SIMULTANEOUS REALIZATION OF MILLIMETER WAVE UNIPLANAR SHUNT STUBS AND DC BLOCK

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Abstract

The exploitation of the potentialities linked to uniplanar technology for telecommunications is only at its debuts and even it significant advances have been realized, the context remains evolutive. This paper therefore proposes a new concept for the generation of millimeter wave uniplanar shunt stubs by means of slotline resonator instead of coplanar line resonators. Thus, the short end slotline stub has now the ability to be configured as shunt and series stubs, and therefore acts as a bandpass and bandstop filters, respectively. This gives additional degrees of freedom to the design. Compared to the existing CPW short-end shunt stub, the advantages which may be derived from the use of the proposed framework are : additional degrees of freedom, lower radiation loss, larger bandwidth, high compactness and a reduction of the number of air bridges which are potentially expensive to build. It worth noting that the new short end shunt stubs provides both bandpass behavior and dc bloking simulatneously which is not the case of the standard CPW shunt stub. Furthermore, the present paper proves that the capability to generate shunt stubs in slot line form allows also to relax the limitations inherent to the realization of low and high impedance levels. In this way, various shunt stubs in slotline form with proposed geometries including rectangular and slot ring shapes are fabricated and accurate on wafer measurements are performed over a large band of interest (1-50 GHz). The realization of these shunt stubs is detailed and also confirmed with experimental results.

I. Introduction

The state of the art development of commercial microwave and millimeter wave components and systems indicates that the uniplanar technology is able to provide a high level of integration and achieve some of these stringent requirements such as low cost and compactness. Indeed, the uniplanar technology has received considerable attention in the microwave research community and commercial sectors. Essentially, the uniplanar distinguishes itself from other planar technologies by the fact that the high isolation of this technology has two practical benefits : first, it allows circuits functions to be designed, built and tested individually and then integrated in large assembly without the usual electromagnetic interaction effects that can occur with microstrip circuits. Second, it allows high levels of integration to be achieved on a single substrate. Another attractive feature of uniplanar technology is the fact that the characteristic impedance of CPW is governed by the ground plane separation and the signal conductor track width. This means that variable geometry, constant impedance transmission lines can be fabricated easily. This variable geometry reduces discontnuities and allows low parasitic interconnections and transitions to be made. In addition, the coplanar waveguide (CPW) has a geometry suitable for monolithic integration, does not require holes for mounting active and passive devices as does microstrip, has low sensitivity to substrate thickness, low inductance acces to topside ground plane, permits realization of both series and shunt transmission line stubs and it has proven a very successful technology both in terms of performance and cost. In light of this, considering that all the degrees of freedom linked to uniplanar technology are not fully exploited yet, the objective of this paper is to show that the coexistence of the principal forms of propagation (CPW and slotline) on one substrate leads to new developments in the design of different types of short end shunt stubs which brings a great flexibility for the designer. It focusses on the design of a new topologies of short-end shunt stubs in slotline form with the purpose to provide a firm foundation for passive and active monolithic and hybrid integrated circuits upon which real systems can be designed. These investigations were conducted at frequencies near 30GHz. Figure 1 shows the physical configuration in which the same slotline resonator has been configured to give series and shunt stubs in slotline form. Indeed, it is shown that the duality functions (Stopband/Bandpass) can be generate through the same slotline resonator as illustrated by Figure 1. This arrangement provides additional degrees of freedom and resulting in extremely compact form suitable for monolithic integration.

II. Design methodology

In uniplanar technology, the short end shunt stubs are often built up with coplanar line. The alternative that propose here consists in the design of a new configuration of short end shunt stubs based on a slotline technique. Instead of using the standard short end CPW shunt stub [1], a better solution consists of using the new topologies described in the Figure 1. Moreover, Figure 1 gives an indication of the possibilities for using the uniplanar technique to produce the main types of elements required in millimeter wave circuitry. It also reveals the possibility of simply coupling slotline to coplanar lines in order to form reactive elements. The different news forms of shunt stubs presented in Figure 1, indicate, firstly, the harmonious coexistence of various propagation modes (slotline and CPW) built into a single structure, and, secondly, the wide range of flexibility and scope for innovation that uniplanar technology offers. Indeed, the high flexibility of uniplanar technology gives rise to the possibility of a multiplicity of possible shapes which can bring viable solutions for the emerging wireless communications industry in general. It is believed that these new architectures investigated in this paper have not yet been exhausted and additional structures will certainly come out in the future.

