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Design of Thick Film Microstrip Lowpass Filters

Vesna Crnojević-Bengin[1], Đurađ Budimir[2]

Abstract - **This paper presents the CAD of RF and microwave filters such as shielded single layer thick film lowpass filters for wireless communication systems. The performances of the filter were investigated and the optimisation of filter elements was performed.**

Key-Words - **CAD, Thick Film Microstrip, Lowpass filters.**

I. INTRODUCTION

The wireless communications market has experienced a rapid growth in the last several years. As a result, frequency usage and commercial wireless applications have continued to move toward the millimetre wave regime, bringing new demands for low-cost, miniaturized, high-volume packages and multi-chip modules. As the level of integration and the operating frequency increase, coupling between components and parasitic reactance within the package play a greater role in the package design, resulting in new technologies for the production of microwave and millimetre-wave integrated circuits (MICs).

Thick films are produced by screening patterns of conducting and insulating materials on ceramic substrates. The technique is used to produce only passive elements, such as resistors and capacitors. Thick-film manufacturing process can be divided into three stages: screen printing, firing and laser trimming and these stages are repeated as many times as needed.

Thick-film technology offers a high level of integration at low costs, and is very suitable for production of custom circuits. In addition to circuit size and weight reductions over standard PCB packaging, it simplifies assembly and offers improvements in circuit performances, achieved by shortened circuit paths and closer spacing that yield reduced noise pickup, enhanced thermal coupling, and improved stability.

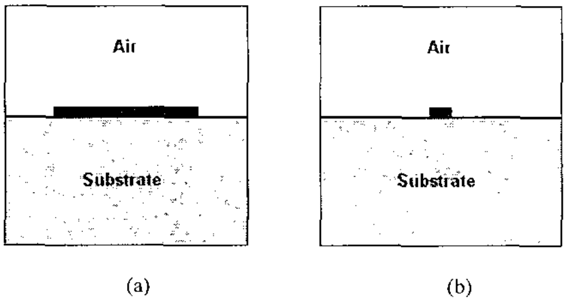
In this paper a shielded single layer thick film lowpass filter (TF LPF) is presented. The filter is Chebyshev type, the 5th order. Stepped-impedance method is used in the design of the filter, where high and low impedance lines sections are cascaded together. Thick film parameters, such as dielectric thickness, metallization thickness and minimum line width are in accordance with those realizable with TF process available in Serbia and Montenegro.

Filter specifications are as follows:

- Cut-off frequency f_c=2 GHz at –3 dB,
- Insertion loss L_I=-20 dB at 3 GHz,
- Pass band ripple $\varepsilon<0.2$,
- Characteristic impedance of the inductive line Z_{0L}=80 Ω,
- Characteristic impedance of the capacitive line Z_{0C}=20 Ω.

II. CONFIGURATION

The 5th order single layer TF LPF on 96% alumina substrate (εr=9, TanD=0.0006, roughness 20 μm) having height of 650 μm is considered. Filter is placed in a metal box, filled with air. The height of the air layer is 10 mm. Metallization layer is 10 μm thick. The cross-section of low (a) and high (b) impedance TF microstrip lines and 3D view of the filter are shown in Figs.1 and 2, respectively.



(a) (b)

Fig.1. Cross section of low (a) and high (b) impedance TF microstrip lines

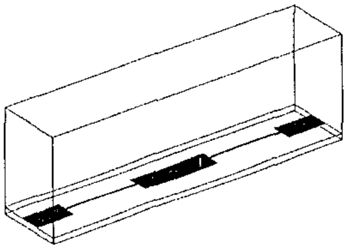


Fig.2. TF LPF, 3D view

Microstrip line widths are 200 μm for inductive and 2.9 mm for capacitive line. Microstrip line lengths were obtained by Akello's relationships for alumina substrates, [2] :

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$L' = 7.82 \cdot 10^{-3} \cdot Z_0 + 0.03$ [nH/mm], if $20 \leq Z_0 \leq 110\ \Omega$ (1)
$C' = 88.9 \cdot 10^{-3} \cdot w/h + 0.08$ [pF/mm], for $0.5 \leq w/h \leq 6$ (2)

Filter components values were obtained from the 5th order Chebyshev LPF parameters. The corresponding widths and lengths of the metallization pattern of the TF LPF are shown in Table 1.

