Resonant Irregular Hybrid Structures

Igor Bondarenko, Aleksandr Galich

Abstract - **Numerical model simulation and experimental device examination defines the conditions of excitation and types of high-Q oscillations in irregular hybrid structures and the conditions for communication of high-Q oscillations with an aperture of a coaxial probe parts are also identified. Irregular hybrid structure in configurations discussed can be effectively used to create high-Q resonator transducers for contactless microwave diagnostics of different objects. The possibilities of the use of irregular resonator structures for the formation of ionizing microwave fields in the electrodeless sulfur lamps, and as a guide elements of light are also investigated. The analysis of resonator structures of different geometry, configuration of the field strength, which are formed, and magnitude of the field strength, amplitude-frequency characteristics are carried out.**

Keywords – **high-Q, resonator, irregular, hybrid, structure, cone, oscillations, electrodeless sulfur lamp.**

I. INTRODUCTION

Volume resonator structures are widely used in various applications of microwave technology due to the high Q factor of the excited oscillations in them. Typically, these resonators are segments of regular waveguide transmission lines (coaxial, prismatic, cylindrical). However, in some cases, such as the need to ensure effective interaction between the components of the electromagnetic field produced by the resonator, with a variety of objects (charged particles, materials, environments, and so on.), type of resonator structure can change drastically, which entails changes in the distribution of fields (oscillation modes) and the parameters of the excited oscillations (resonance frequency and the quality factor).

The non-contact microwave diagnostics of materials and media, in particular scanning microwave microscopy, used extensively resonator measuring transducers (RMT) with microprobe [1, 2]. It is necessary to ensure maximum quality factor of the RMT (defining measurement sensitivity) and an effective pairing its resonator part with a probe.

In [3, 4] to create a RMT is proposed to use converters resonator, in which the transition from the high-Q resonator part of a coaxial probe is smooth due to its conical shape. Excitation of the transducer occurs as coaxial oscillation modes (TEM wave) or higher for such types of structures waves (H and E). It is shown that depending on the geometry and dimensions of such transducers can be excited at a quasi-H_{11n} quasi-E_{011}, quasi-H_{221} and the other oscillation modes.

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Q-factor of the excited oscillations in this case reach values ~ 10^3 ... 10^4.

As proposed by the resonator structure is sufficiently promising to build measuring transducers, and possibly other types of microwave devices, the purpose of this paper is to analyze the conditions of excitation and maintenance at such irregular hybrid structures high-Q oscillation modes.

II. MAIN PART

As a base for the review and analysis it was selected coaxial conical structure with changing the length of the ratio of the inner diameter of the outer conductor to the diameter of the inner conductor. Since the analytical description of such a structure is difficult to analyze it was selected numerical method of mathematical modeling. The reliability of the results obtained in the simulation was verified by measurements in the experimental equipment.

Viewed structure may be excited at different oscillation modes in the operating frequency range.

For coaxial irregular structures with dimensions L = 81 mm, D = 16 mm, d = 1 mm (L - length of the structure, D - the maximum inner diameter of the outer conductor, d - diameter of the inner conductor) in the range 8.02 ... 12.38 GHz arises 8 resonances including resonances n-quarter coaxial resonators and higher modes. Shown on Fig. 1 examples of the distribution of electric fields for the two excitation modes support high-Q oscillations in the structure under consideration, other than TEM, higher for the coaxial structure, and they appear in areas where the ratio of the diameter is maximum.

The number of possible resonances in this structure may be reduced by the choice of construction and the connection point coupling elements for driving the oscillation mode of the selected particular orientation of the magnetic and electric field components.

When selected as the communication device of coaxial lines connected to the structure under study through the end wall or side wall, and the orientation of coupling loops given field configuration desired oscillation mode in the operating range is only three high-Q resonance: I - f = 7.95 GHz, Q = 3820 ; II - f = 10.2 GHz, Q = 12345; III - f = 11.6 GHz, Q = 10632.

For experimental verification of the possibility to consider hybrid structures was made the layout transducer with a coaxial probe, the appearance of which is shown in Fig. 2.

