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NARROW-BAND MICROWAVE FILTERS

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*Original design of the narrow-band compact filters based on the high-quality waveguide-dielectric resonator with anisotropic materials has been presented in this work. Designed filters satisfy the contradictory requirements: they provide the narrow frequency band (*0,05-0,1% *of the main frequency* f_0*) and the low initial losses* $\alpha_0 \leq 1$ *dB.*

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1. INTRODUCTION

Narrow-band filters are used to solve the problem of electromagnetic compatibility and multiplexing of information channels in satellite communication systems and television in the microwave range. They should provide the combination of narrow pass bands and high stop bands with low microwave signal loss, possess stability of the electrical characteristics in a wide temperature range. Narrow-band filters find wide application in microwave generators with low noise level, microwave receiver preselectors, measuring equipment, etc.

2. RESULTS AND DISCUSSION

The present paper is devoted to the development of the narrow-band compact microwave filters based on the high-quality waveguide-dielectric resonator (HQWDR). Filter is a segment of rectangular waveguide with flanges, which contains one or some dielectric liners completely filling the resonator along the narrow waveguide wall and partly along the wide one (Fig. 1a, b). Such filters [1] satisfy the contradictory requirements.

1. They provide the narrow band (0,05-0,1% of the central frequency f_0) in combination with low initial loss α_0 ($\alpha_0 \leq 1$ dB). It is possible due to the use of resonators with the own quality not less than (15-20)·10^3 units, which is achieved by using the monocrystalline materials with low dielectric loss.

2. Resonator rotation by 90° about the H-plane of the waveguide transmission line allows to improve essentially the quality in comparison with the ordinary waveguide-dielectric resonators (WDR) due to the fact that the conduction currents passing before in a metal surrounding dielectric were found to be substantially changed by the bias currents; and this allowed to decrease the average loss power in metal walls of the resonator.

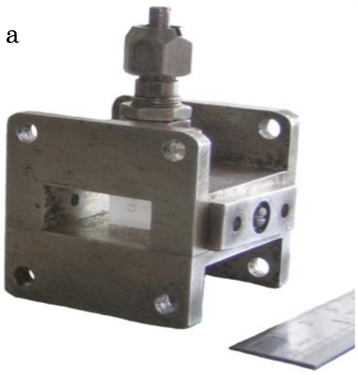
Designed filters possess the following characteristics:

central frequency f_0, MHz	9500-10000
pass band (by the level of 1 dB), MHz	8-10
initial loss α_0, dB	≤ 1

suppression in the stop band:
- for two-mesh filter, dB, not less than 20
- for three-mesh filter, dB, not less than 30

mass, g ≈ 150
dielectric leucosapphire

a



b

Fig. 1 *– Narrow-band microwave filters: single-mesh filter (a); two-mesh filter (b)*

Moreover, a question of technological effectiveness in serial production of such filters is studied in the work, namely, the influence of the surface state of the waveguide and dielectric liner, the choice of the design material, and the tolerances while designing and tuning.

Consider the influence of the material on the main parameters of high-quality resonator. We compared HQWDR based on the waveguide sections made of brass and copper. The same leucosapphire liner was placed into the waveguide sections of the same length (L = 50 mm). Thus, HQWDR were in the same conditions. Numerical data for two resonators in the studied frequency range is presented in Table 1. As seen from this data, material of the waveguide section has essential influence on the resonator characteristics. Copper and silver are the most appropriate materials. Or it is possible to produce the waveguide sections made of other materials but with silvered internal surface and flanges.

Table 1 *– Influence of the section material on the HQWDR parameters*

Parameter	Brass section $\sigma = 1,57 \cdot 10^7$ S/m [2]	Copper section $\sigma = 5,97 \cdot 10^7$ S/m [2]
a/λ	0,384	0,384
α_0, dB	1,84	1,45
$Q_н$	2560	2900
Q_0	13500	19300
a/λ	0,306	0,384
α_0, dB	5,3	5,0
$Q_н$	4300	5800
Q_0	9400	13300

Three liners with the same geometry were manufactured to investigate the influence of the dielectric liner material, and measurements in the same measuring section made of copper were performed. Liners were made of teflon, crystalline quartz, and leucosapphire; their electrical parameters are presented in [3]. The results, which show the explicit dependence of the quality on the dielectric liner material, are given in Table 2. Therefore, it is necessary to choose the material with minimum value of the dielectric loss tangent.

