Printed Band-Pass Filter at L Band

Sinisa Jovanovic[*] and Aleksandar Nesic[*]

Abstract – ***This paper presents a new concept of band-pass filters with capacitive coupled resonators applied for realization of a printed filter in L band. The significant size reduction achieved by the original construction allows filter realization at these very low microwave frequencies. The agreement between the predicted and measured results is excellent.***

Index Terms – ***Bandpass filters, Microstrip, Printed circuits***

I. INTRODUCTION

Making band-pass filters at a frequency range within L-band could be a difficult task. For classical filter structures with lumped elements these frequencies could be too high due to the increasing influence of various parasitic effects within the filter's elements. In the other hand, for classical printed band-pass filters these frequencies are too low requiring impractically spacious structures that occupy a large portion of printed boards. For these reasons band-pass filters at these frequencies usually have a complex mechanical structure requiring some hand-on tuning during production.

The main goal in this paper is developing a printed filter of acceptable size at frequencies from L band. A similar goal is shared by many recent papers [1-7] in which various types of printed band-pass filters were reported.

In [1] is presented a microstrip band-pass filter at 5.3GHz with 57% reduced size relative to the smallest previously known filter of the same class, and 68% when compared with the conventional microstrip filter with coupled half-wavelength resonators [1,2]. The same concept applied on band-pass filter design in L band gives a printed microstrip filter having favorable electrical characteristics with physical size small enough for easy practical implementation and integration within various microwave subsystems.

II. CONCEPT

Fig. 1 shows a basic electric scheme of a filter that consists of four identical resonators (Q1- Q4) electrically coupled by capacitors Cr [1].

Although the scheme has only four variables: Cp, Cr, L1, and L2, by varying of their values it is possible to obtain band-pass filters at different central frequencies and with different bandwidths.

The central frequency of the filter can be approximated as:

$$f_0=(2p(L_RC_R/2)^{1/2})^{-1}, \tag{1}$$

where L_R=L1+L2 and C_R=Cp+CrCp/(Cr+Cp)

From (1) it is obvious that the same central frequency can be obtained with various combinations of the total inductance L_R and the capacitance C_R. In printed filters the parameter Cp, which is a dominant factor in C_R, can be realized as a capacitance between the ground plane and a metal patch. It is usually dominant element for the overall filter size and its reduction is desirable. However, smaller Cp requires bigger inductances L1 and L2 that, in general, occupy less space, but which increasing lead to bigger insertion loss of the filter.

The frequency of the two transmission zeros in proximity of bandpass can be approximated as:

$$f_{z1}=(2p(L1C_R)^{1/2})^{-1} \tag{2a}$$

$$f_{z2}=(2p(L2C_R)^{1/2})^{-1} \tag{2b}$$

As a result of (2), the bigger ratio K=L_1/L_2 leads to wider bandwidth and vice versa if K approaches to 1, the bandwidth approaches to 0 (for practical reasons, assume that L1=L2). For printed filter narrowing the bandwidth by lowering K also leads to the insertion loss increasing, so the overall parameter selection is a result of a compromise.

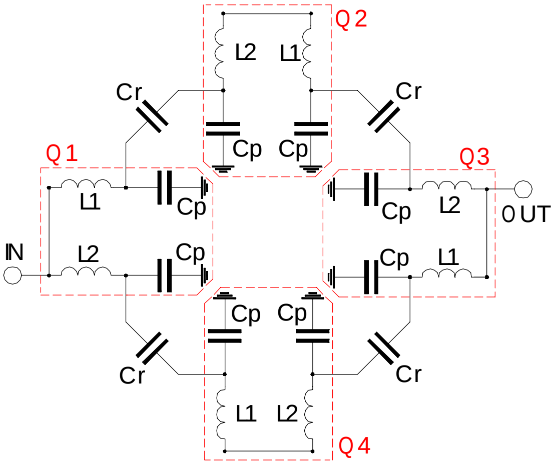

Fig.1 Basic electric scheme of a filter with capacitive coupled resonators

Fig.2. shows the response of the circuit from Fig. 1 for a set of parameter values that favor a small filter size at a center frequency of 1270 MHz.

