A NEW MINIATURE UNIPLANAR LOWPASS FILTER USING SERIES RESONATORS

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Abstract

A new variante of miniature uniplanar lowpass filter suitable for use as a building block for communication systems is investigated. A combination of CPW series resonators and low impedance line sections is used to form this lowpass filter. This is made possible by the potential power offered by the uniplanar technology in terms of the wide range of flexibility and scope for innovation. Furthermore, this alternative structure removes a number of limitations inherent to the conventional configuration. Compared to ladder type built from the cascade of alternate high and low impedance line sections, several advantages are pointed out : very wide stopband with low number of elements (no spurious responses up to 25 GHz), high cutoff rates, low insertion loss, lower radiation loss, high compactness (a significant 35% reduction of the circuit area when compared to ladder type) and additional degrees of freedom by the inclusion of the series CPW series resonators in the filter design. However, to fully benefit from these resonators, it is necessary to have reliable models of each constitutive element of the lowpass filter. It has been shown that the relative flexibility of the space domain integral equation method makes it an attractive tool for the analysis and design of these complex circuits. A principle of achieving these high-quality circuits is described and also confirmed by experimental and theoretical results, which are in good agreement up to 40 GHz. The combination of a series resonators with low impedance line sections gives a new powerful technique for the design of miniature lowpass suitable for monolithic millimetric integrated circuits.

I. Introduction

New systems like communication satellites, mobile and cellular radio communications, continue to require microwave filter with more stringent passband and stopband control, smaller size, and lighter weight. This requirement has stimulated specially sophisticated advances in the minimization of insertion loss and group delay as well as more practical and compact configurations. This paper introduces the design of uniplanar filters in more compact form with significant performance improvements. Recent progress in the uniplanar technology has stimulated many researchers to be interested in the design of filters using this technology [1]-[6]. The association of coplanar and slotline, and the use of both parallel and series elements considerably facilitate circuit technological implementations with respect to the well known microstrip technology and also offers microwave designers more facilities and flexibility for circuit integration. Among these advantages, the inherent decoupling of adjacent lines yields high flexibility in circuit design and miniaturization, without sacrifing the performances. In this optic, a certain number of filters has been realized to demonstrate the efficiency of the design method and the pertinence of the series resonator use in order to get satisfactory performances. This demonstration is made on lowpass filter with aim is to find the best topology to generate very wide stopband, high cutoff rates, small size, low number of elements and low insertion loss in passband, in order to reply of the need for reduced size, weight and for low cost fabrication which is often a priority for good number of microwave devices.

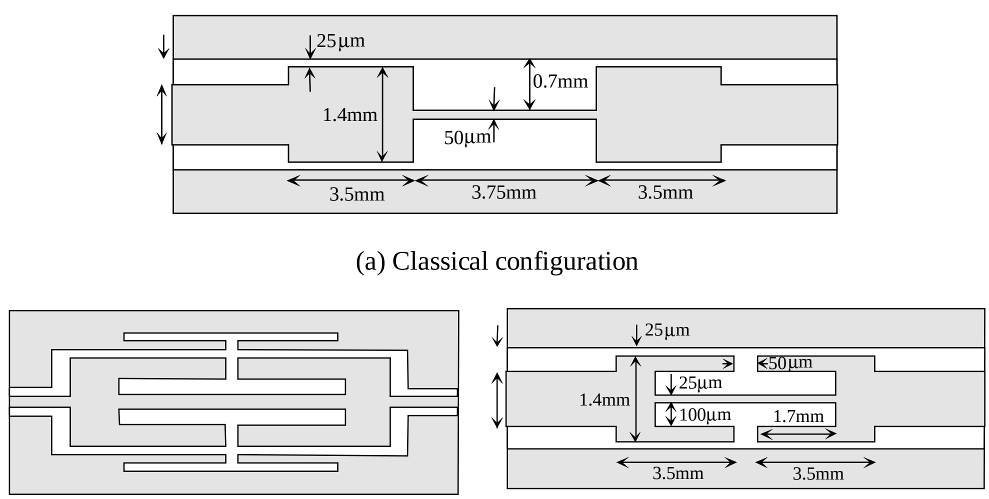
II. Filter topology and constitutive cells

Printed circuit lowpass filters consist of the cascade of alternate high and low impedance line sections [7]. Such geometry results from the conversion of lumped LC ladder prototype, where low impedance sections correspond to capacitors and high impedance sections correspond to inductors. Microstrip or stripline filters have been extensively studied and very accurate design techniques exist already in the literature. Indeed, a variety of methodologies is available for the implementation of planar lowpass filters. The classical design methods are based on lumped prototypes which are transformed into distributed structures [7]. This transformation consists, however, in the direct synthesis of each lumped element by a low or high impedance line section. However, many problems are to be faced in the design of lowpass filter when a very wide stopband is researched. These problems stem both from technological constraints and the design limitations [8] [9]. Moreover, the distributed character of the circuit elements produces spurious response levels in