Table 2 – *Influence of the dielectric liner material on the HQWDR parameters*

Parameter	Teflon liner	Quartz liner	Leucosapphire liner
a/λ	0,348	0,305	0,384
α_0, dB	11,1	5,2	1,32
$Q_н$	3,660	4,240	3050
Q_0	5090	9740	21600

To study the influence of the surface state of HQWDR on its parameters, measurements were carried out for HQWDR based on the waveguide section done of the ordinary waveguide pipe without pretreatment of its internal surface, and the comparison with the HQWDR parameters measured after polish of the internal waveguide surface was performed (see Table 3).

Table 3 – *Influence of the metal surface state on the HQWDR parameters*

Parameter	HQWDR based on unpolished section	HQWDR based on polished section
a/λ	0,384	0,384
α_0, dB	6,6	6,6
$Q_н$	6680	6860
Q_0	12550	13023

The results presented in Table 3 allow to conclude about unessential influence of the waveguide internal surface state on the value of own quality of HQWDR. The necessity of polishing of dielectric liner surface was dismissed by the same reason, and this improves the technological effectiveness of the filters based on HQWDR.

Influence of the tolerances while producing and assembling on the HQWDR parameters was studied. Main assembly of the filter consists in the correct arrangement of dielectric liner in the waveguide section. The optimal position of the liner from the point of view of obtaining the highest indices of the filter is the symmetrical arrangement of dielectric liner with respect to the waveguide sidewalls and flanges. Liner shift (ΔL, mm) was performed relative to its symmetrical arrangement along the resonator length L (with respect to the flanges). Positioning of the liner was realized using clock-type micrometer with an accuracy to 0,1 mm. Shift was done on the first millimeter every 0,2 mm, then every 0,5 mm, keeping the symmetrical position of the sample with respect to the section sidewalls. The resonance frequency (Fig. 2, curve 1), the pass band width on the level of 3 dB (Fig. 2, curve 2), and the HQWDR loss on the resonance frequency (Fig. 3, curve 1) were controlled. Curve 2 in Fig. 3 corresponds to the calculated loaded quality according to the relation [4]

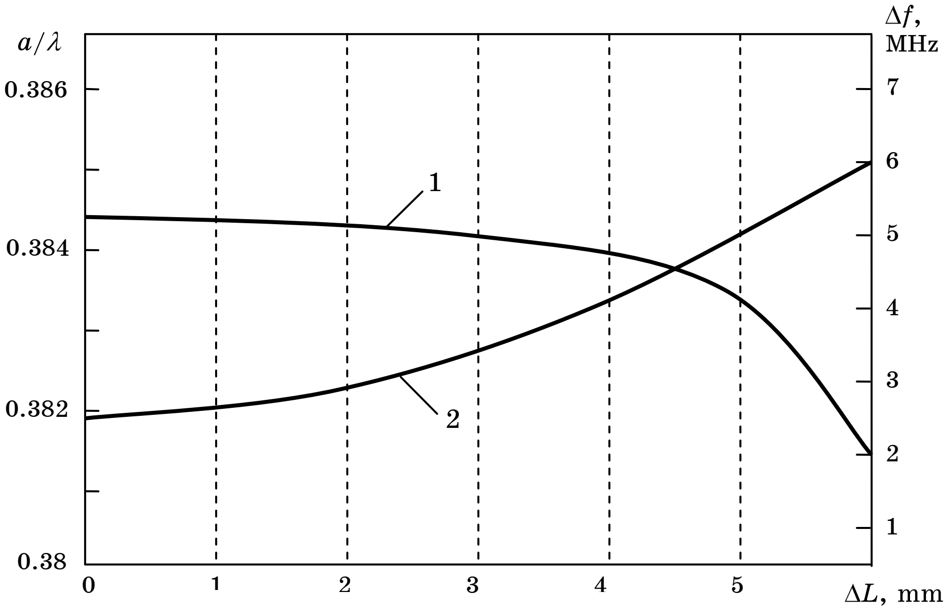


Fig. 2 *– Dependence of the relative resonance frequency a/λ and the pass band width Δf on the sample shift ΔL along the longitudinal axis of the section with respect to the symmetrical arrangement*