In the other hand, Figure 2 presents a flow chart showing how the gneration of the new short end shunt stub in slotline form is accomplished. This flow chart provide a hint as how to apply the design method. It could easily be shown that the resultant structure of Figure 2 is derived directly by cascading of out of phase back to back CPW to slotline transitions. However, it is also advisable to study the optimal geometric configuration of the slotline stubs for the following reason: as predicted in [2] and tested in [3] [7],, the electrical response of a straight double slotline resonator may be deteriorate, especially by the parasitic radiation ; the two slots, with electrical fields oriented in phase, work as a slot antenna.

To minimize this problem related to radiation loss, a bent geometry is recommended ; then, the electrical fields are out of phase, which reduces in a significant way radiation loss. The optimized geometry of the slotline elements is consequently extremely important in the design of wideband and radiation less shunt stubs.

Furthermore, the conventional shunt stubs in coplanar line form covers an impedance range from about 30-80 Ω. Values outside this range cannot be fabricated reliably or cause excessive losses. For several

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

applications, however, it is desirable to use either high and low impedances, as it is the case for instance of the filtering domain, where, for some specific requirements, either very large or very small characteristic impedance levels are often required. Then, the difficulty in realizing low or high impedance levels in conventional shunt stub constitutes a serious limitations in the filter design, particularly at high frequencies. While the upper limit of realizable characteristic impedance is set by manufacturing tolerances, the lower limit depends on the onset of higher order modes which occurs when the transverse dimension relating to the standard CPW stubs becomes comparable with the wavelength or with longitudinal dimension, so that, substantial discrepancies between predicted and actual performances occur when lower and higher values are realized. To overcome this difficulty, it is very advantageous to adopt the concept of shunt stubs in slotline form by using series connection of many single slotline resonators as illustrated for example the Figure 3. In this way, the total line impedance can drastically increase and the the above disadvantages can be removed.

In comparison with the conventional non symmetric short end shunt stub in coplanar line form [1], several advantages are pointed out :

1) One attractive feature of the proposed new short end shunt in slotline form is that, the impedance level requirements can be significantly relaxed, its performance is likely to be significantly better that of a conventional . Therefore, these new short end shunt stubs will greatly expand the freedom in design, resulting in a major reduction of size.

2) Also, one of the most promising aspects of the new short end shunt stub consists in the capability of generating bandpass behavior and dc blocking simultaneously with a the new shunt stubs.

3) The proposed structures are able to demonstrate radiationless and wideband characteristics.

4) Reduction of the number of air bridges which are potentially expensive to build.