0-7803-4471-5/98/$10.00 (c) 1998 IEEE

stopband region due to the physical length related to the different line sections in which the condition ℓ “ λ_g is only valid at low frequencies. In order to obtain a very wide stopband, it is necessary to realize characteristic impedance values which are hardly achievable. Thus, this configurations constitutes a serious limitation in the design of lowpass filter when very wide stopbands are required.
Furthermore, while the field of filters design is now very mature, there is relatively little literature on CPW filters [10] [11]. Therefore, it is possible to envisage the definition of new alternative structures which removes a number of limitations inherent to the conventional configurations. This is made possible by the potentiel power offered by the uniplanar technology in terms of the wide range of flexibility and scope for innovation. Due to the versatility of the uniplanar technology, a special element topologies are adopted to extend the stopband bandwidth and removes a number of limitations inherent to the conventional design approach. Thus, alternative solutions are available to overcome this problem.

One alternative topology is presented in Figure 1b. The utilization of series stubs patterned in the center conductor combined with a low impedance line sections allows to realize configurations of uniplanar lowpass filter in compact form. This design technique uses all potentialities linked to the uniplanar technology for the inductance and capacitance implementations with a compact forms. As illustrated in Figure 1, capacitors are realized by the classic manner from a low impedance line sections with a very small length in regard to wavelength, while, the inductors are realized from series stubs integrated in the low impedance line sections. The different news forms of uniplanar lowpass filters presented in Figure 1, indicate, firstly, the freedom that uniplanar technology gives to the possibility of a multiplicity of possible shapes which have somewhat different characteristics and provide varying degrees of miniaturization. and, secondly, provides an alternative yet compact structures. This will reveal interesting and attractive aspects for future microwave and millimeter wave applications. In order to enact on performances between the classical and new topologies related to the lowpass filter, we have led to basic study on the theoretical and experimental characterization of a series resonators intervening in the filter design



(a) Classical configuration

(b) Very compact topology built from a combination of low impedance line sections and series resonators

Fig.1 A new class of uniplanar lowpass filter including the standard structure

III. Theoretical and experimental characterization of the series resonator

In uniplanar technology, short end series resonators are easily realized. Figure 2 presents one example of a series resonators printed in the center conductor of the main coplanar line. However, a precise study is necessary to understand the electromagnetic behavior of such resonators and our ability to use them in lowpass filters. Therefore, the development of more accurate uniplanar models, based on full wave analysis, is key to improvement of microwave and millimeter wave circuit simulations and reducing lengthy design cycle costs. It has been shown that the relative flexibility of the space domain integral equation method makes it an attractive tool for the analysis and design of these complex circuits [12]. This step is illustrated via the two circuits presented in Figure 2. These circuits are implemented on high dielectric constant substrate ε_r = 9.9, h = 0.254 mm, which is close to the dielectric constant of GaAs and demonstrates the feasibility of integrating this new stub structures into monolithic circuits. Excellent agreement between the full-wave analysis and measurement is observed and was proven to work well in the mm-wave region. This study being made, and in view of the application of the series resonator as an element distributed in replacement of the high impedance line section, we can now discuss the design and the realization of lowpass filters can now be discussed.

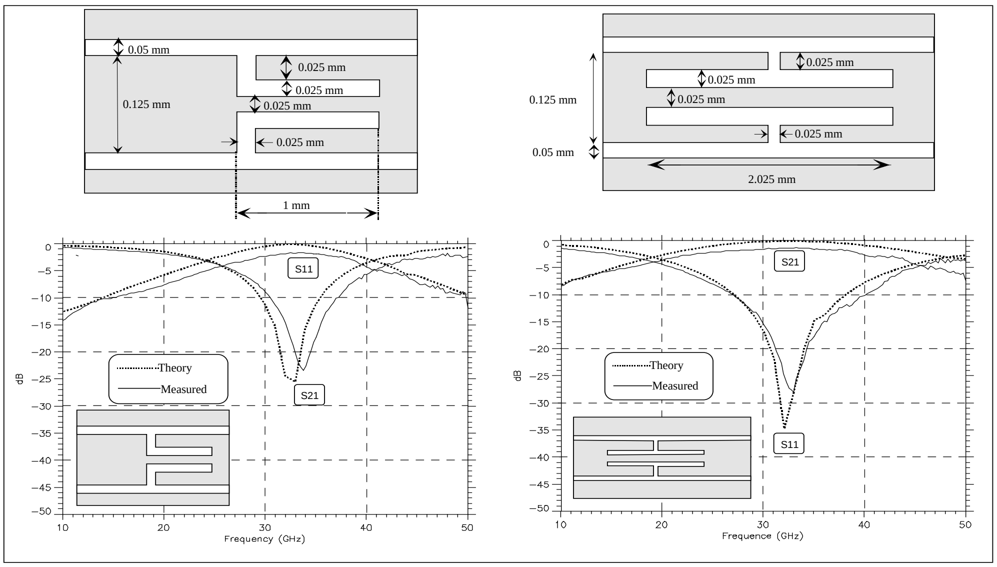


Fig. 2 Scattering parameters of the short-end CPW standard and original series resonators

