The Study of Measurement and Analysis in Dielectric Materials of Microwave and The Application to Antenna Design

李政達、林明星，許崇宜

E-mail: 9510785@mail.dyu.edu.tw

ABSTRACT

Since microwave dielectric materials may greatly influence the performance of high-frequency devices, accurate characterization of microwave dielectric materials becomes very important in high-frequency circuit design. Although many methods have been proposed for measuring the constitutive parameters of a dielectric in the literature, they usually have some limitations. Among those methods, the procedure that employs an open-ended coaxial probe (referred to as the OECP method) is usually favorable, for it is relatively easy to use, simple, nondestructive, and of broad band in nature. In this study, the author will use an HP coaxial probe to measure the reflection coefficients of a material under test (MUT). From these coefficients, the frequency-dependent dielectric constants of a MUT can be computed using the formulas derived in this thesis. The computed dielectric constants are compared with those using the HP 85070D dielectric measurement system to validate the derived formulas. Moreover, with the help of these formulas, measured dielectric constants using a standard HP coaxial probe and those using a simplified laboratory-made open-ended coaxial probe are compared and studied. It is found that the low-cost dielectric measurement system established here can replace the expensive HP 85050D system. Finally, a microwave substrate with its high dielectric constant measured using this low-cost system is applied to design a chip antenna.

Keywords : microwave base plate, dielectric parameters measurement, open-ended coaxial probe, chip antenna

Table of Contents

REFERENCES

[1] W. E. Courtney,“ Analysis and evaluation of a method of measuring the complex permittivity and permeability of microwave insulators, ” IEEE Trans. Microwave Theory and Tech., Vol. MTT-48, pp. 476-485, Feb. 1970.

[2] S.B. Cohn and K.C. Kelly,“ Microwave measurement of high-dielectric constant materials, ” IEEE Trans. Microwave Theory Tech., Vol. MTT-14, pp. 476-485, Jun. 1966.

[3] G. Kent,“ Dielectric resonances for measuring dielectric properties, ” Horizon House Publications, Inc. Microwave Journal. Vol. 31, pp. 94-114, Oct. 1988.

[4] W.R. Humbert and Jr. W. R. Scott,“ A new technique for measuring the permittivity and loss tangent of cylindrical dielectric rods, ” IEEE Trans. Microwave and Guide Wave Letters. Vol. 6, pp.262-264. Oct. 1998 [5] D.K. Ghodgaonkar, V.V. Varadan and V.K. Varadan, “ Free-space measurement of complex permittivity and complex permeability of magnetic materials at microwave frequencies, ” IEEE Trans. Instrumentation and Measurement, Vol. 39, pp. 387-394, Jun. 1990.

[6] V.V. Varadan, R.D. Hollinger, D.K. Ghodgaonkar and V.K. Varadan,“ Free-space, broadband measurements of high- temperature, complex dielectric properties at microwave frequencies, ” IEEE Trans. Instrumentation and Measurement. Vol. 40, pp. 842-846, Dec. 1991.

[7] Chun-Chieh Hung, Cheng-Ta Lee and Ming-Shing Lin,“ Measurement Techniques for Dielectric Properties of Antenna Substrates, ”