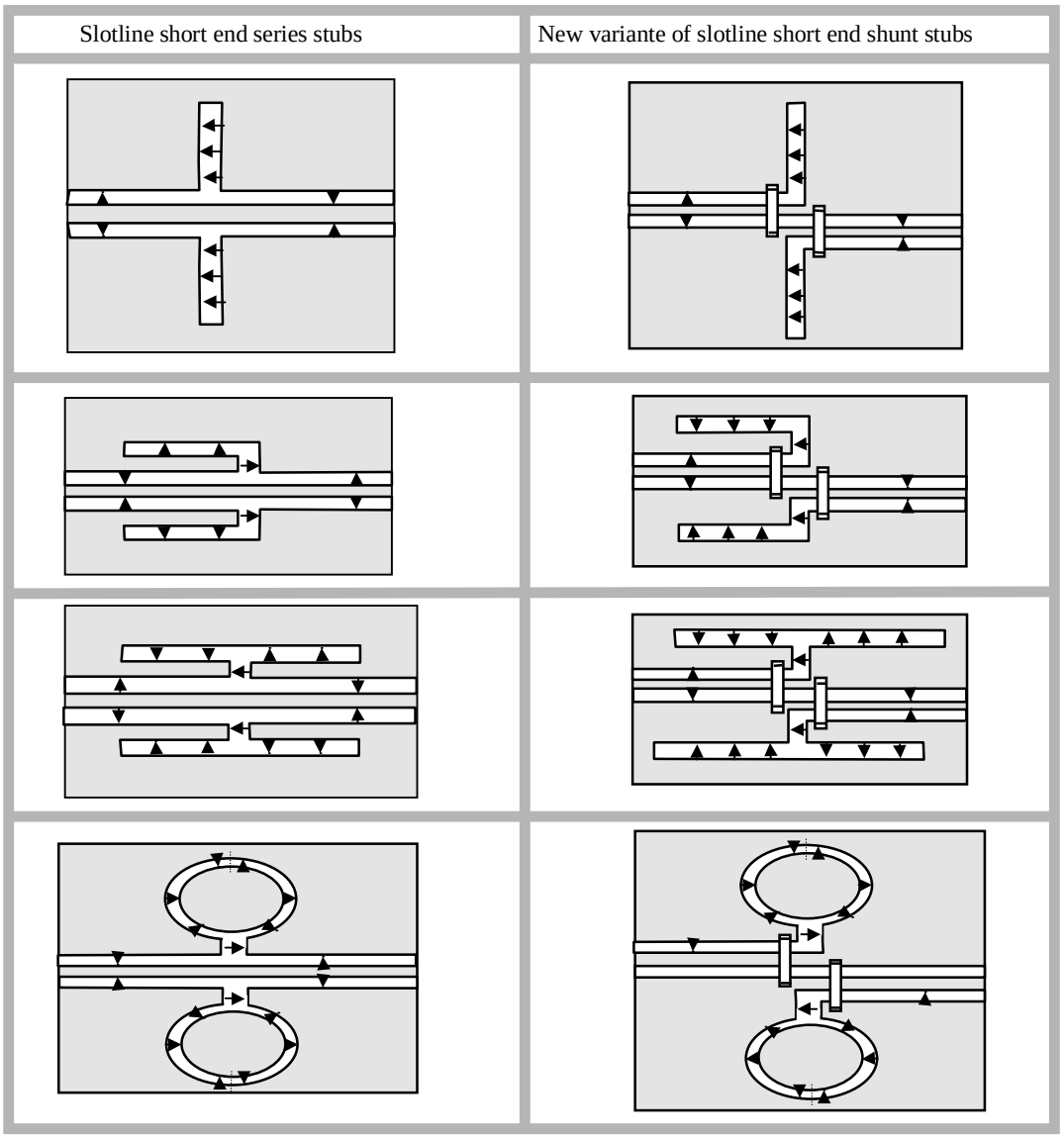

Fig. 1 A new variante of short end shunt stubs in slotline form
including their homologous in series