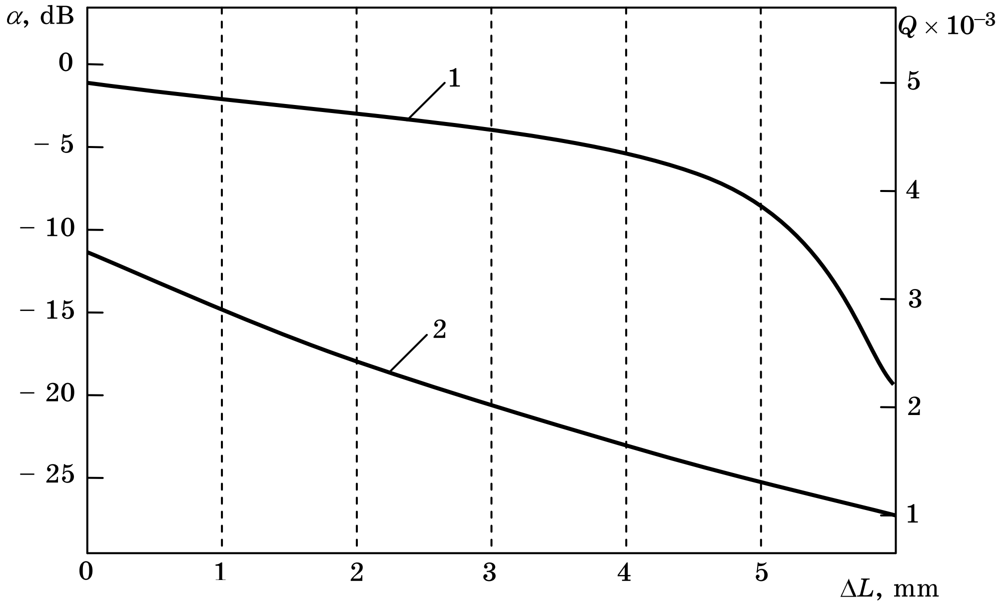


Fig. 3 *– Dependence of the damping α and the quality Q on the sample shift ΔL along the longitudinal axis of the section with respect to the symmetrical arrangement*

$$Q_н = \frac{f_0}{2\Delta f} \cdot (10^{\frac{\alpha-\alpha_0}{10}} - 1)^{1/2},$$

where α_0 and α are the expressed in dB damping on the resonance frequency and at the detuning from the latter, respectively. As seen from the shown figures, shift of the sample from symmetrical position along the longitudinal axis of the resonator at the distance of ± 1 mm does not cause substantial changes in the resonator parameters. Further shift of dielectric liner leads to the essential broadening of the frequency band (0,7 MHz every 1 mm of the shift) and to the increase in the loss α (0,5 dB every 1 mm of the shift). Substantial drift of the resonance frequency arises at 4 mm and more shift. Hence we can conclude that inaccuracy tolerance of the sample arrangement can be ± 1 mm.

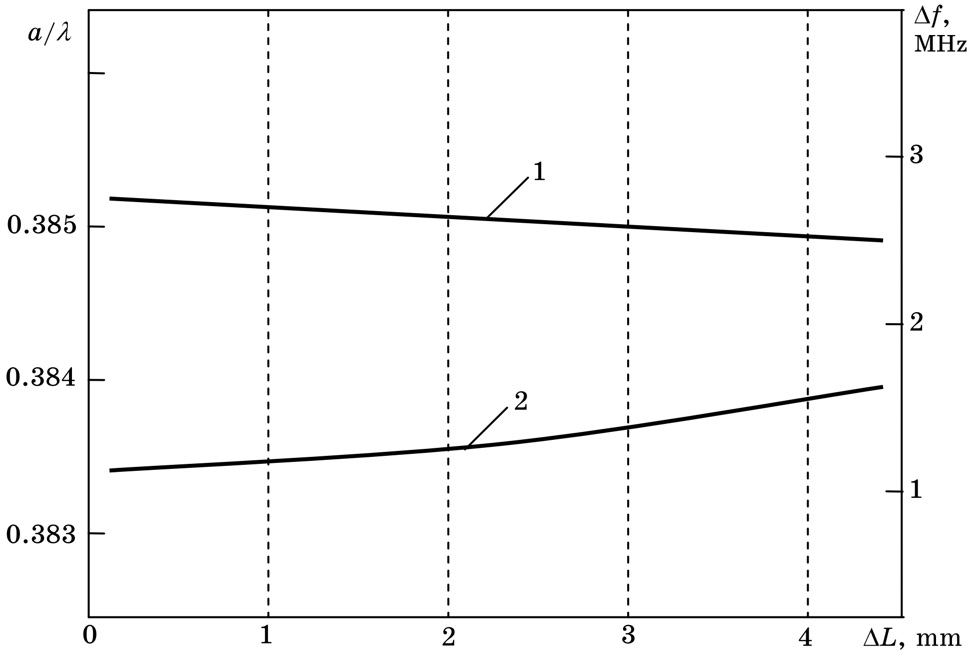


***Fig. 4** – Dependence of the relative resonance frequency a/λ and the pass band width Δf on the sample shift ΔL along the waveguide walls*

