Microstrip Filter with Suppression of Spurious-Bands

V.M. Vladimirov, V.V. Markov, V.N. Shepov

Abstract – **A method of the suppression of spurious bands in the amplitude-frequency response of the filters containing microstrip resonators with the coupling performed by lumped inductances has been proposed. It has been suggested to eliminate spurious bandpass in the amplitude-frequency response of the microstrip filters. It has been achieved by substitution the electromagnetic coupling using lumped inductances connected to the resonators in certain points. This has been simulated in the one-dimensional approximation and confirmed by experiment.**

Keywords – **microstrip resonator, microstrip filter, suppression of spurious bands.**

I. Introduction

The suppression of the spurious bands in the amplitude-frequency response (AFR) of the microstrip filter (MSF) is one of the most important problems in designing a bandpass MSF. These spurious bands are due to the occurrence of the higher mode resonances of the microstrip resonators (MSR).

The solution of this problem is considered in many papers, see for example [1-5]. However, to suppress higher mode resonances in the microstrip bandpass filters is rather difficult. In these papers the MSR higher mode resonance expansion by a stepped change of the stripline conductor width allows one to obtain high levels of the spurious band suppression only in the narrow frequency range. Moreover, increasing the number of elements in such MSF results in narrowing the frequency range of the spurious band suppression due to increasing interaction between the MSR high frequency modes.

In the present work it is suggested to eliminate the electromagnetic interaction between the resonators in order to suppress spurious bands in the amplitude-frequency response of the microstrip bandpass filters. Here, the coupling between quarter-wave MSRs is realized using the lumped inductances connected to the resonators in the antinode of the high frequency current of the MSR higher modes.

II. Filter Design

Fig. 1 shows the simplest design of the four-resonator MSF with parallel coupled quarter-wave MSRs. The width of the strip conductors of four resonators is the same and amounts to 1 mm. MSF is made on a dielectric substrate with the permittivity (ε) = 80, 24 mm in length, 15 mm in width and 1 mm in thickness.

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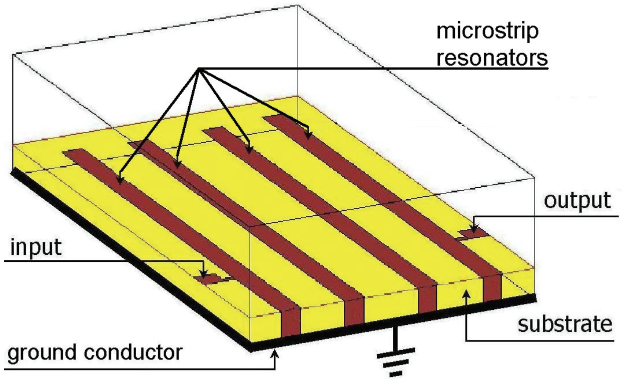

Fig. 1. Microstrip filter consisting of parallel-coupled resonators

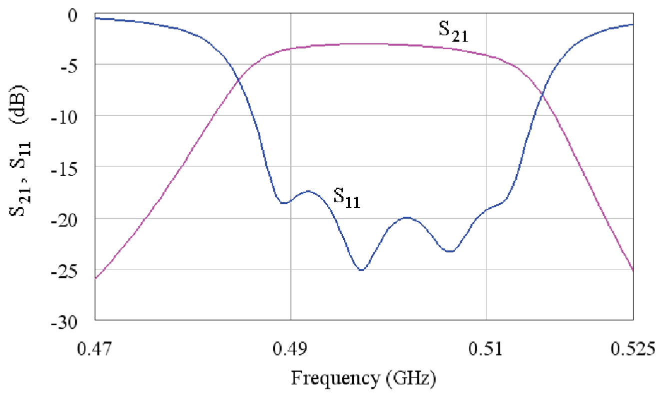

Fig. 2. Simulated results for the microstrip filter comprising parallel coupled resonators

Fig. 2 presents simulated parameters S_{11} and S_{21} of this MSF in the operating bandwidth.

