

Microstrip Filters and Diplexer for the Receiver of the Global Navigation Satellite Systems «GLONASS», «GPS» and «GALILEO»

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Abstract – A new design of the microstrip bandpass filters and diplexer for the combined bandwidth receiver of the global navigation satellite systems «GLONASS», «GPS» and «GALILEO» is presented.

Keywords – Microstrip Filters, Diplexer, Global Navigation Satellite Systems, «GLONASS», «GPS», «GALILEO».

I. INTRODUCTION

Comparatively large overall dimensions of microstrip filters (MSF) do not allow them to become widely used in home receivers of the global navigation satellite systems «GLONASS», «GPS» or «GALILEO». However, in the special purpose equipment requiring high operational reliability of the apparatus at increased levels of radiation and vibration and in the wide temperature range, such filters are used both in piece and mass production.

The aim of the present work is to design MSF with low losses in the bandpass for the low noise amplifier (LNA) and MSF for the diplexer combining the channels *L1* and *L2* for the combined bandwidth receiver of the global navigation satellite systems «GLONASS» and «GPS», as well as MSF of the combined bandwidth *L2* + *L3* for the systems «GPS» and «GALILEO». Constructional and electrical parameters of MSF have to be reproducible in serial production and costs of the filters should be minimal.

II. FILTER AND DIPLEXER DESIGN

One of the main requirements in the serial production of filters for LNA and diplexer for the frequency band *L1*, *L2* and *L3* is the cost minimization for the filter production and their adjustment. Therefore, filters are designed based on microstrip resonators (MSR). Though resonators on suspended substrate have high unloaded *Q*, the fabrication and tuning of the filters on suspended substrate are less manufacturable. In order to decrease the dimensions MSF are designed on quarter wave irregular MSR with increasing capacitance and inductance of the resonators by widening strip conductors in the capacitance part of the resonators and their narrowing in the inductance part [1].

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Therefore, for MSF being developed for LNA the decrease of the strip conductor width of the quarter wave MSR in the antinode of the MSR high frequency current is limited by the allowable level of the insertion losses in the MSF bandpass of 1 dB, with the level of the return losses being 14dB.

The requirements for the MSF performance in the operating temperature range from +70 to - 50°C as well as the spread in values of the substrate permittivity impose the necessity of designing MSF with a larger bandpass width, higher bandwidth ratio of the amplitude-frequency response (AFR), lower insertion and higher return losses in the bandpass. In this case the adjustment of the MSF bandpass is made by means of the screen height (which is provided by the peculiarities of the MSF design), decreasing significantly the adjustment time of one filter at their serial production.

TABLE I
THE MEASURED CHARACTERISTICS OF THE INPUT MSF

The parameter name	Band <i>L1</i>	Band <i>L2</i>
Bandpass, MHz	1565 - 1610	1217 - 1257
Minimal losses in the bandpass, dB	0,5	0,6
Irregularity of AFR in the bandpass, dB	0,2	0,1
Voltage-standing wave ratio of the input and output in the working frequency band	1,35	1,32
Irregularity of the group delay in the working frequency band, ns	3	3
Signal attenuation upon detuning of ± 150 MHz from the center frequency of the bandpass, dB	-17	-18
	-25	-23

Table 1 presents the measured MSF characteristics for LNA of the bands *L1* and *L2*. Both filters are implemented using three co-directional quarter wavelength MSR. The MSF overall dimensions with the body and screen are 9×7×4 mm. The thickness of the dielectric substrate is 1 mm, the permittivity is 80. The filter input and output are stripline.

MSF for the diplexer is simulated using four quarter wave MSR. Fig. 1 demonstrates the design of the *L1* frequency band MSF.

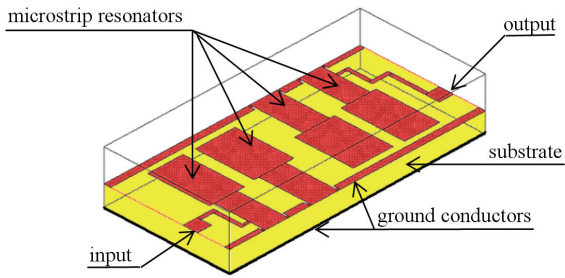


Fig. 1. The *L1* frequency band MSF

Fig. 2 presents the simulated frequency dependences of the parameters $|S_{21}|$ and $|S_{11}|$ of the *L1* frequency band MSF, with the distance from the MSF substrate to the screen being 1.7 mm (dark circles) and 1.6 mm (light circles).

