WAVEGUIDE FILTERS USING DIELECTRIC RESONATOR FOR CESIUM-BEAM FREQUENCY STANDARD

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ABSTRACT

The results of experimental research of band-rejection and band-passing waveguide filters based on dielectric resonators in cutoff and beyond-cutoff waveguides in a microwave circuit of the Cs standard are given. Considered is a dielectric resonator of DRD type made of B40 ceramic material with dielectric permittivity ε = 43. The band-rejecting filter is formed by placing a dielectric resonator on the dielectric base directly in the waveguide. The band-passing filter is formed by introducing an additional body with a beyond-cutoff window inside of which the dielectrical resonator on dielectrical base is placed. Given are curves for the load quality and attenuation at the resonance frequency depending on length of beyond-cutoff part.

The structure of re-adjustable band-passing filter in the dimensions of standard waveguide is described. Given are the parameters of resulting filter.

Discussed is a possibility of utilizing these filters for filtering of products of non-multiple frequency transformation in RF excitation signal.

Keywords: Cs standard, wavequide filters, dielectric resonators, filtering the RF signal.

1. INTRODUCTION

In atomic-beam frequency standards using atomic beam tube with U shape RF cavity an RF excitation signal is provided often by the section of rectangular waveguide with dimentions of 10×23 mm – Ref, 1-4. Filtering of main RF component corresponding to clock transition 9192,6 MHz from products of non-multiple transformation of frequency – Ref, 5, first of all from carrying frequency 9180 MHz accurs by high quality RF cavities. There is some interest to use for this purposes a waveguide filters based on dielectric resonators (DR) giving an opportunity to decrease the dimensions and cost of RF guide.

2. FILTERS BASED ON DR

Let's consider a case of monoresonator filters and evaluate an opportunity of realization the band-rejection and band-passing filters in case of 10×23 mm waveguide section as a dielectric DRD type resonator made of B40 ceramic material with dielectric permittivity ε = 43.

Basic laws in RF line with DR are determined by coupling coefficient – Ref.6 which can be expressed as:

$$K = \frac{Q_0}{Q_b}, \qquad (1)$$

where Q_0, Q_b – its own and external quality of DR respectively.

With account of one-wave mode waveguide operation, matched RF line with basic wave mode H_{10}, for any type of oscillations of DR in case lumped coupling with RF line expressions for reflection factor Γ, passage T and absorption χ on resonance frequency will look like

$$\Gamma = \frac{K}{1+K}, \quad T = \frac{1}{1+K}, \quad \chi = \frac{2K}{(1+K)^2}. \qquad (2)$$

Thus the loaded quality Q_n is defined by expression

$$Q_n = \frac{Q_0}{(1+K)} \qquad (3)$$

In case of flat cylindrical DR of DRD type with a diameter of 5,75 mm, thickness of 2,3 mm and Q_0 = 5000 taking in account the waveguide crossection dimensions and wavelength of analyzed signals the coupling coefficient can be determined proceeding magnetic-dipole DR module.

For lowest $H_{01\delta}$ type of oscillation for DR the coupling coefficient is defined by expression

$$K = \frac{60\pi^2 M h_b^{\,2}}{P\lambda_0}, \qquad (4)$$

where P represents RF power in waveguide, λ_0 – wavelength in free space, corresponding to the resonance frequency of DR, h_b – component of not disturbed RF field coincide with the direction dipole momentum of resonator at the point of DR location, M – multiplier factor determined by the form of DR.

It follows from given expressions, that the basic laws in RF line with DR, given by the coupling coefficient K are defined by transmitted RF power and square of a magnetic component of RF field in the location of DR.

However by virtue of approximated description the waveguide with DR to design such filter with given parameters the experimental research of construction is needed to choose dimensions and materials. The simplest version of the waveguide filter is a band-rejection filter with DR accommodated inside waveguide of RF line with magnetic coupling, see fig.1.

The results of an experimental research of the given filter show, that when changing a position of DR along the X axis: 1) loaded quality remains practically constant and equal to a value about 2200±300; 2) the attenuation value at the resonant frequency also kept at level 35÷40 dB; 3) detuning of resonator changes in the large amount, about 300, and the approaching DR to a narrow wall of waveguide increases the frequency.

The band-passing filter is given in fig.2. In contrast to the band-rejection filter the band-passing filter requires introduction an additional body forming a beyond-cutoff waveguide (frame 4) inside of which on dielectrical base 3 the DR 2 is placed.

The measurement results of parameters of band-passing filter at square window side of beyond-cutoff waveguide equal to a narrow wall are shown in fig.2b. It is seen that at small length of beyond-cutoff section (thickness W) the direct passage signal losses are minimal, however thus the loaded quality is insignificant. With increase of thickness W the quality Q_n is increased, thus the losses to direct passage of signal are increased also.

The reduction of window cross section reduces own quality of the filter, increases losses in pass-band, increases frequency of the basic $H_{01\delta}$ type of oscillations DR and reduces frequency of higher E-type oscillations, approaching those to operating frequency. Therefore final choice of the window size and thickness of the filter frame is a matter of compromise requiring an experimental improvement.

So to reach the quality of filter about 1000 and least dimensions with an opportunity of fastening it between standard flange of waveguide the design of tunable filter construction is tested (fig.3). Thickness of the frame W=11 mm, size of window:

width = 9 mm, height = 6 mm.

The measured parameters of given filter:

Quality Q_n = 1100.

Attenuation in a pass-band A = 4÷5 dB.

Frequency adjustment band from 9140 MHz up to 9240 MHz.

Frequency sensitivity via temperature 20 kHz/C°.

