Shielded Micro machined Micro strip Lines Form Ultra-Wideband Band pass Filters

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ABSTRACT

Using the method of moments (MoM) the analysis and the design of a compact ultra wideband (UWB) bandpass filter using shielded micromachined microstrip lines are presented. The design of the UWB filter is based on the use of impedance steps and coupled-line sections. The center frequency around 6.85 GHz was selected, the bandwidth is between 4-10 GHz, the insertion-loss amounts to around 0.02 dB and the return loss is found higher than 20 dB in a large frequency range (4.8-9 GHz). For the selected center frequency and on a substrate with a dielectric constant of 11.7, the micromachined microstrip filter is only 0.1 × 0.5 × 17.45 mm in size.

Keywords **- Analysis and design, compact filter, micromachined microstrip filter, MoM method, ultra wideband bandpass filter.**

I. INTRODUCTION

Today's microwave and millimeter-wave markets are driving three important requirements: low cost, performance and small size. Silicon micromachining has been applied to microwave and millimeter-wave circuits in many ways since its introduction in the late 1980s. Micromachining, or sculpting crystal Si can be made using either orientation dependent (anisotropic) or orientation-independent (isotropic) etchants. Silicon micromachined, dielectric membrane supported structures, such as antennas, transmission lines and filters have shown improved performance and have extended the operating range of planar circuits to W-band frequencies and beyond [1-3]. In addition, silicon micromachined-based packaging provides a high isolation self-package without the need for external carriers or external hermetic shielding. This method of circuit integration provides a comprehensive technique to integrate a very large degree of functionality with extremely high density and at a relatively low cost.

The vertically layered structure of the micromachined circuit presents an excellent opportunity for three-dimensional integration, resulting in the potential for substantial reductions in size. Micromachined circuits are an ideal way to integrate MEMS devices and provide components with performance and size advantages from 1 GHz to terahertz regime. However, they demonstrate their greatest promise at K-band and above. Micromachining is truly an excellent integration technology with the opportunity for an order of magnitude or more reduction in the size, weight and cost of planar circuits, which can have a major impact on radar and communications applications in the military, commercial and space arenas.

Micromachining techniques can be applied to any semiconductor substrate, but the use of Si substrate layers as the foundation of the micromachined structure has major advantages in cost and the direct integration of SiGe and CMOS circuits. High resistivity Si also has mechanical, thermal and electrical properties that compare well with the best ceramics, and as a result has been successfully demonstrated as the substrate of choice in three-dimensional integrated circuit [4]. Cost comparisons have been made for simple circuit applications and show one- and two-orders of magnitude cost reductions over the same circuit packaged in ceramic. Circuit integration based on micromachined fabrication technology promises to be the key to achieving the very demanding cost, size, weight and simplicity goals required for the next advances in communications and radar systems commercial, space and military applications.

Since the Federal Communications Commission (FCC) released the unlicensed use of ultra-wideband (UWB: 3.1 to 10.6 GHz) wireless systems in February 2002 [5], many researchers have started exploring various UWB components, devices, and systems [6], [7]. As one of the key circuit blocks in the whole system, the UWB bandpass filter (BPF) has been studied through the use of the matured filter theory [8] and other techniques [9], [10]. On the basis of impedance steps and coupled-line sections as inverter circuits, several works were interested in the design of planar broadband filters (using microstrip, striplines and CPW [11]) with low loss, compact size, high suppression of spurious responses, and improved stopband performances [11], [12].

In this article, we are interested in the study of an ultra wideband (UWB) bandpass filter using shielded micromachined microstrip lines with Si substrate. The proposed filter has a compact size and can be easily designed and fabricated.

II. SHIELDED MICROMACHINED MICROSTRIP LINES AND NUMERICAL RESOLUTION

The cross-sections of a shielded micromachined microstrip line and coupler are respectively shown in figure 1-a and 1-b. The structures are assumed to be lossless with a microstrip (w) wide and (t) thick and with a dielectric material (Si) having a relative dielectric constant of ε_{r2}=11.7. For the coupler the separation distance between the symmetrical strips is designed by (s).

Electrically, the isolated line of figure 1-a, is described in terms of its inductance and capacitance per unit length (L and C) and in term of its characteristic impedance Z_0 [13]. On the other hand, the electrical properties of the lossless and symmetrical coupler presented in figure 1-b can be described in terms of its primary parameters [L] and [C], and its secondary parameters k, Z_{0e} and Z_{0o} [13-15].

