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A Planar High Pass Filter with Quasilumped Elements for ISM, Wimax and Wlan Applications

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Abstract*—This paper presents a quasilumped Microstrip structure High Pass Filter having a cutoff frequency 2.5 GHz. The quasilumped elements are used with the objective of obtaining the behavior of a high-pass filter with high bandwidth, reducing the size of the filter and improving the electrical performances. The proposed filter is designed on an FR-4 substrate having a thickness of 1.6mm, a dielectric permittivity constant of 4.4 and loss tangent of 0.025. The proposed filter is optimized and validated by using three electromagnetic solvers (ADS, HFSS and CST-MWS).The whole area of the proposed circuit is 19 x 16 mm2.

***Keywords*—Microstrip High pass filter, quasilumped element.**

I. INTRODUCTION

Modern Telecommunications systems are reaching an increasingly large number of people, which leads inexorably to intensive use of the microwave range. In many applications, the low in-band and wide-band stop filter is very important because it can significantly improve the signal quality in the band by removing as much of the built-in power from out-of-band interference as possible. In addition, the filter should be compact and inexpensive to manufacture.

A filter is an electronic circuit, characterized by a transfer function, which performs a signal processing operation. It is based on the coupling between several resonant cells which ultimately form a certain model in terms of losses, transmission and reflection. It attenuates certain components of a signal on one frequency band and lets others pass in another frequency band called bandwidth.

Planar technologies consist of a substrate which is in the form of a dielectric plate. Thin metallic layers are deposited on one or both sides of the substrate.

The filter in localized elements consists of capacitors in series and inductors in parallel. Its behavior at low frequencies remains respectable, but when the frequency is increased this set loses its efficiency, hence the transition to Microstrip technology [1-3].

A high pass filter is a filter that lets high frequencies through and attenuates low frequencies, that is, frequencies below the cutoff frequency. High-pass Microstrip filters can also be designed by using more modelling techniques to obtain more precise and faster performance, among these techniques we find the QLE techniques [5-7].

Quasi lumped element (QLE) filters have a size advantage over distributed filters. QLE filters could be smaller than equivalent distributed filters and can realise filters with large bandwidths [4].

High pass filters constructed from quasilumped elements may be desirable for many applications, provided that these elements can achieve good approximation of desired lumped elements over the entire operating frequency band [8-11].

To obtain the parameters of a high pass filter with QLE we use the following equations [2]:

$$C(pF) = 3.937\times10^{-5}\, l(\varepsilon_r + 1)\left[0.11(n-3)+0.252\right] \quad (1)$$

With n is the number of fingers, w is the width of the fingers. For n given, it is necessary to respect the two conditions:

$$w \geq s \text{ and } h \gg w$$

Where s is the space between the fingers and h the height of the substrate.

And for the dimensions of the short-circuited stub which the equivalent of the inductance we can use the following equations:

$$jZ_c \tan\left(\frac{2\pi l}{\lambda_{gc}}\right) = j\omega_c L_2 \quad (2)$$

For $W/h \geq 1$

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-0.5} \quad (3)$$

$$Zc = \frac{\eta}{\sqrt{\varepsilon_{re}}}\left\{\frac{W}{h} + 1.393 + 0.677 \ln\left(\frac{W}{h} + 1.444\right)\right\}^{-1} \quad (4)$$

With η=120π Ohm

$$\lambda_g = \frac{300}{f(GHz)\sqrt{\varepsilon_{re}}} mm \quad (5)$$

$$\beta = 2\pi / \lambda_g \quad and \quad \theta = \beta l \quad (6)$$

II. DESIGN SPECIFICATIONS

The filter in localized elements consists of capacitors in series and inductances in parallel.Fig.1. Its behavior at low frequencies remains respectable, but when the frequency is increased, this assembly loses its efficiency, hence the switch to Microstrip technology.