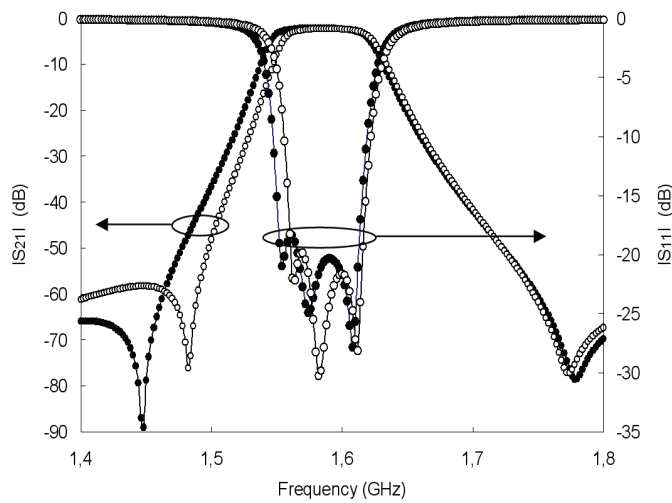


Fig. 2. Simulated insertion and return losses of the *L1* band MSF at two screen heights

One can see in Fig. 2 that the filter designed such that there are low frequency and high frequency attenuation poles to the left and to the right from the filter bandpass. The frequency of the high frequency attenuation pole and high frequency boundary of the filter bandpass almost do not depend on the height of the filter screen changing from 1.7 mm to 1.6 mm. While the location of the low frequency attenuation pole and low frequency boundary of the bandpass strongly depends on the screen height. When decreasing the distance from the MSF substrate to the screen from 1.7 mm to 1.6 mm, the low frequency boundary of the bandpass at the level of -1dB increases almost by 10 MHz, which corresponds to the relative decrease of the bandpass width of about 20%. It should be noted that return losses in the microstrip filters bandpass at the mentioned changes of the screen height always remain not more than -18 dB.

Increasing the frequency of the low frequency attenuation pole upon decreasing the screen height results only in increasing the steepness of the low frequency slope of the MSF amplitude frequency response. Here, it is necessary to obtain the signal attenuation of -40 dB at a given detuning from the center frequency of the MSF bandpass when simulating it for the

L1 MSF. The signal attenuation achieved in the MSF developed is more than -50 dB at the indicated changes of the screen height. To decrease the overall dimensions of the *L2* frequency band MSF the topology of the resonator stripline conductors in this filter is designed so as to decrease the coupling coefficient between MSR. As a result, the overall dimensions of the filters of both bands *L1* and *L2* are the same and amount to (along with the body and screen) 14x7x3 mm. Fig. 3 shows the design of the *L2* frequency band MSF.

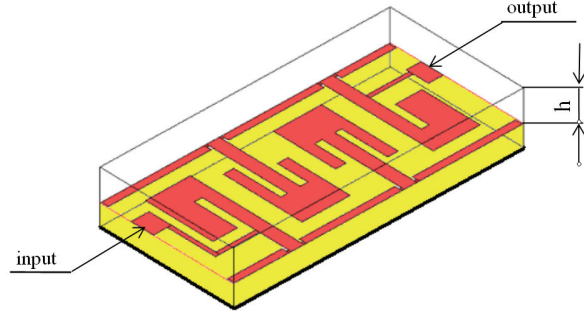


Fig. 3. The *L2* frequency band MSF

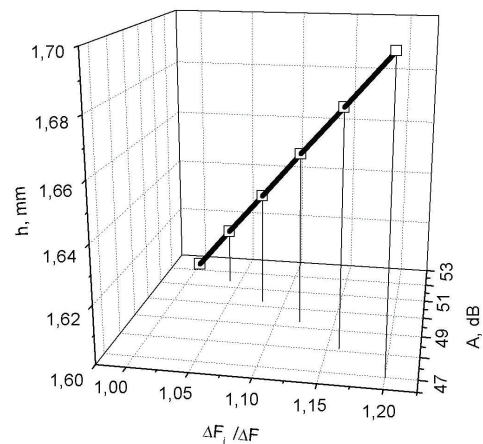


Fig. 4. The simulated dependences of the relative change of the bandpass and least attenuation in the stop band on the height of the screen for the *L2* frequency band MSF

Fig. 4 presents the simulated dependences of the relative change of the bandpass width at the level of -1 dB ($\Delta F_i/\Delta F$) and the least attenuation (A) in the stop band on the height of the screen (h) for the *L2* frequency band MSF. It should be noted that the change of the bandpass width both in the *L2* MSF and *L1* MSF is caused by the shift of the low frequency edge. The high frequency edge is almost not shifted when the screen height is changed from 1.7 mm to 1.6 mm.

One can see in Fig. 4 that in this filter when decreasing the distance from the MSF substrate to the screen from 1.7 mm to 1.6 mm the relative decrease of the bandpass width is about 20%, which almost coincides with the data for the *L1* frequency band MSF. The simulated minimal attenuation of the signal in the stop band is -47 dB, with the required attenuation being -40 dB. Here, the return losses in the filter bandpass at the mentioned changes of the screen height as well as in the *L1* MSF are always at least -18 dB.

Thus, the above considered peculiarities of the designed filters of the frequency bands $L1$ and $L2$ allow one to implement fine-tuning of their bandpass width only by changing the screen height after previous adjustment of the upper boundary of the bandpass.

Fig. 5 presents the measured AFR of the $L1$ and $L2$ frequency band diplexer. One can see in Fig.5 that the suppression of the signal in the adjacent channel of the diplexer is more than -55 dB, while the required level is -40 dB.

