SENSITIVITY OF STRESS AND BOUNDARY IMPERFECTION OF DIELECTRIC RESONATOR DISKS

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13. ABSTRACT *(Maximum 200 words)*

The objective of the research is to investigate (a) the sensitivity of the resonant frequencies of the dielectric disks under various applied forces and accelerations, and (b) the effect of the boundary imperfections of the dielectric disks on the resonances.

The present research is a continuation of an ARO-supported project (DAAL 03-90-G-0079, 26909 MA). The research is conducted in two aspects: (1) for isotropic dielectrics and (2) for anisotropic dielectrics. The results for the present period are listed below.

(i) The stress effect on the resonant frequencies of TE modes in isotropic circular disks were obtained by a perturbation method for three cases of loading conditions: (1) a pair of diametral forces, (2) steady vertical acceleration, and (3) steady horizontal acceleration.

(ii) The above study has been extended to include both the TE and TM modes in circular disks.

For anisotropic dielectrics:

(iii) A system of 2-D governing equations for guided waves in anisotropic dielectric plates has been derived and dispersion relations computed from these 2-D equations are compared with those obtained from the 3-D Maxwell's equations.

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SENSITIVITY OF STRESS AND BOUNDARY
IMPERFECTION OF DIELECTRIC RESONATOR DISKS

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I. STATEMENT OF THE PROBLEM STUDIED

The purpose of the proposed research is to investigate the changes in the resonance frequencies of circular dielectric resonators (1) when the disks are subjected to applied forces or accelerations, and (2) when the disk boundary contains imperfections.

In dielectric resonators, the applied forces produce stress distributions which, in turn, influence the change in the dielectric impermeability tensor by the piezooptic effect, and hence, cause the changes in wave speed and shifts in resonances.

The imperfections of the disk boundary alter the directions of the boundary normals from being in the radial direction, and, hence, cause the changes in the directions and magnitudes of the reflected and refracted EM waves at the interface. Consequently these imperfections result in the changes of mode shapes and frequencies-shift.

We propose to study the sensitivity of frequency-shift by perturbation methods: by the volume perturbation for the stress effect and by boundary perturbation for the effect of boundary imperfection.

A number of important parameters such as the types of forces, conditions of supports, and functions representing boundary imperfection, will be included in the computation for a systematic study of the resonator's sensitivity.

It is hoped that a clear understanding of the effect of each individual or combinations of these parameters will reveal the means to reduce the sensitivity to a minimum. Hence, the research results should be useful for the engineering designs of stable dielectric resonators against force and acceleration bias.

II. SUMMARY OF THE MOST IMPORTANT RESULTS

1. Two-dimensional governing equations for guided electromagnetic waves in isotropic or cubic crystal dielectric plates[1] are extended to include the piezo-optic effect in the constitutive equations. These equations are then employed to study the frequency shifts of transverse electric modes caused by stresses in circular disk dielectric resonators under three cases of loading conditions: (1) a pair of diametral forces, (2) steady vertical acceleration, and (3) steady horizontal acceleration. In the latter two cases, the bottom face of the disk is bounded to a rigid supporting base (See III-1).

2. The stress and acceleration effects on the EM resonances of both the transverse electric (TE) and the transverse magnetic (TM) modes in circular disk dielectric resonators are studied by applying a perturbation method to the three-dimensional Maxwell's equations and by the use of the recently obtained closed form two-dimensional solutions of the free vibrations[2] as the approximate solution of the zero-order perturbation (See III-2).

3. A system of two-dimensional governing equations for guided EM waves in the general anisotropic dielectric plates has been derived and dispersion relations computed from these 2-D equations are compared with those[3] obtained from the 3-D Maxwell's equations (See III-3).

REFERENCES FOR SECTION II

1. P.C.Y. Lee and J.S. Yang, "Two-dimensional Equations for Guided EM Waves in Dielectric Plates Surrounded by Free Space," *Proc. 45th Ann. Symp. Freq. Control,* pp. 156-165, 1991. Also in *J. Appl. Phys.* **73** (11), 1 June 1993, pp. 7069-7082.

2. P.C.Y. Lee and J.S. Yang, "Vibrations of Circular Disk Dielectric Resonators," *1992 IEEE Proc. Freq. Contr. Symp.,* pp. 626-638. Also in *J. Appl. Phys.* **73** (11), 1 June 1993, pp. 7083-7092.

3. P.C.Y. Lee and J.D. Yu, "Guided Waves in Anisotropic Dielectric Plates," *Proc. 1992 IEEE Ultrasonics Symp.,* pp. 999-1004. Also in *J. Appl. Phys.* **74** (8), 15 October 1993, pp. 4823-4838.

III. LIST OF PUBLICATIONS AND TECHNICAL REPORTS

1. P.C.Y. Lee, J.S. Yang, and A. Ballato, "Stress Sensitivity of Resonances of TE Modes in Circular Disk Dielectric Resonators," *J. Appl. Phys.* **76** (1), 1 July 1994, pp. 63-72.

2. P.C.Y. Lee, J.S. Yang, and A. Ballato, "Force and Acceleration Sensitivities of Electromagnetic Resonances in Circular Disk Dielectric Resonators," to be published in *Proc. 1994 IEEE International Ultrasonics Symposium.*

3. P.C.Y. Lee and J.D. Yu, "Two-Dimensional Equations for Guided Electromagnetic Waves in Anisotropic Dielectric Plates Surrounded by Free Space," to be published in *Proc. 1994 IEEE International Frequency Control Symposium.*

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