Where: $[L]=\begin{bmatrix} L_{11} & L_{12} \\ L_{21} & L_{22} \end{bmatrix}$; $[C]=\begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix}$

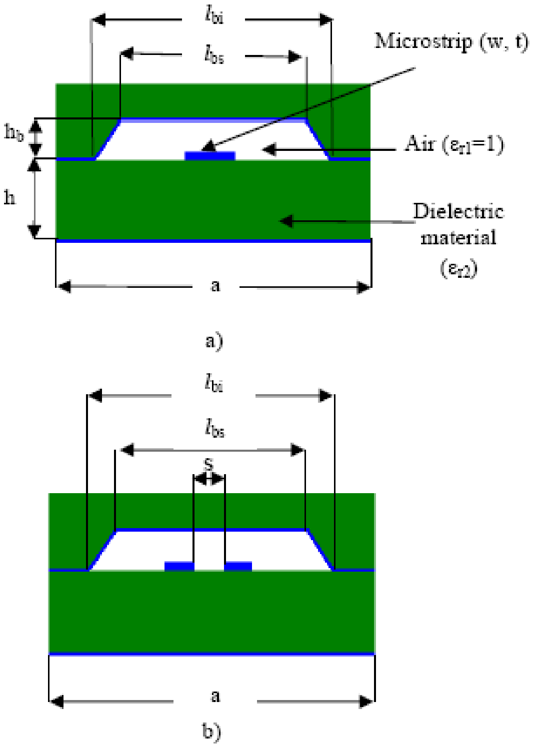

Fig. 1. Cross-sectional views of shielded micromachined microstrip (a) line and (b) coupler (MMC).

The inductance matrix [L] contains the self-inductances on the diagonal ($L_{11}=L_{22}$ are the proper inductances) and the mutual inductances ($L_{12} = L_{21}$) between the two coupled lines.

Matrix [C] accounts for the capacitative effects between the two coupled lines, characterizing the electric field energy storage in the coupler. ($C_{11}=C_{22}$) are the proper capacitances and ($C_{12}=C_{21}$) is the coupling capacitance

$k=\frac{L_{12}}{L_{11}}=\frac{C_{12}}{C_{11}}$; is the coupling coefficient and (Z_{0e}, Z_{0o}) are respectively the even and the odd mode characteristic impedances of the coupler.

The numerical calculations of these electromagnetic parameters were carried out with LINPAR for windows (Matrix Parameters for Multiconductor Transmission Lines), a 2D Method of Moments (MoM) software for numerical evaluation of the quasi static matrices for multiconductor transmission lines embedded in piecewise-homogeneous dielectrics [16]. The technique used in the program is based on an electrostatic analysis. In this analysis the dielectrics are replaced by bound charges in a vacuum, and the conducting bodies are replaced by free charges. A set of integral equations is derived for the charge distribution from the boundary conditions for the electrostatic potential and the normal component of the electric field. The method of moments is applied to these equations, with a piecewise-constant (pulse) approximation for the total charge density and the Galerkin technique. LINPAR for windows can analyze arbitrary planar transmission lines and can also analyze any other structure defined by the user.

For our study, we were obliged to supply the cross section of the structures and all relevant dielectrics characteristics including the segmentation by using our programs in FORTRAN.

When the electromagnetic parameters are determined, it is possible to estimate the resulting scattering parameters of the UWB BPF constituted by portions of shielded micromachined microstrip lines using an adapted numerical model [17].

III. ANALYSES AND DESIGN OF UWB FILTER USING MICROMACHINED MICROSTRIP LINES

Figure 2 shows the circuit of the proposed UWB BPF. An isolated micromachined microstrip line in the middle and a coupled line with micromachined coupled microstrips at the two ends [18]. To achieve the specified UWB passband, the three sections of this filter are arranged with the lengths of about one quarter-, one half-, and one quarter-wavelength, i.e., λ/4, λ/2 and λ/4, as marked in figure 2.

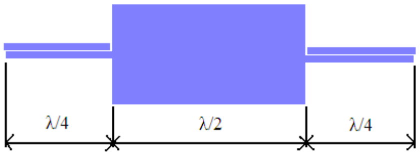

Fig. 2. The layout of the proposed UWB BPF using portions of shielded micromachined microstrip.

We applied the MoM-based numerical tool to the analysis and design of the UWB BPF using portions of shielded micromachined microstrip lines. The MoM approach makes it possible to simulate the performance of a design and decides if a given set of constraints makes it possible to realize the filter.