TABLE 1.
PARAMETER VALUES FOR THE TF LPF

Filter comp.	Comp. value	Line impedance, [Ω]	Width	Length	Length value, [mm]
C1	1.1 pF	20	2.9 mm	P1	2.53
L2	7.3 nH	80	200 μm	P2	11.88
C3	3.5 pF	20	2.9 mm	P3	8.05
L4	7.3 nH	80	200 μm	P2	11.85
C5	1.1 pF	20	2.9 mm	P1	2.53

Software package *Sonnet 8.51-Lite* was used for the electromagnetic simulations of the filter. The corresponding s_{11} and s_{21} responses of the proposed filter are shown in Fig.3. It can be seen that the filter does not meet the specifications and, therefore, optimisation is required.

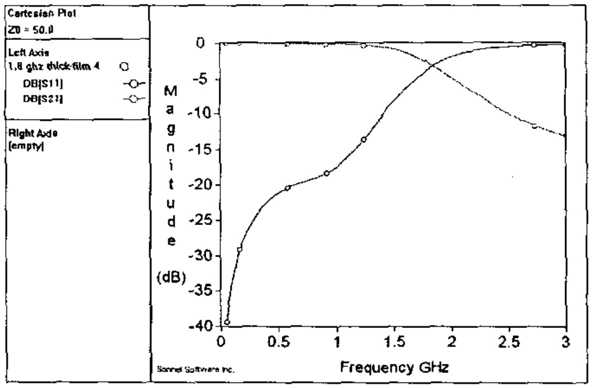

Fig.3. TF LPF response prior to optimisation

III. SIMULATED RESULTS

Ansoft's software package *Serenade SV 8.5* was used for the optimisation of the filter, as well as Agilent's *Advanced Design System*. Frequency range used in simulations was set to [0MHz, 3.5GHz], step size 10MHz. In optimisation procedure lengths of elements **P1**, **P2** and **P3** were varied, while widths values were fixed. Initial lengths were set to values obtained by Akkelo's relations, Table 1.

Optimisation goals are shown in Table 2.

Method of optimisation was *random* and optimisation goals were reached after approx. 500 iterations. Obtained microstrip line lengths are shown in Table 3.

TABLE 2.
OPTIMIZATION GOALS

Frequency range, [GHz]	Goal
0.5 GHz – 2 GHz	$s_{21} > -3$ dB
3 GHz	$s_{21} = -20$ dB
3.1 GHz - 3.5 GHz	$s_{21} > -20$ dB

TABLE 3.
OPTIMIZATION RESULTS

Length	Length value, [mm]
P1	4.9
P2	8.8
P3	7.4

The corresponding s_{11} and s_{21} responses of the optimised filter are shown in Fig.4. The filter meets the specifications, exhibiting attenuation of –3 dB at 2 GHz and –20 dB at 3 GHz.

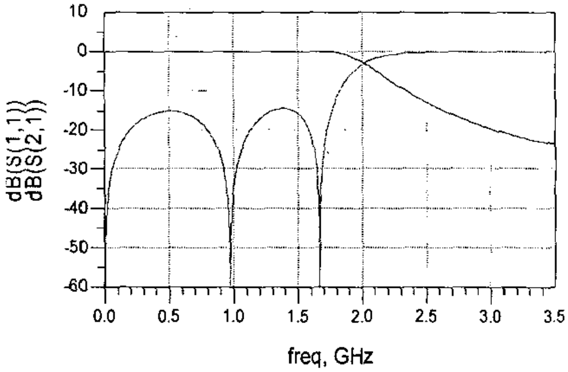

Fig. 4. TF LPF response after optimisation

The enlarged detail shown in Fig. 5, illustrates low pass band ripple factor (less than 0.16dB).

IV. CONCLUSION

In this paper a single layer thick film microstrip lowpass filter has been presented. The performances of the filter were investigated with electromagnetic simulations and the optimisation of microstrip lines lengths was performed. The resulting filter conforms to the required specifications. All parameters related to thick film process, such as dielectric

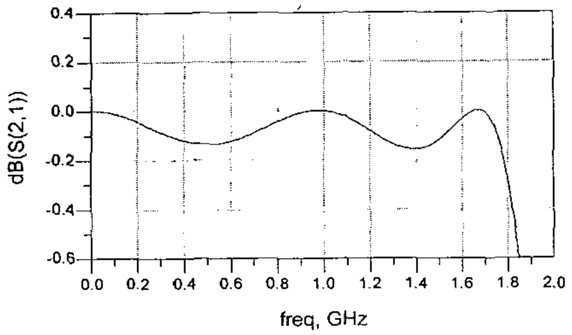

Fig. 5. TF LPF response after optimisation, detail

thickness, metallization thickness and minimum line width were in accordance with those realizable in Serbia and Montenegro.

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