CONCLUSION

Thus is shown, that waveguide filters based on dielectric resonators allow effectively to filter an RF signal of excitation an atomic transition from non-multiple products due to frequency conversion. At small indexes of phase modulation in a circuit of non-multiple frequency conversion more effectively to filter carrying frequency f_n by means of band-rejection filter and for large indexes of modulation more effectively to use a band-passing filter for a filtration of basic signal with the frequency of clock transition f_0.

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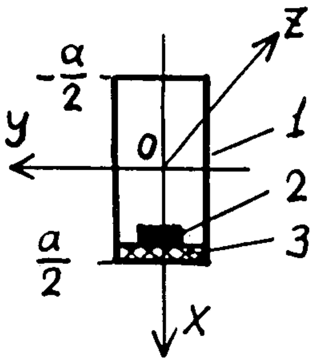

Fig.1. Band-rejection filter
1 – waveguide; 2 – DR; 3 – dielectric pedestal. The Z axis coincides with an waveguide axis.
Length of a wide wall of waveguide – a.

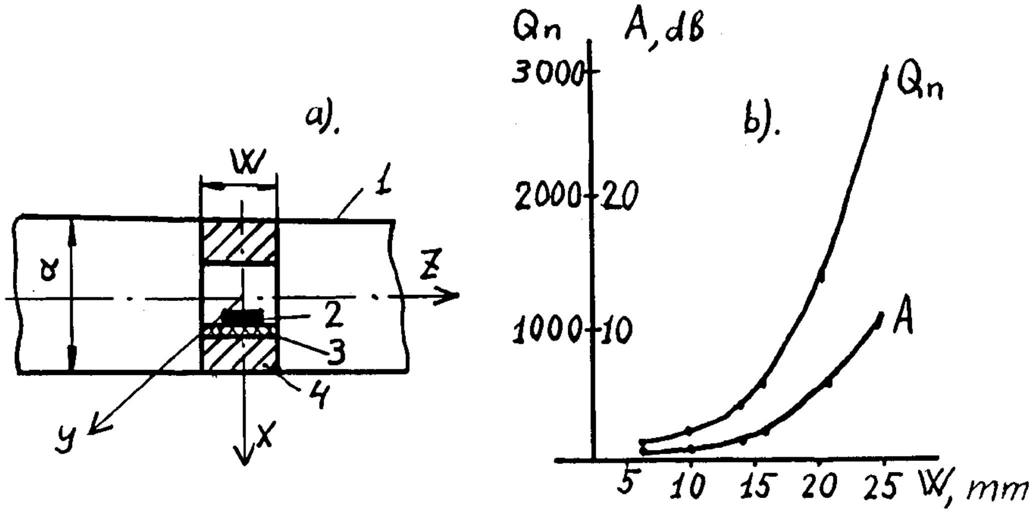

Fig.2. Band-passing filter
a/ A filter construction in longitudinal cross section of waveguide; 1 – rectangular waveguide;
2 – DR; 3 – dielectric base; 4 – frame.
b/ dependence of the loaded quality Q_n and attenuation A on resonance frequency via thickness W

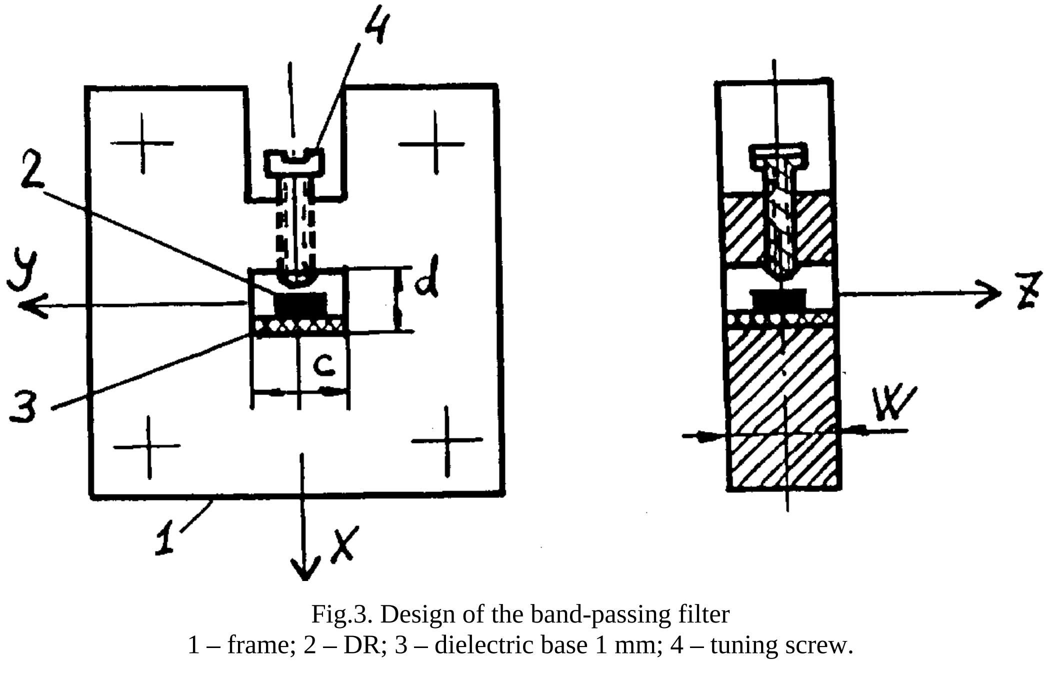

Fig.3. Design of the band-passing filter
1 – frame; 2 – DR; 3 – dielectric base 1 mm; 4 – tuning screw.