IV. Filter design and performance

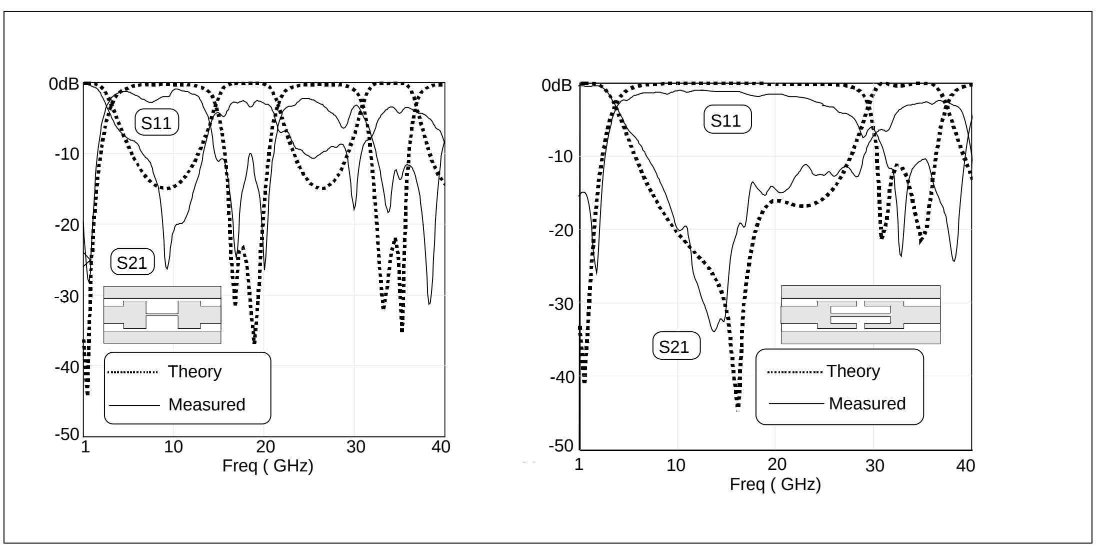


Fig 3 Theoretical and experimental results of classical and compact lowpass filters

By analogy with the standard design of microstrip lowpass filters, it is possible to translate this well known configuration in uniplanar technology. A universal topology relating to the lowpass filter is the shown in Figure 1a. It is constituted of a cascade of alternate high and low impedance line sections. The synthesis procedure of this filter type is described in reference [7]. In order to discusses the performances between the classical and new topology relating to lowpass filter, two experimental circuits (figure 3) were designed and fabricated on Alumina substrates ($\varepsilon_r = 9.9$, h=0.254 mm). The 3th order filter investigated consists of one inductive line (Zc=143Ω) and two capacitive lines (Zc=26Ω). Its cut-off frequency is 3 GHz with 0.1 dB ripple. The elements of the filter are calculated using a standard design procedure [7]. On the other hand, the alternative configuration is built through a specific short end series resonator integrated within the low impedance line sections which simulating parallel capacitors. The figure 1b presents a geometrical configuration of one of the uniplanar lowpass filters, conceived and realized from series resonator. The experimental results of the classical and compact filters are plotted in Figure 3. It can be observed that the compact filter does not present any significant degradation in terms of bandwidth. In addition, one can noticed that there is no shift of the cut-off frequency and the transmission loss remain lower than 0.4dB. It worthy to note that the proposed compact filter allows a significant reduction of the circuit area (35% for the compact circuit) In addition, this configuration improves the behavior of the filter in the stopband region resulting in the suppression of spurious responses through a large bandwidth beyond the cutoff frequency of the lowpass filter. In comparison with the classical structure, the advantages which may be derived are : very sharp rejection slope, high compactness, lower insertion loss in passband, lower radiation loss, very wide stopband with low number of elements (the spurious responses are rejected at higher frequencies up to 25 GHz) and especially the high design flexibility leading to excellent filter performances as demonstrated by the experimental results. Lastly, this compact filter represents a viable way to implement a third-order semi-lumped lowpass Chebyshev filter type in uniplanar form suitable for monolithic microwave circuits. Beside, this filter demonstrates the efficiency of the approach by using resonator series to get best performances. The good agreement between simulation results and experimental data justifies the design procedure and validates our original concept.

Conclusion

Our work certainly illustrates the potentiel power offered by the uniplanar technology in terms of the wide range of flexibility and scope for innovation, and secondly, provides an alternative, yet, compact structures for the design of classical filters. Cost, compatibility, reliability, compactness and design flexibility are all reasons for the designer to go for such an approach. Uniplanar technology, contrary to the microstrip technology, allows the realization of very compact lowpass filters with good performance. These performances are reached under the utilization of compact specific resonators, whose frequency responses is mastered by the application of the full wave method. The series resonators patterned on the center conductor has found a fruitful application in the lowpass filter synthesis by providing additional degrees of freedom and resulting in extremely compact configuration which are attractive for passive and active monolithic integrated circuits. Lastly, this compact uniplanar filter has emphasized the impact of the proposed resonators on filter performance.

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