During further numerical and experimental studies have shown:

– quality factor for high types oscillations of a coaxial line actually several times higher than the Q n-quarter-wave oscillation modes TEM type;

– high-Q oscillation modes in irregular coaxial structure are not connected with its outlet aperture coaxial probe part, while the TEM quarter-wave resonances are strongly dependent on the characteristics of the medium and the position of objects near it;

– high-Q resonances are stored in these structures and in the absence of a central conductor in the area of their excitation;

– high-Q resonances exist in the volume of the conical structure without any central conductor and placed at her not prohibitive part for this type oscillations;

– the optimal choice of the length of the central conductor oscillations coaxial irregular structure can provide a link high-Q oscillations with coaxial probe, which is evident in changes in the quality factor and the resonant frequency when changing the environment and objects in its aperture.

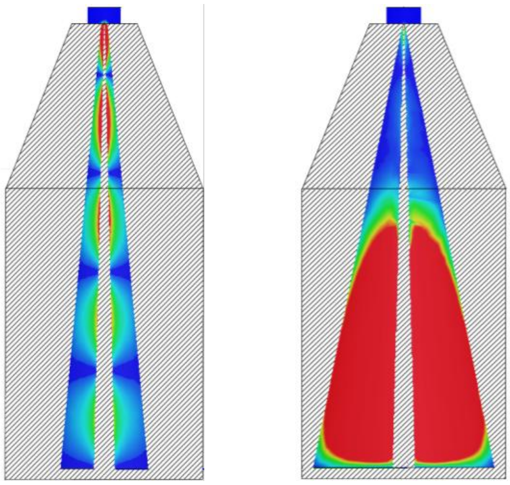

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Fig. 1 The structure of E in conical coaxial resonator

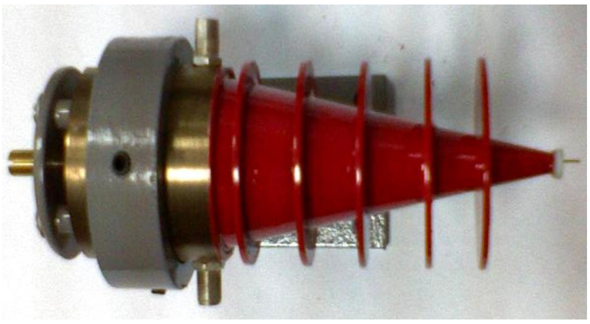

Fig. 2 The appearance of the conical coaxial RMT

In recent years, intensive research related to the development and study of the functioning of the microwave sulfur lamps [5]. Sulphur microwave lamps have a number of advantages over other light sources: the absence of electrodes, high efficiency ~ 25%, a high color index of ~ 70-80%, the spectral characteristics similar to sunlight. Their operating principle is to stimulate the microwave electromagnetic field mode of ionization of neon and shock excitation of the molecular and atomic sulfur neon ions with subsequent emission of photons. The minimum field strength necessary for the emergence of the space charge in the buffer gas, is ~ 20-30 kV / m [5]. Essential disadvantages of microwave lamps are: the need for high-power sources of microwave radiation (from hundreds of watts to kilowatts or more) and, as a consequence, their relative fragility, due to the elaboration of resource microwave source, increased requirements for operating the thermal regime, the complexity of interfacing light source excited microwave radiation from the light guide elements.

Feature of this resonant structures is that they have an axial symmetry, and their shape can simultaneously fit designs reflective mirror elements and the light guide light source [6]. High Q factor achieved in such structures (10^3 ... 10^4), allows field strength sufficient for initiating volume discharge at much lower power sources of microwave radiation.

Numerical model analysis shows the ability to achieve high field strengths in the areas of formation of the corresponding resonances. At a pump power of several watts reaches the value of the electric field sufficient for initiating the discharge of sulfur-containing medium (Fig 3).