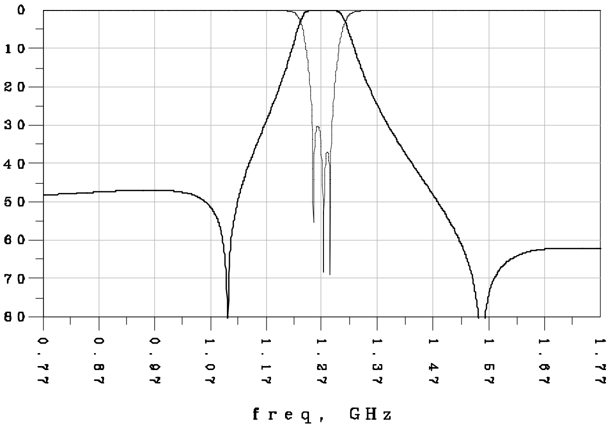

Fig.2 S21 and S11 frequency response of the circuit from Fig. 1 for the following values of lumped lossless components: Cp=2.3pF, Cr=0.15pF, L1=8.5nH, L2=4.3nH.

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III. FILTER'S DESIGN AND REALIZATION

The major challenge is to realize a printed filter that accurately corresponds to the structure presented in Fig. 1 and to precisely fabricate a set of variables' values from Fig.2, especially capacitances. One possible solution in the microstrip technique is proposed in Fig. 3.

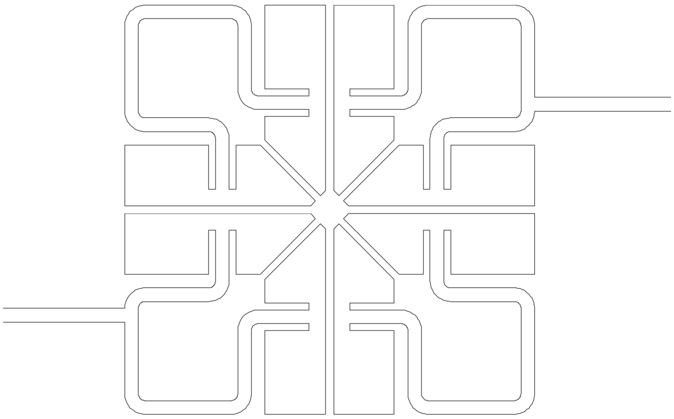

Fig.3 Layout of printed microstrip filter with capacitive coupled resonators

The overall filter is square-shaped in order to minimize the occupied space. The required inductances L1 and L2 are realized as microstrip transmission lines with Zc=50 Ohm. In case of loaded (input and output) resonators those microstrip transmission lines are divided into two unequal parts by input and output 50 Ohm-microstrip lines in order to obtain the required K ratio and to achieve the 0? feed structure [7]. The microstrip line within the resonator is meandered for minimization of the resonator and overall filter size, and terminated on both ends with wide microstrip patches that form required capacitances to ground (Cp). The coupling capacitances Cr are formed between adjacent pairs of patches belonging to the neighboring resonators.

The layout in Fig.3 introduces some parasitic elements not shown in Fig.1. The most significant among them is the capacitance Cm formed between the two capacitive patches that belong to the same resonator, and the distributed capacitance of the microstrip transmission lines. These two types of dominant parasitic elements are included in the circuit simulator scheme presented in Fig.4.

The scheme from Fig.4 is used in a circuit simulator for the first-draft optimization of the filter's layout, mainly to optimize the lengths of the microstrip transmission lines and to estimate the influence of the capacitance Cm which tends to lower the filter's center frequency and to broaden the pass band. The realization of the filter's inductances as microstrip lines causes the appearances of parasitic pass-bands that do not exist in filter with ideal lumped elements as shown in Fig.5.

The final fine-tuning of all layout dimensions is performed by the program for EM analysis IE3D [8]. The most sensitive dimension of the filter's layout is the width of the gap between the resonators because it dominantly influences the value of coupling capacitance Cr. Results of EM analysis are presented in Fig.6. These results differ from the circuit simulator results for losses taken into account by the EM simulator.

