoidal refocusing
Antenna	Type	Gaussian-forming corrugated horn
	Features	Axially symmetrical beams with low side lobes
	Operating frequency range	75 - 110 GHz
	Aperture diameter	40 mm
	Gain	26 dB
Splitted -form bench	Type	Splitted-form with motor-driven rail on both sides of the MUT
	Size	1350 mm × 625 mm
	Maximum path length	1750 mm (= 2×625 mm + 500 mm)
	Supporting calibration method	TRL
	Maximum moving distance	25 mm on each side of the MUT
	Resolution	< 0.001 mm

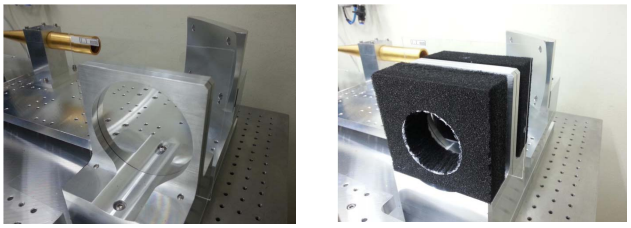

Fig. 2. MUT holder (Left) without and (Right) with two EM absorbers with a circular hole of 75 mm diameter on each side of the holder.

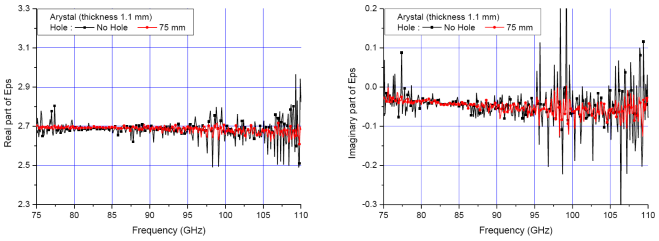

Fig. 3. (Left) Real and (Right) imaginary parts of W-band relative permittivity of an arystal plate of 1.1 mm thickness. These results are obtained with and without two EM absorbers with a circular hole of 75 mm diameter on each side of the holder.

4. Conclusion

In free-space material measurements, it is known that the minimum size of a planar MUT in free-space material measurements should be larger than three times the beam waist of the antenna to neglect diffraction effects at the edges of the MUT. To hold the MUT, its holder has the aperture size larger than the minimum MUT size.

This paper shows in W-band that even though metal MUT holders have the aperture diameters larger than four times the beam waist, their edge diffraction effects are not small and need to minimize. It is also shown that using the EM absorber with a circular hole on each side of the MUT holder reduces the edge diffraction effects and gives reduced ripples on material parameter results.

References

[1] D. K. Ghodgaonkar, V. V. Varadan, and V. K. Varadan, "A free-space method for measurement of dielectric constants and loss tangents at microwave frequencies," *IEEE Trans. Instrum. Meas.*, vol. 37, no. 3, pp. 789–793, Jun. 1989.

[2] N. Gagnon, J. Shaker, P. Berini, L. Roy, and, A. Petosa, "Material characterization using a quasi-optical measurement system," *IEEE Trans. Instrum. Meas.*, vol. 52, no. 2, pp. 333–336, Apr. 2003.

[3] D. Bourreau, A. Péden, and S. L. Maguer, "A Quasi-Optical Free-Space Measurement Setup Without Time-Domain Gating for Material Characterization in the W-Band," *IEEE Trans. Instrum. Meas.*, vol. 55, no. 6, pp. 2022–2028, Dec. 2006.

[4] NIST Technical Note 1355-R, 1993.