ICEMAC04, Measurement of Dielectric Properties., Vol. pp. Aug. 2004.
[8] B. Jokanovic and M. Rakic. " Broadband electrical characterization of microwave substrates using T-resonator technique ", Telecommunications in Modern Satellite, Cable and Broadcasting Service 2003. TELSIKS 2003. 6th International Conference on, Vol. 1, pp.348-351, Oct. 2003.
[9] R.L. Peterson and R.F. Drayto, " A CPW T-resonator technique for electrical characterization of microwave substrates, " IEEE trans. Microwave and Guided Wave Letters, Vol. 12, pp. 90-92, Mar. 2002.
[10] J.R. Aguilar, M. Beadle, P.T. Thompson, M.W. Shelley, " The microwave and RF characteristics of FR4 substrates, " IEE Colloquium, vol. 2, pp. 1-6, Feb. 1998.
[11] P. Kabacik, M.E. Bialkowski, " The temperture dependence of substrate parameters and their effect on microstrip antenna performance, " IEEE Trans. Antennas and Propagation, Vol. 47, Issue: 6, pp. 1042-1049, Jun. 1999.
[12] C. Deffendol, C. Furse, " Microstrip antennas for dielectric property measurement, " IEEE Trans. Antennas and Propagation Society International Symposium, Vol. 3, pp. 1954-1956, Jul. 1999.
[13] M. Bogosanovich, " Microstrip patch sensor for measurement of the permittivity of homogeneous dielectric materials, " IEEE Trans. Instrumentation and Measurement, Vol. 49, Issue: 5, pp.1144-1148, Oct. 2000.
[14] M.A. El Sabbagh, O.M. Ramahi, S. Trabelsi, S.O. Nelson, L. Khan, " Use of microstrip patch antennas in grain and pulverized materials permittivity measurement, " IEEE Trans. Antennas and Propagation Society International Symposi., Vol. 4, pp. 42-45, Jun. 2003.
[15] J. Baker-Jarvis, M. D. Janezic, Jr. J. H. Grosvenor and R. G. Geyer, " Transmission/Reflection and Short-circuit Line Methods for Measuring Permittivity and Permeability, " NIST Technical Note 1355 (revised), National Institute of Standard and Technology, Boulder, CO. 1993.
[16] Yansheng Xu and P. G. Bosisio, " Nondestructive measurements of the resistivity of thin conductive films and the dielectric constant of thin substrates using an open-ended coaxial line, " IEE Proceedings-H, Vol. 139, No.6, Dec. 1992.
[17] I. Ganchev, Nasser Qaddoumi, Sasan Bakhtiari, and Reza Zoughi, " Calibration and measurement of dielectric properties of finite thickness composite sheets with open-ended coaxial sensors, " IEEE Trans. Instrumentation and Measurement, Vol. 44, No. 6. Dec. 1995.
[18] S. Bakhtiari, S.I. Ganchev and R. Zoughi, " Analysis of radiation from an open-ended coaxial line into stratified dielectrics, " IEEE Trans. Microwave Theory and Tech., Vol. MTT-42, Issue 7, pp. 1261-1267, Jul. 1994.
[19] W. Wu, and C.E. Smith, " Dielectric measurements using the HP 85070A probe, " IEEE Southeastcon '92, Proceedings., 12-15, Vol. 1, pp.83-86, Apr. 1992.
[20] D. Berube, F.M.Ghannouchi, P. Savard, " A comparative study of four open-ended coaxial probe models for permittivity measurements of lossy dielectric/biological materials at microwave frequencies, " IEEE Trans. Microwave Theory and Tech., Vol. MTT-44, Issue 10, pp. 1928-1934, Oct. 1996.
[21] G. Chen, Li Kang and Ji Zhong, " Bilayered dielectric measurement with an open-ended coaxial probe ", IEEE Trans. Microwave Theory and Tech., Vol. MTT-42, Issue 6, pp. 966-971, Jun. 1994.
[22] Y.Y. Lim, M.D. Rotaru, A. Alphones and A.P. Popov, " Simple and improved dielectric parameter extraction of thin organic packaging materials using open-ended coaxial line technique ", IEE Proceedings - Microwaves, Antennas and Propagation, Vol. 152, Issue 4, pp. 214-220, Aug. 2005.
[23] A. Nyshadham, C.L. Sibbald and S.S. Stuchly, " Permittivity measurements using open-ended sensors and reference liquid calibration-an uncertainty analysis, " IEEE Trans. Microwave Theory and Tech., Vol. MTT-40, Issue 2, pp. 305-314, Feb. 1992.
[24] D.V. Blackham and R.D. Pollard, " An improved technique for permittivity measurements using a coaxial probe ", IEEE Trans. Instrumentation and Measurement, Vol. 46, Issue 5, pp.1093-1099, Oct. 1997.
[25] G.P. Otto and W.C. Chew, " Improved calibration of a large open-ended coaxial probe for dielectric measurements, " IEEE Trans. Instrumentation and Measurement, Vol. 40, Issue 4, pp. 742-746, Aug. 1991.
[26] S. Van Damme, A. Franchois, D.De Zutter and L. Taerwe, " Nondestructive determination of the steel fiber content in concrete slabs with an open-ended coaxial probe, " IEEE Trans. Geoscience and Remote Sensing, Vol. 42, Issue 11, pp.2511-2521, Nov. 2004.
[27] H. Zheng and C.E. Smith, " Permittivity measurements using a short open-ended coaxial line probe, " IEEE [see also IEEE Microwave and Wireless Components Letters] Microwave and Guided Wave Letters, Vol. 1, Issue 11, pp.337-339 Nov. 1991.
[28] Ta-Chih Huang, " Study and fabrication of ceramic helical antennas, " Master's thesis, Department of electrical engineering National Sun Yat-Sen university, Jun. 2001.
[29] " Agilent Basics of Measuring the Dielectric Properties of Materials ", Agilent Technologies, Inc. 2005 Printed in USA, Apr. 28, 2005.
[30] Yun-Zhong Lee, " Coaxial line reflection method for measuring dielectric properties of agricultural products, " Master's thesis, Department of electrical engineering national Taiwan university, Jun. 1992.
[31] Chin-Ming Wu, " The study of multi-band meander line antenna " Master's thesis, Department of communication engineering Da-Yeh university, Jun. 2006.