Design of Multiband-Filters for Mobile Radio Applications

Mohamed Karim LAOUFI [1], Slimane MEKAOUI[1], Mohamed Lamine TOUNSI [2]

[1] Laboratoire LCPTS, Faculty of electrical engineering, USTHB University, Algiers, Algeria
[2]Laboratoire LCDEP, Faculty of electrical engineering, USTHB University, Algiers, Algeria
E-mail: mltounsi@ieee.org

Abstract

In this paper, a new multi-standard filter with four resonance frequencies is proposed for radio-mobile including GSM/4G LTE, WLAN and 5 G applications. The design and synthesis is resolved using a new formulation of the FDTD method. The metal finite conductivity and thickness are rigorously taken into account. The FDTD computed results are in good agreement with simulated data obtained with CST electromagnetic tool.

1. Introduction

With the increasing development of multi-service wireless communication networks, it has become essential to synthesize microwave systems and components with various modern communication standards [1]. Furthermore, in order to satisfy the strict constraints related to high-speed and high-capacity transmission, future mobile communication systems must use simultaneously several frequency bands in a single circuit [2]. Thus, transceivers operating on multiple bands are highly preferred [3]. Recently, there has been a strong demand for planar filters with multiple resonances, compact size, low insertion losses and low integration cost [4],[5]. Several prototypes of two-, three-, and four-band planar filters have been proposed [3]. However, without increasing the effective size of the filter, it becomes difficult to combine multiple frequencies on a single circuit [6]. Therefore, using a single multi-band filter operating at different frequencies can only reduce the overall size of system [7],[8]. In [9], the frequency transformation method is employed. The authors are based on the parallel association of one band-pass resonator and three band-stop ones to generate four resonance frequencies in a lumped-element configuration. In [10], quad band band-pass filters (BPFs) was presented using stub loaded resonators (SLR). The proposed resonator has been analyzed using even–odd mode approach. In [11], quad-band (BPFs) were realized by using stepped-impedance coupled-line quad-mode resonators (SICLQMRs). Multi-section parallel and interdigital coupling structure are used in this design.

In this paper, we propose a new topology of a multi-band filter that can be used simultaneously for GSM/4G LTE (around 1.8 GHz), 5G (3.5 GHz) and WLAN (5.42 GHz) applications. The design of the proposed filter is resolved in fullwave-mode using a new FDTD formalism which simultaneously takes into account the finite conductivity as well as the thickness of the metallic thin film. We note also that the proposed update equations remain applicable for any planar structure with an imperfect thin film conductor with an arbitrary number of metallization levels.

2. Modified FDTD Algorithm

First, we present a modified FDTD formulation to model imperfect metallic thin films [12], which consider the finite conductivity and thickness. The tangential components (parallel to the plane of the circuit) are given by:

$$E_x^{n+1}(m+\frac{1}{2},p_c,q) = AE_x^c.E_x^n(m+\frac{1}{2},p_c,q) + E_{x1}^n(m,p_c,q) + E_{x2}^n(m,p_c,q) \quad (1.1)$$

$$E_z^{n+1}(m,p_c,q+\frac{1}{2}) = AE_z^c.E_Z^n(m,p_c,q+\frac{1}{2}) + E_{z1}^n(m,p_c,q) + E_{z2}^n(m,p_c,q) \quad (1.2)$$

$$E_{x1}^n(m,p_c,q) = BE_x^c.[\, H_z^{n+\frac{1}{2}}(m+\frac{1}{2},p_c+\frac{1}{2},q) - H_z^{n+\frac{1}{2}}(m+\frac{1}{2},p_c-\frac{1}{2},q)] \quad (2.1)$$

$$E_{x2}^n(m,p_c,q) = CE_x^c.[H_y^{n+\frac{1}{2}}(m+\frac{1}{2},p_c,q+\frac{1}{2}) - H_y^{n+\frac{1}{2}}(m+\frac{1}{2},p_c,q-\frac{1}{2})] \quad (2.2)$$

$$E_{z1}^n(m,p_c,q) = BE_Z^c.[H_y^{n+\frac{1}{2}}(m+\frac{1}{2},p_c,q+\frac{1}{2}) - H_y^{n+\frac{1}{2}}(m-\frac{1}{2},p_c+\frac{1}{2},q)] \quad (2.3)$$

$$E_{z2}^n(m,p_c,q) = CE_Z^c.[H_x^{n+\frac{1}{2}}(m,p_c+\frac{1}{2},q+\frac{1}{2}) - H_x^{n+\frac{1}{2}}(m,p_c-\frac{1}{2},q+\frac{1}{2})] \quad (2.4)$$

The coefficients AE_u^c, BE_u^c and CE_u^c (u=x or z) are given in [13]. Equations (1) are expressed at instant $(n+1)\Delta t$. Δt is the time step, while m and q denote the mesh indices along the x and z directions respectively, p_c refers to the index corresponding to the metalized interface [14].