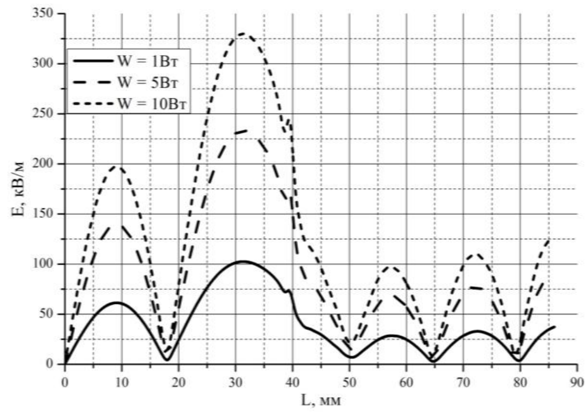

Fig. 3 Graphs the distribution of the electric field along the axis of the conical cavity at different values of the power of the pump source

The levels of microwave power to the unit, or even tens of watts achieved by semiconductor generators, which opens up the possibility of reducing energy consumption, improving reliability and durability of the microwave sulfur lamps, as well as the creation of small light sources of this type.

Analysis of the structure of the fields observed in irregular resonator structures at resonances shows that the siting of a coaxial conductor structure similar to the structure of the field of standing waves in the coaxial lines.

Accordingly, this part of the resonator can be transformed into the feed coaxial line with a small degree of irregularity for matching with a high-volume resonator.

The geometry of a high-field resonance part of the proposed resonant structures can be adapted to the requirements of the formation of the desired direction of light emission.

Numerical modeling study of resonator structures, the geometry of which is close to the geometry of the guide light reflectors, show that the possibility of initiating high-Q modes in this case is also saved.

Was analyzed resonator structure with dimensions: the radius of the curved part $R_c \approx 9,5$ mm, an outer diameter $D_{out} \approx 25,2$ mm, length $L \approx 25$ mm (Fig. 4). This was obtained by resonance frequency 9.664 GHz with $Q \sim 1,19 \cdot 10^4$.

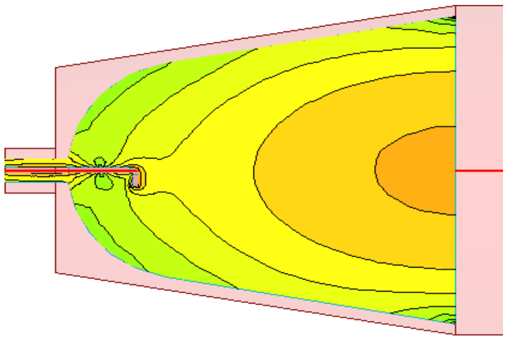

Fig. 4 The distribution of electric field intensity in a hybrid resonator structure with an irregular shape of the light reflector

Since these structures are designed for simultaneously solving the problems of gas ionization and formation of the beam, analyze the characteristics of the resonator structure of the simulator flask ionized gas in the form of a conductor with a high conductivity, placed in the region of increased electric field intensity are carried out (Fig. 5). In this case as well, a resonance is observed at a frequency of 9.55 GHz with a $Q \sim 0.72 \cdot 10^4$.

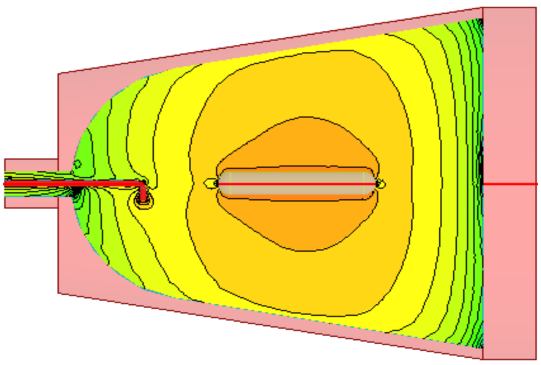

Fig. 5 The distribution of the electric field in the hybrid resonator structure with an irregular shape of the reflector and light bulb simulator ionized gas

III. Conclusion

Irregular hybrid structures in the configurations discussed in the paper can be used effectively to create a high-Q resonator transducers for contactless diagnostics of materials and media, as well as to improve the microwave sulfur lamps.

Based on the analysis of processes of excitation irregular resonant structures in the higher oscillation modes detected the possibility of achieving the intracavity intensity of the electric field sufficient to produce a sulfur-containing plasma discharge at power levels of the microwave signal pumping the order of tens of watts.

Using regular resonance structures allows a single design to combine properties that provide high Q microwave resonance and formation of directional light, as well as significantly reduce the requirements for the microwave source.

The results obtained can not be directly used in the design of microwave lamps, however, according to the authors offers additional opportunities of their improvement and modernization.

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