# Measurement of Complex Permittivity Printed Circuit Boards Using BCDR and Free-Space Method Up to 90GHz

M.Tomioka[1], S. Naito[1], Y. Akatsuka[1], K. Obinata[1], T. Kitazawa[2], D. Fujimoto[2], J. Chakarothai[3], Y. Hayashi[2], and T. Kasuga[2]

[1] National Institute of Technology, Nagano College, 716 Tokuma Nagano, Nagano 381-0041, Japan, emails: m_tomioka@nagano-nct.ac.jp, kasuga@nagano-nct.ac.jp

[2] Nara Institute of Science and Technology, 8916-5 Takayama Ikoma, Nara 630-0192, Japan, email: kitazawa.taiki.kq8@is.naist.jp, fujimoto@is.naist.jp, yu-ichi@is.naist.jp

[3] National Institute of Information and Communications Technology, 4-2-1 Nukui-Kitamachi Koganei, Tokyo 184-8795, Japan, email : jerd@nict.go.jp

***Abstract*—In this study, the complex permittivity of dielectric substrates up to 90GHz is measured using a balanced type circular disk resonator (BCDR) and the free-space method. The dielectric constants of FR-4 substrates, which are commonly used as base materials, and evaluation substrates of MEGTRON, a multilayer substrate material for high-speed transmission, were measured. The BCDR measurement results showed a difference in measurement accuracy between FR-4 and MEGTRON, with MEGTRON, which supports high-speed transmission, maintaining measurement accuracy up to around 90GHz. The free-space method showed measurement accuracy in the high-frequency band, where losses are higher, indicating that the combination of the two measurement methods enables measurement over a wide bandwidth.**

## I. INTRODUCTION

In recent years, the amount of data handled by AI, cloud services, and other applications has been dramatically increasing. Since data is processed as electrical signals through E/O conversion in routers, it is necessary to take measures to increase the speed of the printed circuit boards through which the electrical signals flow. FR-4 substrates are still used as substrates for many electronic devices, but they are inferior in high-frequency characteristics. Although MEGTRON (Panasonic) is available as a substrate material for high-speed transmission, its characteristics have not been sufficiently evaluated. In this study, the complex permittivity of dielectric substrates was measured by the balanced type circular disk resonator (BCDR)[1] and the free-space method in order to evaluate the complex permittivity of dielectric substrates at frequencies up to 90 GHz.

## II. METHODOLOGY

In the BCDR, electromagnetic waves are injected from a vector network analyzer (VNA:Keysight N5222B+N5292A) into a resonator through excitation lines to excite specific electromagnetic field modes in the resonator. When the center of the disk resonator is excited by the coaxial excitation line, only the $TM_{0m0}$ mode, whose order m (=1,2,3,...) varies in the radial direction, is excited. Since the electric field has modes in the vertical direction, the frequency dependence of the complex permittivity in the vertical direction is measured. In the free-space method(EM Lab:FS-330), a signal is applied from the VNA to the Port1 antenna with dielectric lens, and the S-parameter is measured from the reflected or transmitted wave from the sample. Since the radio wave is emitted perpendicular to the sample surface, the direction of the electric field is horizontal to the sample surface, so the free-space method measures the horizontal dielectric permittivity.

## III. RESULTS AND CONCLUSIONS

Figure 1 shows the measurement results of the complex permittivity. Figure 1(a) shows the relative permittivity, and Fig. 1(b) shows the dielectric loss. The BCDR measurement results showed high measurement accuracy for the complex permittivity up to 60 GHz for FR-4 and up to around 90 GHz for MEGTRON. The free-space method results indicated high measurement accuracy in the frequency range above 40 GHz for both FR-4 and MEGTRON. It is considered that combining these two measurement methods would enable measurements over a wider bandwidth.

The dielectric constant measurement results showed a difference between the BCDR and the free-space method. This was considered to be due to anisotropy.

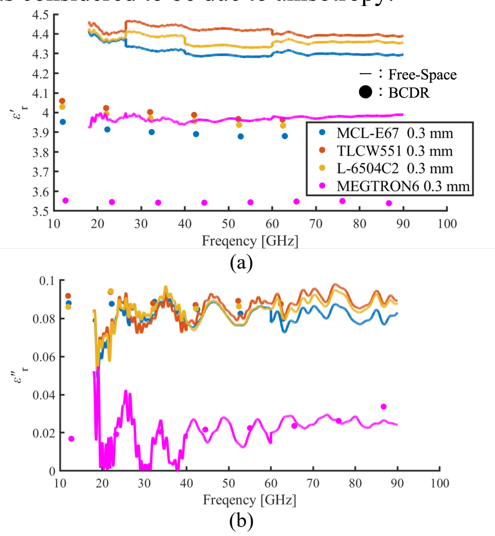


Fig. 1. Measurements of complex dielectric constant: (a) Relative permittivity; (b) Dielectric loss.

## ACKNOWLEDGMENT

This study was supported by a Grant-in-Aid for Scientific Research (24K07498). MEGTRON was provided by Panasoinic Industry.

## REFERENCES

[1] H. Kawabata, et al, European Microwave Conference, Manchester, pp. 388-391, Sep. 2006