In order to assure for the shielded micromachined microstrip coupler a coupling coefficient of approximately 5 dB, we have varied the distance (s) between the coupled microstrips with the following features: h_b= h, l_{bs}=4h, l_{bi}=7h, a=10h, w=0.17h and t=0.02h.

The segmentation of the charged surfaces of the coupler using LINPAR is shown in figure 3.

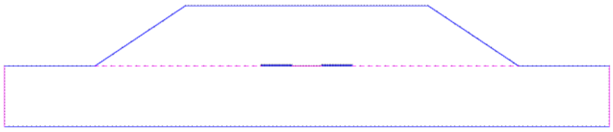

Fig. 3. Segmentation of the charged surfaces used to analyse the cross section of the coupler.

A coupling coefficient of approximately 6 dB was obtained for a separation distance s=0.1h, yielding a characteristic impedance of around $\sqrt{Z_{0e}\, Z_{0o}} = 70\ \Omega$ and primary parameters of:

$$[L]=\begin{bmatrix} 625.8 & 327.4 \\ 327.4 & 625.8 \end{bmatrix}\left(\frac{nH}{m}\right);$$

$$[C]=\begin{bmatrix} 138.4 & -68.28 \\ -68.28 & 138.4 \end{bmatrix}\left(\frac{pF}{m}\right)$$

For the middle line of the UWB BPF represented in figure 2, the value of the ratio (w/h) was varied as needed to change the characteristic impedance (Z_0).

Figure 4 shows the segmentation of the charged surfaces used to analyse the cross section of the middle line of the UWB BPF using shielded micromachined microstrip line. A low impedance of 19 Ω was chosen for the middle line of the UWB filter.

All of the dimensions and the electromagnetic parameters, obtained for the middle line are provided in table 1.

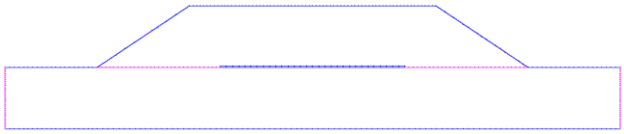

Fig. 4. The segmentation of the charged surfaces used to analyse the cross section of the middle line of the UWB BPF.

Table I: Design parameters for the middle line of the UWB BPF.

Middle line of the UWB BPF	
w/h	3
ε_r	11.7
Z_0 (Ω)	19.3
L (nH/m)	158.2
C (pF/m)	436.3

To verify the predicted electrical performance of the circuit presented in figure 2, the proposed UWB BPF using portions of shielded micromachined microstrip lines is simulated using MATPAR software [17]. The designed UWB filter occupies the overall length of 17.45 mm that is about one guided-wavelength at 6.85 GHz. Figure 5 provides plots of the resulting scattering parameters of the designed UWB BPF in the frequency range (2-12) GHz.

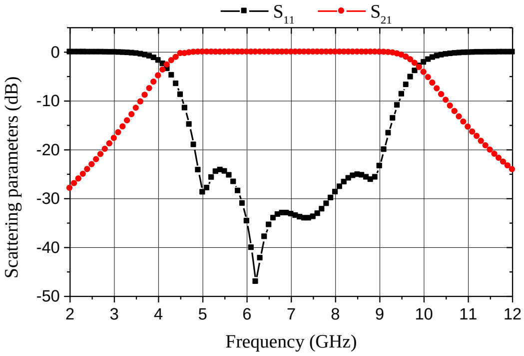

Fig. 5. Simulated responses of the designed UWB bandpass filter

It can be seen that the simulated responses of the UWB BPF with compact size obtained by using portions of shielded micromachined microstrip lines, are in very reasonable agreement with those using classical planar structures. The bandwidth is between 4-10 GHz, the insertion-loss amounts to around 0.02 dB and the return loss is found higher than 20 dB in a large frequency range (4.8-9 GHz).

IV. CONCLUSION

In summary, a compact UWB filter using shielded micromachined microstrip lines is presented, analyzed and designed. The designed filter is only $0.1\times0.5\times17.45$ mm in size and can be easily designed and fabricated.

The bandwidth is between 4-10 GHz, the insertion-loss amounts to around 0.02 dB and the return loss is found higher than 20 dB in a large frequency range (4.8-9 GHz).

To reach these results, it was necessary to determine the electromagnetic parameters of each portion of the proposed filter ([L], [C], …). In the frequency range (2-12) GHz, the resolution of the problem is based on the quasi-static assumption and was made by the method of moment.

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