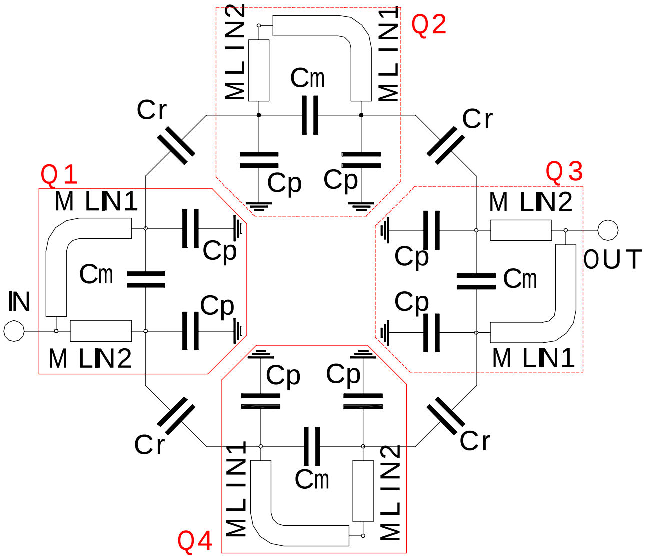

Fig.4 Circuit simulator scheme with added parasitic capacitance Cm and inductances L1 and L2 realized as microstrip transmission lines MLIN1 and MLIN2

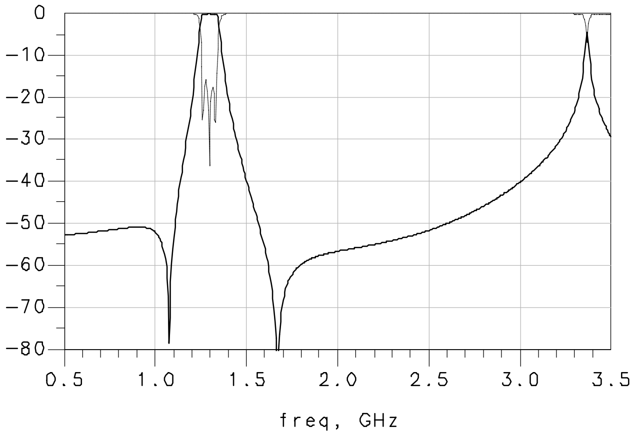

Fig.5 Circuit simulator results for S21 and S11 frequency response of the circuit from Fig. 4

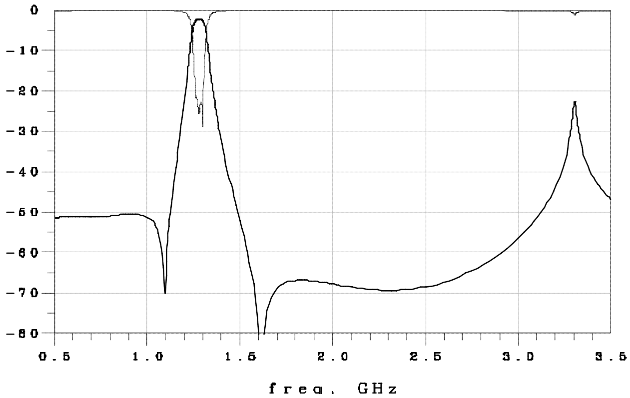

Fig.6 EM simulation results for S21 and S11 frequency response

IV. MEASURED RESULTS

The filter is realized on the dielectric substrate RO3010 (Er=10.2, h=0.635mm) at the center frequency of 1270MHz. It is possible to use dielectric substrates with lower Er, but it would increase the overall filter size, however, thinner substrates allow smaller filter size. Fig. 7 presents a picture of the realized filter. The filter is square-shaped with dimensions 16.5x16.5mm. This size makes it suitable for integration within various microwave subsystems.

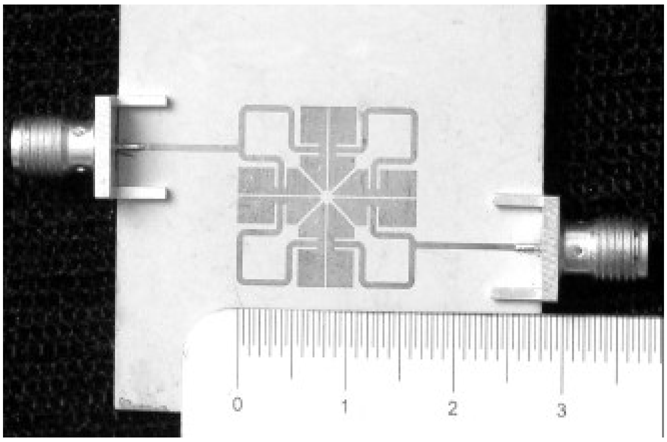

Fig.7 Photograph of realized filter

Fig.8 shows measured results of filter's S21 and S11 frequency response in range from 0.77 to 1.77 GHz, while Fig. 9. shows response from 0.5 to 3.5 GHz.