The liner shift with respect to the symmetrical position along the wide resonator wall (the size b) was studied. Measurement and control of the parameters was realized as that described in the previous case. Positioning of the sample was carried out using a calibrated arbor, the thickness of which was changed by 0,2 mm on the first millimeter of the shift, and then by 0,5 mm. Thickness calibration was performed with an accuracy of ± 0,02 mm. Dependences of the relative resonance wavelength (a/λ) (curve 1) and the pass band width Δf on the level of 3 dB (curve 2) versus the liner shift ΔL are presented in Fig. 4. Dependences of the HQWDR loss α_0 on the resonance frequency (curve 2) and the loaded and own quality Q of the resonator (curves 3 and 1, respectively) are shown in Fig. 5. It is seen that in the case of the shift of leucosapphire sample from its optimal position toward the waveguide side-walls, at the same time keeping the symmetry with respect to the flanges, changes in the electrical parameters of HQWDR are substantially less than in the previous case. Changes in the resonance frequency, pass band width on the level of 3 dB, and loaded quality are insignificant before the shift value of ΔL = 4,5 mm from the symmetrical position. The most increase in the HQWDR loss on the resonance frequency (about 0,35 dB) at the shift of ΔL = 4,5 mm leads to the decrease in the own quality of the resonator on the quantity of $Q_0 \approx 3000$ units. This implies about weak influence of the shift of leucosapphire liner toward the waveguide sidewalls.

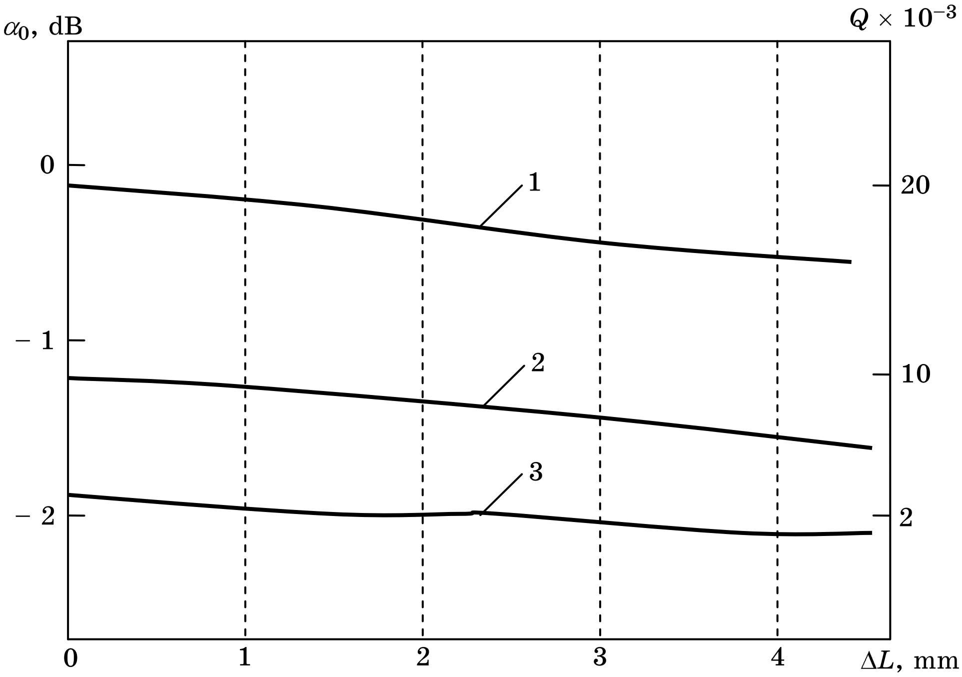


***Fig. 5** – Dependences of α (curve 2), Q_0 (curve 1), and Q_l (curve 3) on the sample shift ΔL along the waveguide walls with respect to the symmetrical position*

3. CONCLUSIONS

Original narrow-band compact filters based on the high-quality waveguide-dielectric resonator with anisotropic materials are described. The designed filters satisfy the contradictory conditions: they provide the narrow band (0,05-0,1% of the central frequency f_0) in combination with low initial loss $\alpha_0 \leq 1$ dB. It is possible due to the use of resonators with the own quality, which is not less than $(15\text{-}20)\cdot 10^3$ units and is achieved by using the monocrystalline materials with low dielectric loss. Resonator rotation by 90° about the H-plane of the waveguide trans-mission line allows to improve essentially the quality in comparison with the ordinary waveguide-dielectric resonators. The investigations preformed in the given work allow to conclude that the designed filters are practically feasible in serial production.

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