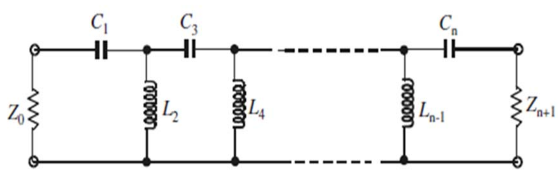

Fig. 1. high-pass filter in localized elements

The calculation of low pass filters allows the calculation of high pass filters. For that one can pass by the law of chebyshev. Using the Fig.2, the values of the coefficients g_i can be determined.

For passband ripple L_{Ar} = 0.1 dB

n	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}
1	0.3052	1.0								
2	0.8431	0.6220	1.3554							
3	1.0316	1.1474	1.0316	1.0						
4	1.1088	1.3062	1.7704	0.8181	1.3554					
5	1.1468	1.3712	1.9750	1.3712	1.1468	1.0				
6	1.1681	1.4040	2.0562	1.5171	1.9029	0.8618	1.3554			
7	1.1812	1.4228	2.0967	1.5734	2.0967	1.4228	1.1812	1.0		
8	1.1898	1.4346	2.1199	1.6010	2.1700	1.5641	1.9445	0.8778	1.3554	
9	1.1957	1.4426	2.1346	1.6167	2.2054	1.6167	2.1346	1.4426	1.1957	1.0

Fig. 2. Coefficients gi

We have used the equations (7) and (8) to determine the values of the components of the filters.

$$C_i = \frac{1}{Z_0 \omega_c \Omega_c g_i} \quad (7)$$

$$L_i = \frac{Z_0}{\omega_c \Omega_c g_i} \quad (8)$$

III. DESIGN AND SIMULATION RESULTS

In this paper, a highpass filter having a cutoff frequency 2.5 GHz has been validated, the configuration of the proposed filter is shown in the Fg.3. The proposed HPF shows a passband from 2.4 GHz to 7 GHz. In order to validate the different calculations, the proposed filter has been simulated by using ADS, it is printed on a low cost FR-4 substrate with a dielectric constant εr = 4.4, a thickness h=1.6 mm, a loss tangent tan (δ) = 0.025 and a metal thickness of t=0.035 mm.

The optimized parameters of the proposed filter are illustrated in TABLE.I.

TABLE I. DIMENSION OF THE PROPOSED FILTER

Parameter	Value
C(pF)	1.03
L(nH)	2.31

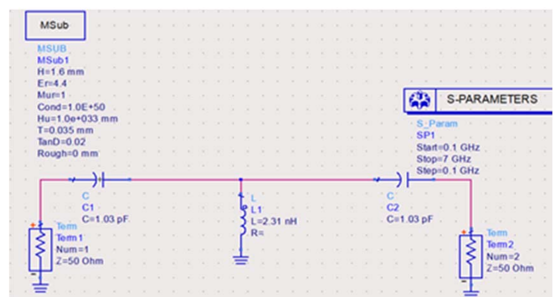

Fig. 3. Design of proposed filter with localized elements simulated by ADS

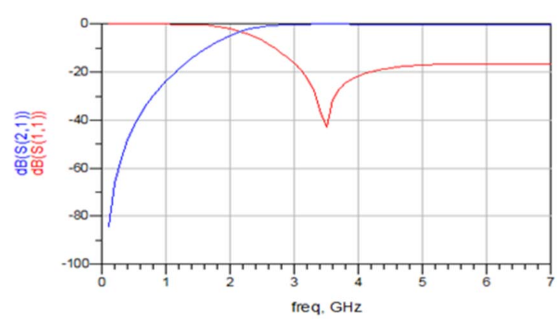

Fig. 4. S-parameters versus frequency of the proposed filter.

To determine the dimensions of the interdigital capacitor we have used the equation (1) and the dimensions of the short-circuited section, we have also used the equations (2-6).

The optimized parameters of the High pass filter with quasilumped elements are illustrated in TABLE.II.