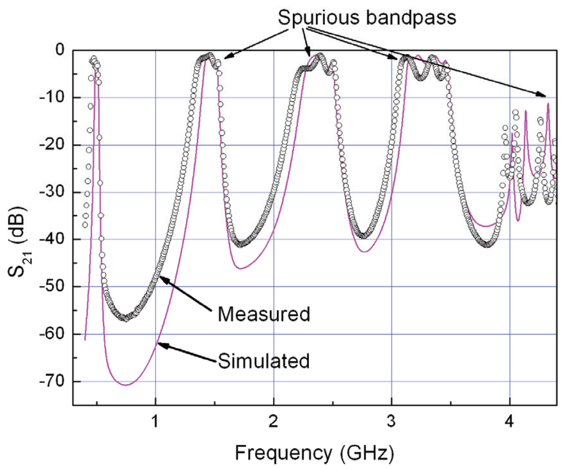

Fig. 3. Simulated and measured results S_{21} for microstrip filter comprising parallel coupled resonators in a wide band

Fig. 3 shows simulated and measured S_{21} of such MSF in a wide band. The MSF amplitude-frequency response in Fig. 3 shows that besides the main bandpass with the center frequency of 500 MHz there are additional spurious bands with the center frequency of about 1.47GHz, 2.4GHz, 3.3 GHz, 4.3 GHz and higher.

To suppress these spurious bands, consider two-resonator filter shown in Fig. 4.

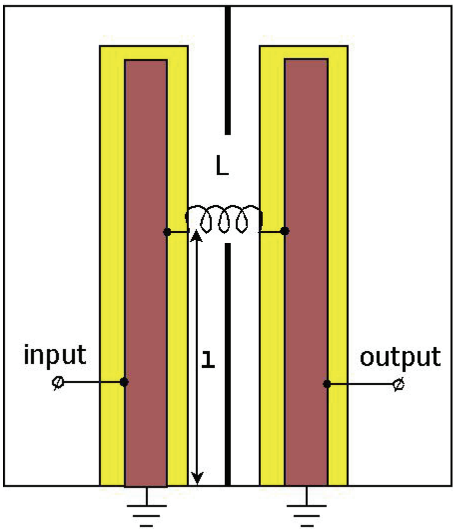

Fig. 4. Two-resonator microstrip filter with lumped inductive coupling

This filter consists of two MSRs, coupled by the lumped inductance. Each MSR is made on a separate dielectric substrate. Ceramic with the high permittivity (ε) = 80 and thickness of 1 mm was used as a substrate for MSR. This ceramic is identical to that used in the filter shown in Fig. 1. The strip conductor width of MSR is 1 mm.

To eliminate the electromagnetic interaction, MSRs are separated by a screening wall along the whole length of the resonators. The screening wall is soldered to the main screen. MSRs are coupled by the lumped inductance inserted in the aperture of the screening wall and connected to MSRs. The points of the lumped inductance coupling to MSR are chosen so that they should be in the antinode of the high frequency field for the suppressed MSR mode.

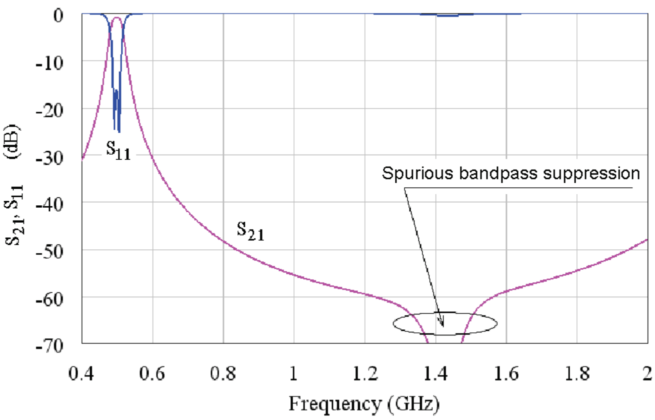

Fig. 5. Simulated results for MSF with lumped inductive coupling

Fig. 5 presents the simulated AFR of such MSF. The bandpass width and return loss in the operating bandwidth of this filter were tuned to be about the same as those of the filter shown in Fig. 1. Used as the inductive coupling was the standard inductance L, soldered to MSR at a certain distance from the strip conductor end of the resonator l, in the antinode of the high frequency field for the third (3ω0) mode of MSR. The bandpass width was tuned by the value of the lumped inductance L. Fig. 5 shows that in such filter design it is possible to effectively suppress one spurious band of the filter with the help of one lumped inductive coupling.