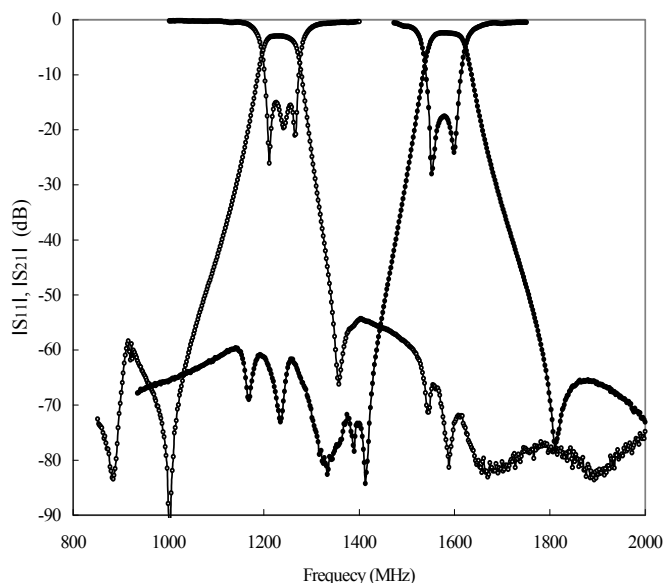


Fig. 5. The measured insertion and return loss of the $L1$ and $L2$ diplexer

If necessary, in the diplexer the $L2$ MSF can be substituted with the $L2 + L3$ MSF with the identical overall dimensions. Fig. 6 demonstrates the measured AFR of the channel of the $L2 + L3$ combined frequency band diplexer. The MSF input and output of the frequency bands $L1$, $L2$ and $L3$ employed in the diplexer as well as MSF input and output used in LNA are stripline.

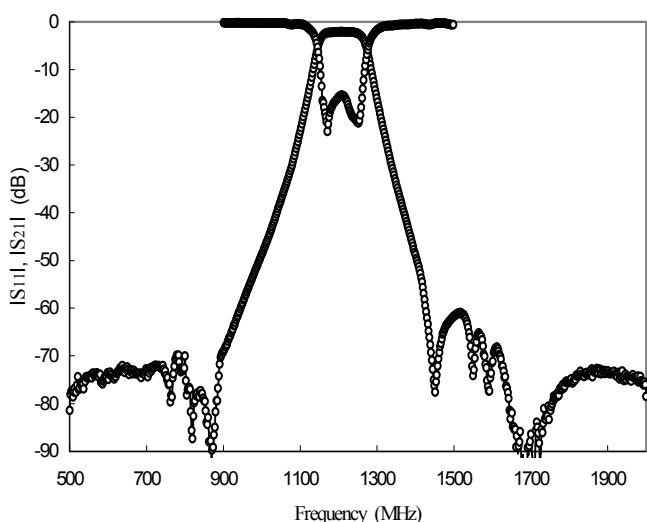


Fig. 6. The measured insertion and return loss of the $L2+L3$ filter

To increase the AFR selectivity it is possible to implement the cascade connection of two MSF of each diplexer channel by conductive-inductive coupling. With such connection of the quarter wave MSR, in contrast to half wave resonators, the low frequency mode caused by collective resonance of the coupled resonators is absent [2]. Based on these MSF a microassembly has been developed with the cascade connection of two MSF of each channel of the diplexer using conductive-inductive coupling employing the microwave amplifier. Fig. 7 presents the measured AFR of one channel of the microassembly consisting of the cascade connection of two MSF. As is seen in Fig. 7, the signal suppression in the stop band of the MSF cascade coupling is more than -70 dB.

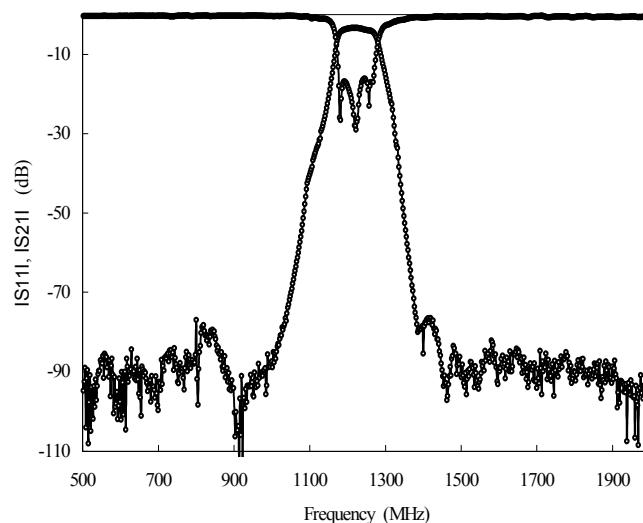


Fig. 7. The measured insertion and return losses of the cascade connection of the diplexer channels

III. CONCLUSION

The designed MSF and diplexer of the combined bandwidth of the global navigation satellite systems «GLONASS», «GPS» and «GALILEO» have been subjected to thermal tests (+70 - 50°C) and vibration testing. Their serial production has been started. Also, individual MSF for each frequency bandwidth have been developed.

It should be noted that when designing these MSF, their capability for serial production with minimal interference of the regulator is taken into account.

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