3. Design of multi-band filters

In this part, the proposed FDTD algorithm is applied to the synthesis of a shielded filter with four pass bands. Two forms of resonators (S and L shaped) are considered. The inter-resonator coupling essentially depends on the distance S separating them. The resonators are parallel coupled and judiciously placed in order to obtain the desired specification filter. The chosen substrate and conductor are respectively alumina (ε_r=9.4) and copper (σ=5.8. 10^6 S/m, thickness t= 5 μm). The shield height is b=9.92 mm. The dimensions of the filter are (figure 1): L_x=2.54 mm, L_z=10.04 mm, L=26.77 mm, w=1.42 mm, s=0.87 mm, G=1.9 mm, a=23.18 mm, h=1.86 mm. Figures 2 and 3 illustrate respectively the insertion loss and the return loss versus frequency. A good agreement is obtained compared to data simulated with CST commercial software. Table 1 shows better performance especially in terms of return loss (RL) compared to some 4-band filters [15] [16].

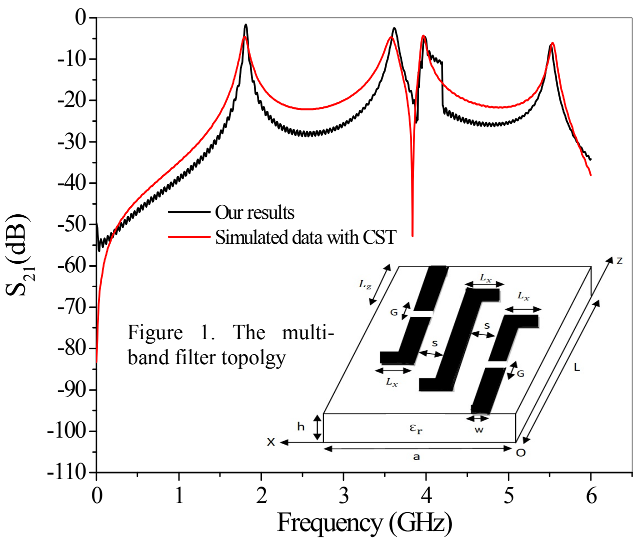

Figure 2: Insertion losses versus frequency

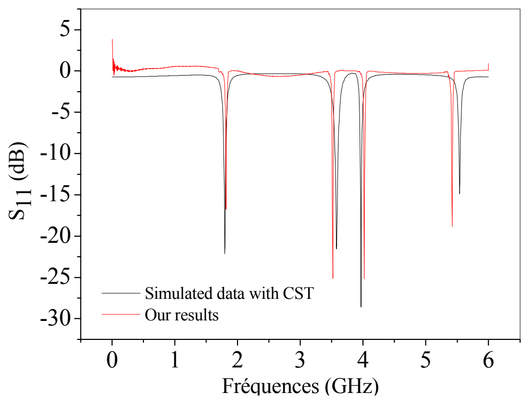

Figure 3: Return loss versus frequency

Table 1: Comparison results with other works

Réf	$f_1/f_2/f_3/f_4$ (GHz)	IL (dB)	ISO (dB)	RL (dB)	Size/λ_g
[15]	1.55/2.2 3.45/5.3	2.9	12	10	0.5x0.36
[16]	2.46/3.41/ 6.65/9.09	2.23	26	14	0.59x0.26
Our results	1.78/3.5 3.88/5.42	3.5	31	15	0.42x0.48

(IL: insertion losses, ISO: minimum isolation between bandwidths, RL : minimum return loss)

4. Conclusion

In this paper, a new design of quad-band shielded BPFs was proposed for GSM/4G LTE, WLAN and 5G applications. Good performances have been obtained comparing to other works: the filter is compact, the isolation between resonances is greater than 31 dB, the insertion losses do not exceed 3.5 dB. A good matching is also signaled (greater than 15 dB). In addition, the particularity of the proposed filter is that the topology is relatively simple than those reported in the literature. Finally, a modified formulation of the FDTD algorithm has been proposed to rigorously taking into account the finite conductivity of the metallic thin film as well as its thickness. Note that this technique can be further extended to any planar structure with an imperfect thin film conductor and an arbitrary number of metallization levels.

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