TABLE II. DIMENSION OF THE QUASILUMPED ELEMENTS OF THE PROPOSED FILTER

Parameter	Value (mm)
l(C)	4.7
w(C)	0.3
l(L)	3
w(L)	2.2

After many series of optimization and from the dimensions in TABLE II, we have simulated the design by two identical interdigital capacitors, and the shunt inductor, we have obtained the different results shown in Fig.5

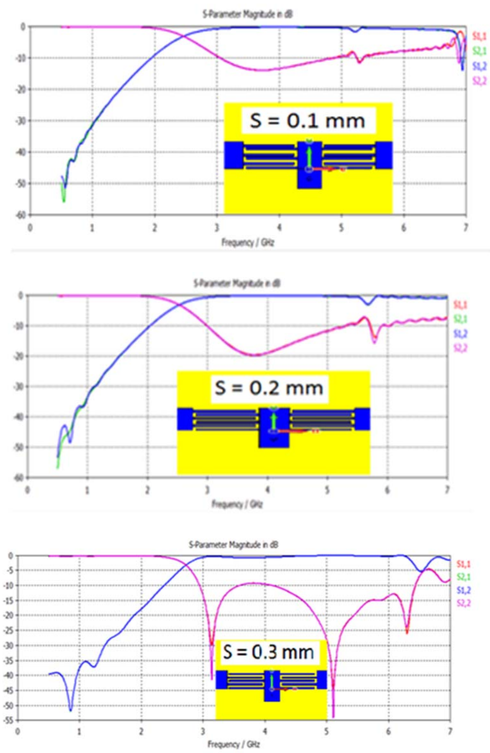

Fig. 5. S parameters versus frequency in GHz.

For s = 0.2 mm, we get a response from a high pass filter, we notice a good improvement in bandwidth (Fig.6). The instability in bandwidth is due to the quasilumped elements.

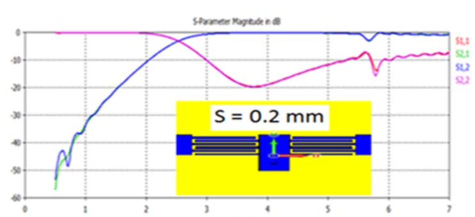

Fig. 6. Design, S-parameters and the bandwidth of proposed filter with quasilumped elements simulated by CST

In order to verify the simulation results obtained in CST-MW, we have conducted the same study by using another electromagnetic solver which is HFSS. We can see that we have a HPF behavior with a slight difference which is due to the different numerical methods used in these electromagnetic solvers as shown in Fig.7.

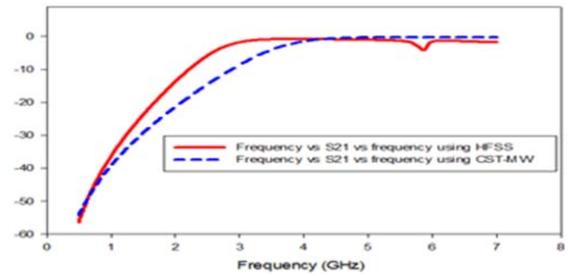

Fig. 7. A comparison between the simulation results of the proposed filter under CST and HFSS solver.

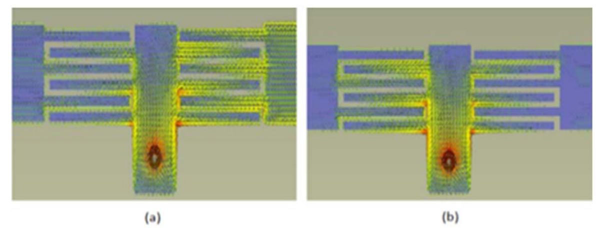

Fig. 8. Current distributions of the proposed filter at (a) at 2.2 GHz and (b) at 3.6 GHz

Fig.8 describes the surface current results of the designed HPF at 2.2 GHz and 3.6 GHz, the first frequency in the rejection band and the second one in the bandwidth. As we can see for 2.2 GHz we have a high attenuation of the signal but for 3.6 GHz the signal passes from port 1 to port2 which validate the proposed HPF.

IV. CONCLUSION

In this study, we have validated a planar Compact high-pass filter based on Quasi-lumped Elements. This proposed circuit was designed and optimized by using two electromagnetic solvers ADS and CST Microwave studio and the results were verified by using HFSS. The proposed filter is mounted on an FR4 substrate. This HPF is suitable for ISM, Wimax and Wlan applications.

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