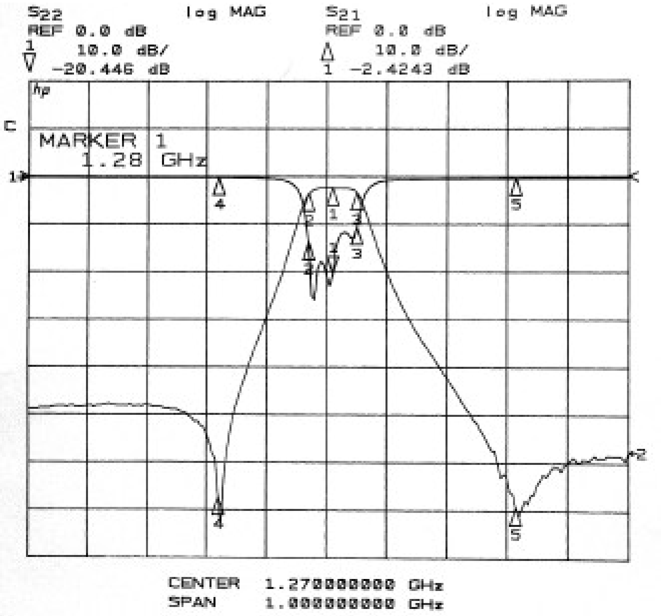

Fig.8 Measured S21 and S11 frequency response in 1GHz span around center frequency

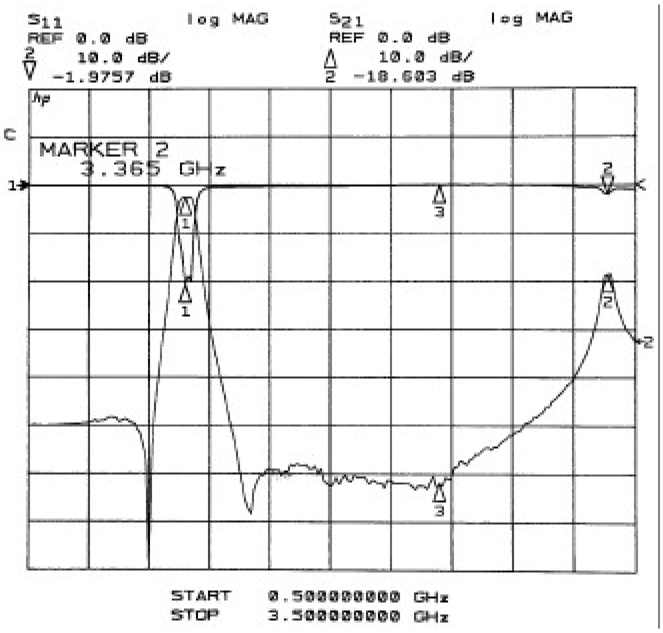

Fig.9 Measured frequency response from 0.5 to 3.5 GHz

The agreement between the measured results and the results from EM analysis is excellent, and even the circuit simulator gives a very good prediction for the filter characteristics. The realized filter has a pass-band at a central frequency of 1280MHz, which is less than 0.8% higher than designed. This difference is caused by tolerances during the filter's fabrication. The biggest influence comes from the width of the microstrip transmission lines within the filter's resonators. The insertion loss at a central frequency is 2.4 dB. The measured 3 dB bandwidth is 7.6%, while 1 dB bandwidth is 6.3% with return loss in the same frequency range better than 12 dB. The attenuation in lower stop-band is around -50dB and around -60dB in upper stop-band. The first spurious resonance occurs at 3.365GHz, which is 2.63 f_0, so that the insertion loss at $2f_0$ is 62 dB. The S21 frequency response has two deep minimums of –70 dB at 0.851 f_0 and at $1.238f_0$.

V. CONCLUSION

A printed band-pass filter realized at a very low microwave frequency is presented. Because of its simple structure the filter is very easy for design and realization. The agreement between simulated and measured results is excellent. Other advantages are wide rejection band that is extended beyond 2fc and deep transmission zeros in proximity of both ends of the pass-band region. Besides microstrip, the proposed concept is suitable for multilayer structures that could allow even smaller overall size.

ACKNOWLEDGMENT

The authors would like to thank M. Marijanovic and M. Tasic for their help in realization of the experimental models. This work is supported by the Ministry of Science and Environmental Protection of the Republic of Serbia.

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