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Simple Technique for Biconical Cavity Eigenfrequency Determination

M. V. Andreev[1*], O. O. Drobakhin[1], D. Yu. Saltykov[1***], N. B. Gorev[2], and I. F. Kodzhespirova[2]**

[1]*Oles Honchar Dnipro National University, Dnipro, Ukraine*
[2]*Institute of Technical Mechanics, NASU & NSAU, Dnipro, Ukraine*
**ORCID: 0000-0001-7360-8058, e-mail: mik.v.andreev@gmail.com*
***ORCID: 0000-0003-2624-9122, e-mail: drobakhino@gmail.com*
****ORCID: 0000-0001-5403-4773, e-mail: d.yu.saltykov@gmail.com*

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Abstract—A number of features of biconical cavities make them attractive for various applications. Expressions for the calculation of the eigenfrequencies of a biconical cavity with large cone angles can be derived using the overlapping domain decomposition method in combination with the collocation method; however, the expressions reported in the literature involve only a single pair of collocation points, thus giving no way to estimate the eigenfrequency determination accuracy. The aim of this paper is to calculate the biconical cavity eigenfrequencies for an arbitrary number of collocation point pairs. An equation in the biconical cavity eigenfrequencies for an azimuthally symmetric transverse electric field at an arbitrary number of collocation point pairs is derived. The equation reduces to two equations, whose solution requires far less computational effort in comparison with the original equation. The solution of one of the two equations are based on modes symmetric about the cavity symmetry plane, and the solutions of the other are based on antisymmetric modes. The calculated eigenfrequencies converge rapidly with increasing number of collocation point pairs, while the use of only one collocation point pair may introduce noticeable error. The proposed technique may be used in the development of components and units on the basis of biconical cavities.

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1. INTRODUCTION

Cavity-based measurement methods are traditionally used in the extraction of the electrophysical parameters of various materials [1, 2]. Cylindrical cavities operating on azimuthal symmetric modes have found the most use as sensing devices [3–6]. However, they suffer from a number of drawbacks: resonance frequency shift and Q-factor reduction caused by specimen insertion holes in the end walls, the need for a high degree of orthogonality of the end walls with respect to the longitudinal axis, and the possibility of transformation of the operating mode into another mode with the insertion of a test specimen.

Biconical cavities are mainly free from the above drawbacks. Due to the presence of evanescent zones near the cone vertices, holes can be made there without significantly affecting the field structure or the resonance frequencies [7]. This feature allows one to use biconical cavities in various engineering problems, for example, in displacement measurement, in the in-stream characterization of liquid, gaseous, and bulk materials, [8, 9] etc. Another useful feature of biconical cavities is the splitting of the high-Q H_{01p} modes and the low-Q E_{11p} modes, which in cylindrical cavities are mutually degenerate in terms of frequency, the splitting degree increasing with the cone angle.

The use of a differential measurement scheme in a system of two coupled biconical cavities makes it possible to improve the accuracy and reliability of measurements by reducing the negative effect of external factors (temperature, humidity, instrument instability, etc.) [9] at the expense of using one of the cavities as a reference cavity.

Biconical cavities are systems with noncoordinate boundary conditions. A rigorous analysis of such systems is hardly possible, if at all [10]. Because of this, the key point in the use of biconical cavities is the possibility of determining their eigenfrequencies, preferably by a relatively simple yet sufficiently accurate algorithm [11–14]. Such an algorithm may be developed on the basis of the overlapping domain

REFERENCES

1. V. N. Egorov, "Resonance methods for microwave studies of dielectrics (Review)," *Instrum. Exp. Tech*. **50**, No. 2, 143 (2007). DOI: 10.1134/S0020441207020017.
2. M. N. Afsar, J. R. Birch, R. N. Clarke, G. W. Chantry, "The measurement of the properties of materials," *Proc. IEEE* **74**, No. 1, 183 (1986). DOI: 10.1109/PROC.1986.13432.
3. H. E. Bussey, D. Morris, E. B. Zal'tsman, "International comparison of complex permittivity measurement at 9 GHz," *IEEE Trans. Instrum. Meas.* **23**, No. 3, 235 (1974). DOI: 10.1109/TIM.1974.4314270.
4. E. Ni, U. Stumper, "Permittivity measurements using a frequency-tuned microwave TE01 cavity resonator," *IEE Proc. H - Microwaves*, *Antennas and Propagation* **132**, No. 1, 27 (1985). DOI: 10.1049/ip-h-2:19850005.
5. C. K. Kling, K. W. Whites, L. J. Groven, "Accurate specimen placement for dielectric measurements in TM0n0 cylindrical cavity," *Proc. of IEEE Int. Symp. on Antennas and Propagation*, APSURSI, 26 June-1 July 2016, Fajardo, Puerto Rico (IEEE, 2016), pp. 1995-1996. DOI: 10.1109/APS.2016.7696704.
6. V. A. Sydoruk, F. Fiorani, S. Jahnke, H.-J. Krause, "Design and characterization of microwave cavity resonators for noninvasive monitoring of plant water distribution," *IEEE Trans. Microwave Theory Tech.* **64**, No. 9, 2894 (2016). DOI: 10.1109/TMTT.2016.2594218.
7. O. O. Drobakhin, P. I. Zabolotnyy, Ye. N. Privalov, "Taking into account the impact of coupling elements on the resonance phenomena in biconical resonators," *Radioelectron. Commun. Syst.* **53**, No. 7, 389 (2010). DOI: 10.3103/S0735272710070071.
8. O. O. Drobakhin, Ye. N. Privalov, D. Yu. Saltykov, "Open-ended waveguide cutoff resonators for monitoring dielectrics parameters of gases," *Telecommun. Radio Eng.* **72**, No. 7, 627 (2013). DOI: 10.1615/TelecomRadEng.v72.i7.60.
9. M. V. Andreev, O. O. Drobakhin, Ye. N. Privalov, D. Yu. Saltykov, "Measurement of dielectric material properties using coupled biconical resonators," *Telecommun. Radio Eng.* **73**, No. 11, 1017 (2014). DOI: 10.1615/TelecomRadEng.v73.i11.70.
10. A. A. Alimov, A. A. Radionov, "The open limit biconical resonator calculation," *Antennas*, No. 4, 40 (2015). URI: https://elibrary.ru/item.asp?id=23366163.
11. J. P. Van't Hof, D. D. Stancil, "Eigenfrequencies of a truncated conical resonator via the classical and Wentzel–Kramers–Brillouin methods," *IEEE Trans. Microwave Theory Tech.* **56**, No. 8, 1909 (2008). DOI: 10.1109/TMTT.2008.927408.
12. D. B. Kuryliak, Z. T. Nazarchuk, O. B. Trishchuk, "Axially-symmetric TM-waves diffraction by sphere-conical cavity," *PIER B* **73**, 1 (2017). DOI: 10.2528/PIERB16120904.
13. R. H. W. Hoppe, Yu. A. Kuznetsov, "Overlapping domain decomposition methods with distributed Lagrange multipliers," *J. Numerical Math.* **9**, No. 1, 285 (2001).
14. O. O. Drobakhin, P. I. Zabolotnyy, Ye. N. Privalov, "Approximate calculation of eigenfrequencies of biconical microwave cavities," *Radioelectron. Commun. Syst.* **56**, No. 3, 127 (2013). DOI: 10.3103/S0735272713030035.