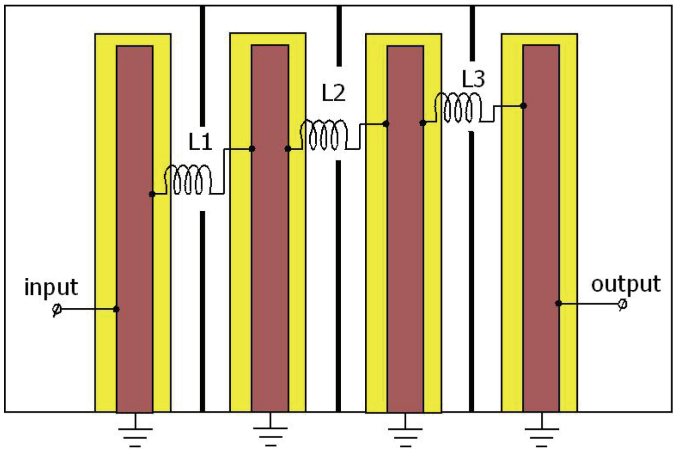

Fig. 6. Four-resonator MSF with lumped inductances

Let us apply the principle of the spurious band suppression to a multi-resonator filter. Such a four-resonator filter is presented in Fig. 6.

All MSR are made on separate dielectric substrates and coupled by the lumped inductances. The photo of this MSF is given in Fig. 7.

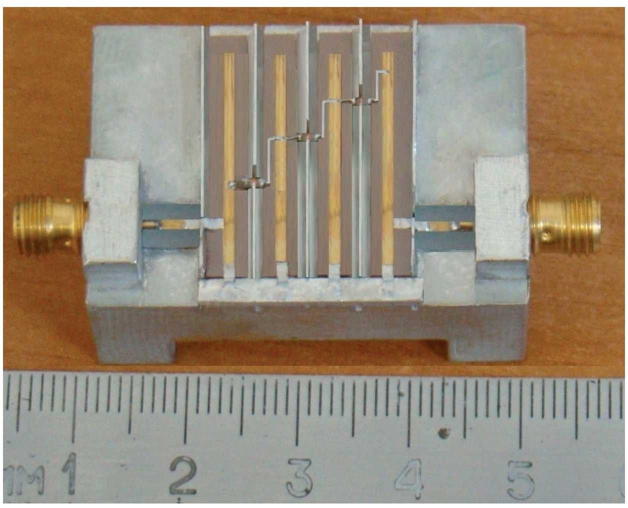

Fig. 7. Photograph of microstrip filter

The high frequency spurious bands in the filter were suppressed by choosing points of connection of the lumped inductances L1, L2 и L3 in the antinode of the high-frequency current I for the third (3ω0), fifth (5ω0) and seventh (7ω0) oscillation modes of the MSR, respectively [6]. The nineth spurious band in such a filter is suppressed when introducing the lumped inductance into the antinode of the high frequency current for 3ω0.

The coupling coefficient between the resonators in such a filter depends on the values of the lumped inductances and on the points of connection to the resonators. Since the points of the lumped inductance connection to the resonators were chosen based on the condition of the high frequency spurious band suppression, the coupling coefficient in the operating bandwidth was adjusted by the value of the lumped inductances L1, L2 and L3.

