MICROWAVE RESONANT SYSTEMS BASED ON
CHAOTIC BILLIARD GEOMETRY

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Abstract: We describe investigations of eigenvalues and eigenfunctions of chaotic billiard-shaped microwave cavities in millimeter waveband using high-resolution 3D scanning device and computerized microwave measuring complex.

INTRODUCTION
Investigations of resonant properties and electromagnetic field patterns in oversized microwave cavities has been suggested in [1] for microwave modeling of quantum chaos phenomenon in mesoscopic systems. In [2] similar properties, but for different purposes have been studied in millimeter wave band chaotic resonators. Chaotic resonator usage as wideband oscillatory systems in chaotic waveform generators of microwave and millimeter wave bands is another promising application that has been suggested in [3,4]. In the paper, we briefly describe experimental setup for investigation of eigenmode frequencies and eigenmode field patterns in 2D oversized resonators. The resonator was specifically designed to have possibility of reconfiguration of its boundary from integrable geometry to nonintegrable one. Some results of experimental investigations of various chaotic resonant systems with nonintegrable boundaries in millimeter waveband are presented.

MATERIALS AND TECHNIQUE
The basic configuration of the microwave cavity under investigations is shown in Fig.1. It has the following sizes: the width is 58 mm, the length is 120 mm, and the height is 3 mm. At the geometrical center of the cavity, the axially symmetrical metal disk of the 3mm height and 18 mm radius may be inserted. In this way, the chaotic resonator with nonintegrable geometry of 2D Sinai billiard is formed. All inner parts of the cavity are made of high quality copper and carefully polished. Excitation of electromagnetic fields in the cavity is performed with the help of an external tunable source of single frequency oscillations. Those oscillations are fed into the cavity through a narrow slot made in a specially formed waveguide. This excitation method provides rather weak coupling between the source and the cavity within a rather wide frequency range.

RESULTS AND DISCUSSION.
With the help of the above experimental setup, investigations of eigenmode spectrum of the regular and chaotic microwave cavities were carried out and spacing statistics is calculated. The spectrums of microwave cavity and cavity with disc insertion placed inside it are shown in Fig.3.
The eigenvalue spacing statistics is one of the most important characteristics for nonintegrable resonant systems that enable investigators to distinguish between regular resonant systems and chaotic ones. The spacing statistics calculation is performed in three steps: (1) measurement of the eigenmode spectrum; (2) calculation of the neighboring resonances spacing: \( \Delta f_{i,i+1} = f_{i+1} - f_i = s \), and (3) evaluation of the spacing statistics using equation: \( P(s) = N(\Delta s) / \bar{s} \), where \( \bar{s} \) is averaged spacing, while \( N(\Delta s) \) is the number eigenmode spacings within the spacing interval \( \Delta s \). The spacing statistics for the microwave cavity with rectangular geometry and the cavity with metal disc inserted at the center of the cavity are shown in Fig.5. The spacing statistics for the rectangular microwave cavity (Fig.5a) has Poisson’s distribution, while that for the Sinai’s billiard cavity follows the Wigner-Dixon distribution (Fig.5b). The Poisson’s distribution is a signature of regular/nonchaotic resonant systems with integrable geometry, while the Wigner-Dixon distribution shows signature of chaotic resonators having nonintegrable geometry.

Mapping of eigenfunctions (electric field patterns) related to the resonant frequencies was carried out by using the small perturbation method. The method consists in that the small perturbation object (absorbing or scattering probe) placed inside the cavity causes both reduction of the resonant mode amplitude and shift of the resonant frequency \( f_0 \), which are proportional to the square of the \( E_z \)-field at that point.

For the given frequency, one obtains the E-field pattern moving the probe inside the cavity and recording the value of the E-field intensity changing. In our case, the metal dipole of 2.5 mm length and 0.3 mm diameter was used as the probe. The probe is moved inside the cavity with the help of static magnetic field, formed by two magnets placed co-axially above the upper wall of the resonator and under the lower one. The magnets are tied with the platform of the three-coordinate scanner controllable via the personal computer. Several field patterns are shown in Fig.6 for certain resonant frequencies of the resonators under investigation. It is seen that there is no periodical structures in the E-field pattern along X- and Y-axes. That approves the essential influence of the non-integrable geometry of the resonator on its new resonant properties. For non-resonant frequencies (Fig.4), the E-field patterns have much less regularity, but still they have a finite value of the field amplitude. In those cases, the resonator with chaotic billiard geometry is suitable for its usage as an oscillatory system for chaotic waveform generators [3,4].
Fig. 5. Eigenvalue spacing statistics for rectangular microwave cavity (a) and Sinai billiard cavity (b)

Fig. 6. E-field patterns for different resonant frequencies in chaotic billiard resonators

REFERENCES


