

The Analysis and Design of Open-Ended Coaxial Probe for Measurement of Dielectric Parameters of Liquids

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ABSTRACT

Open-ended coaxial line has been designed for the measurement of dielectric properties of liquids. These applications are based on the principle that characteristics of the reflection signals produced by the coaxial opening depend upon the sample material terminating the probe. Then the dielectric parameters of the material sample can be found by using the specific formulation for aperture admittance of coaxial probe and dielectric constant of material. This thesis used common 3.6 mm OD semirigid coaxial line and measured different materials with a vector network analyzer (VNA). Finally, a quasi-static approximation analysis of open-ended coaxial line has been formulated to determine the dielectric parameters of liquids under test.

Keywords : dielectric properties ; coaxial probe ; aperture admittance ; quasi-static approximation analysis

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REFERENCES

[1] S. Jenkins, " Dielectric measurements on reference liquids using automatic network analysers and calculable geometries ", Meas. Sci. Technol. 1(1990) 691-702.

[2] Annex J(informative), " Measurement of the dielectric properties of liquids and uncertainty estimation " , IEC62209/CD.

[3] D. K. Mirsa, " Noninvasive Electrical Characterization of Materials at Microwave Frequencies Using an Open-Ended Coaxial Line: Test of an Improved Calibration Technique " , IEEE Trans. Trans . vol. MTT-38, no. 1, January. 1990.

[4] Y. Z. Wei, " Radiation-corrected open-ended coax line technique for dielectric measurements of liquids up to 20 GHz " , IEEE Trans . vol. MTT-39, no. 3, March. 1991.

[5] A. Nyshadham, " Permittivity measurements using open-ended sensor and reference liquid calibration-an uncertainty analysis " , IEEE Trans. Microwave Theory Tech. Vol MTT-40, no.2, February 1992 [6] D. K. Mirsa, " Measurement of the Complex Permittivity of Materials by an Open-Ended Coaxial Probe " , IEEE Microwave and Guided wave letters, vol. 5, no. 5, May 1995.

[7] H. Zheng, " Permittivity Measurements Using a Short Open-Ended Coaxial Line Probe " , IEEE Microwave and Guided wave letters, vol. 1, no. 11, November 1991.

[8] R. D. Nevels, " The annular slot antenna in a lossy biological medium " , IEEE Trans . vol. MTT-33, no. 4, April. 1985.

[9] A. Boughriet, " The Measurement of Dielectric Properties of liquids at Microwave Frequencies Using Open-Ended Coaxial Probe " ,1st World Congress on Industrial Process Tomography, Buxton, Greater Manchester, April14-17, 1999.

[10] IEEE Std 1528-200X: DRAFT Recommended Practice for Determining the Spatial-Peak Specific Absorption Rate (SAR) in Human Body Due to Wireless Communication Devices: Experimental Techniques.

[11] FCC OET Bulletin 65, Version 97-01: Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields.

[12] Agilent Technologies: 85070C Dielectric Probe Kit.

[13] U. S. Inan, Engineering Electromagnetics, Addison-Wesley, 1999.

[14] 郭仁財, 微波工程. 高立出版社, 2001.

[15] D. K. Mirsa, " A quasi-static analysis of open-ended coaxial lines " , IEEE Trans. Trans . vol. MTT-35, no. 10, October. 1987.

[16] R. F. Harrington, Time Harmonic Electromagnetic Field. New York: McGraw-Hill, 1961, pp.93, 110-113.

[17] L. L. Tasi, " A numerical solution for the near and far fields of an annular ring of magnetic current " , IEEE Trans. Antennas Propagat., vol. AP-20, no. 5, pp. 569-576, Sept 1972.

[18] C. L. Pournaropoulos, " The co-axial aperture electromagnetic sensor and its application in material characterization " , Meas. Sci. Technol. 8 (1997) 1191-1202. Printed in the UK.

[19] M. Abramowitz and I. T. Stegun, Eds, Handbook of Mathematical Functions. New York. Dover, 1965. p 591.

[20] D. V. Blackham, " An improved technique for permittivity measurements using a coaxial probe " , IEEE Trans. Instrum. Meas, vol.46, no.5 ,October 1997 [21] Dr Nguyen Tran, <http://microwaveprocessing.com/> [22] IEEE Std 1528-200X: Annex B (Dielectric Property Measurements), Annex C (Recommended Recipes for Phantom Head-Tissue Simulant).

[23] J. M. Anderson, " Dielectric measurements using a rational function model " , IEEE Trans . vol. MTT-42, no. 2, February. 1994.