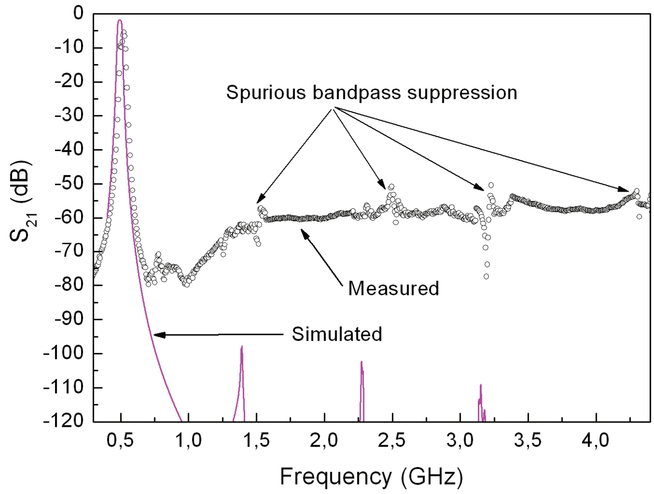

Fig. 8. Simulated and measured results for the final version of the filter design in a wide frequency band

Given in Fig. 8 is the comparison of the simulated in a one-dimensional approximation (solid line) and experimental amplitude-frequency response (points) of the filter consisting of the four microstrip resonators with lumped inductances in a wide frequency band.

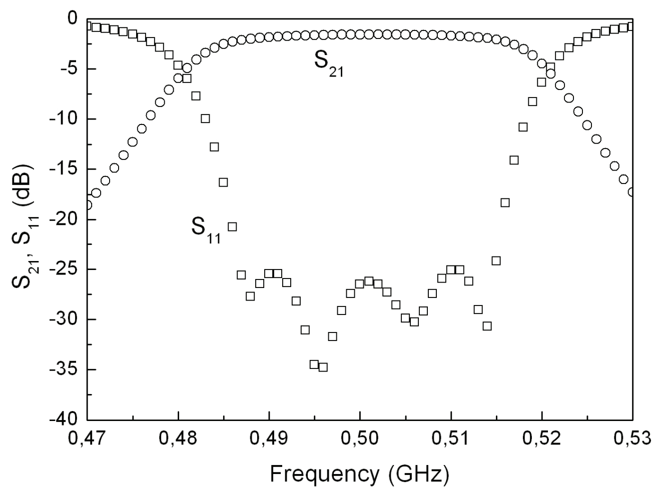

Fig. 9. Measured results for the final version of MSF in the bandpass

Figs. 8 and 9 show that there is a good agreement between the simulation in a one-dimensional approximation and the experiment in determining the width of the bandpass and stopband. However, the measured level of the stopband attenuation is somewhat lower than the simulated one. This can be accounted for by the filter response simulation error in a one-dimensional approximation and incomplete elimination of the electromagnetic interaction between MSRs in the experiment. It should be emphasized that the level of the spurious band suppression obtained by experiment in this work of at least -50 dB down to 11ω0 is not ultimate for such filter types and can be increased by more thorough screening of MSR.

Fig. 9 shows the measured direct and return losses of the filter in the operating bandwidth.

III. Conclusion

To conclude, a method of suppression of the spurious bands in the filters consisting of the microstrip resonators coupled by lumped inductances has been suggested. It has been simulated in a one-dimensional approximation and confirmed by experiment at the example of MSF using four quarter-wave resonators with lumped inductances that it is possible to considerably increase stopband attenuation in the amplitude-frequency response in the designed filter owing to the elimination of the electromagnetic couplings between the resonators, while using lumped inductances allows one to suppress spurious bandpasss.

It is worth noting that increasing the number of sections in MSF with lumped inductances would allow still greater expansion of the stopband, as opposed to MSF, where the shift of the high frequency resonances of MSR with the jump of the strip conductor width is used to suppress the spurious bands.

The actual level of the spurious band suppression in the given filter is much higher than that in MSR using the difference of the higher mode resonance frequencies of MSR with the jump of the strip conductor width to suppress spurious bands [1-5].

References

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