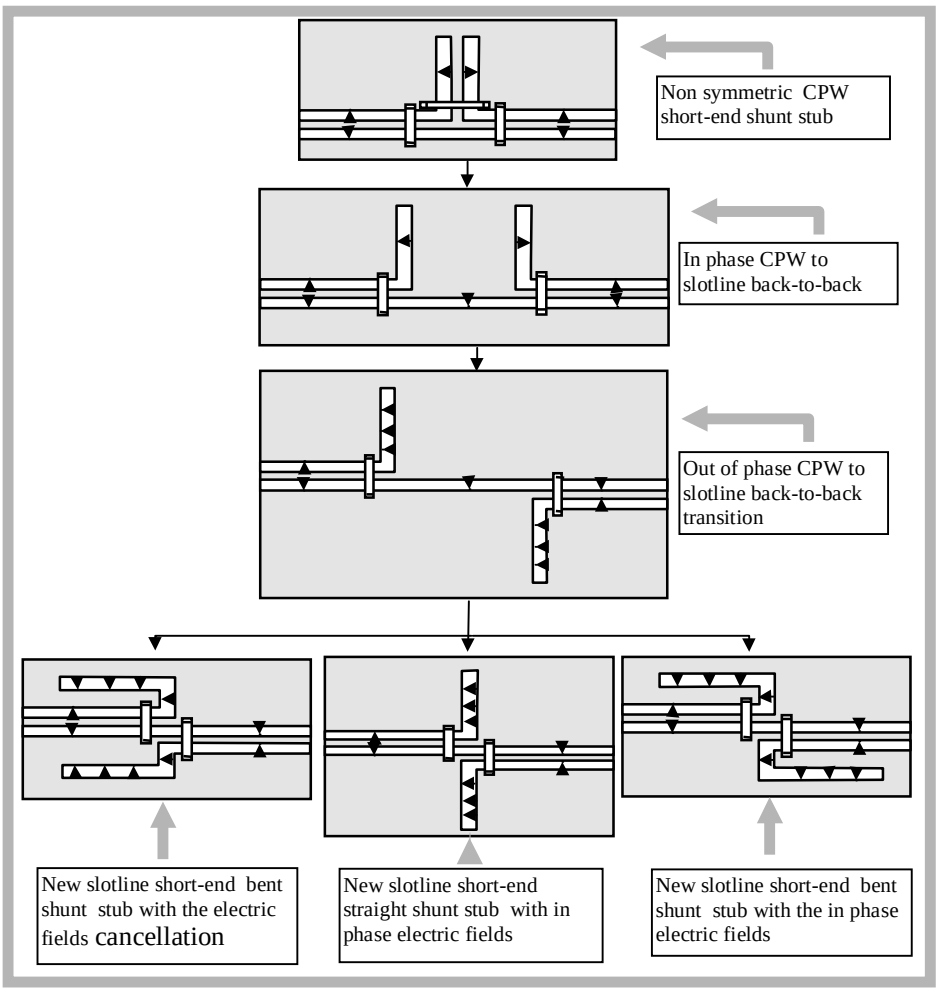

Fig. 2 Flow chart showing the derivattion of the new short end shunt stub in slotline form

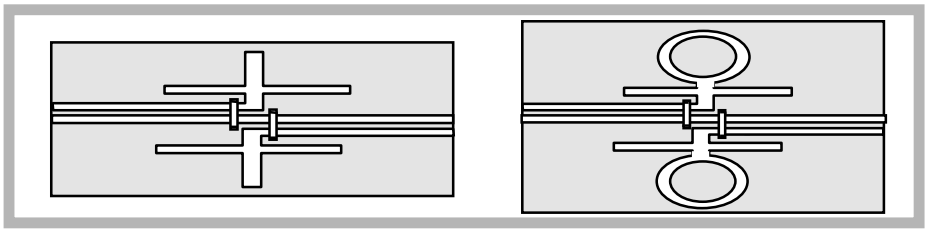

Fig. 3 Possible topologies for high impedance levels using the multi-stubs concept.

III. Experimental results

Based on the approach mentioned in the previous section, four experimental circuits (figure 4) were designed near f_o = 30 GHz and fabricated on Alumina substrates ($\varepsilon_r = 9.9$, h=0.254 mm).

In order to give an impression on the degrees of freedom linked to short end slotline resonator, it has been judged useful to built both possible configurations, namely series and parallel. It can be noticed that both configurations have approximatively the same resonant frequency. However, it is obvious that both configuration have different characteristics, as illustrated in Figure 4. Thus, it may be concluded that even through both configurations uses the same resonator type and have the same dimension, each produces a different behaviour depending on the topology type. Thus, the short end slotline stub has now, the ability to be configured as shunt and series stubs, and therefore, acts as a bandpass and bandstop filter, respectively. Furthermore, the experimental results presented in Figure 4 provide very strong indications as to the exciting low loss and a very broad band performance that provides the new shunt stubs. It worth noting that one of the most promising aspects of the new shunt stub consists in the capability to provide the two characteristics namely bandpass type and dc blocking, simultaneously, and thus, it can be seen that it have certain similirities to open end CPW series stub patterned in the center conductor [5]-[6], Due to its performance, such structures can be used to build bandpass filters.

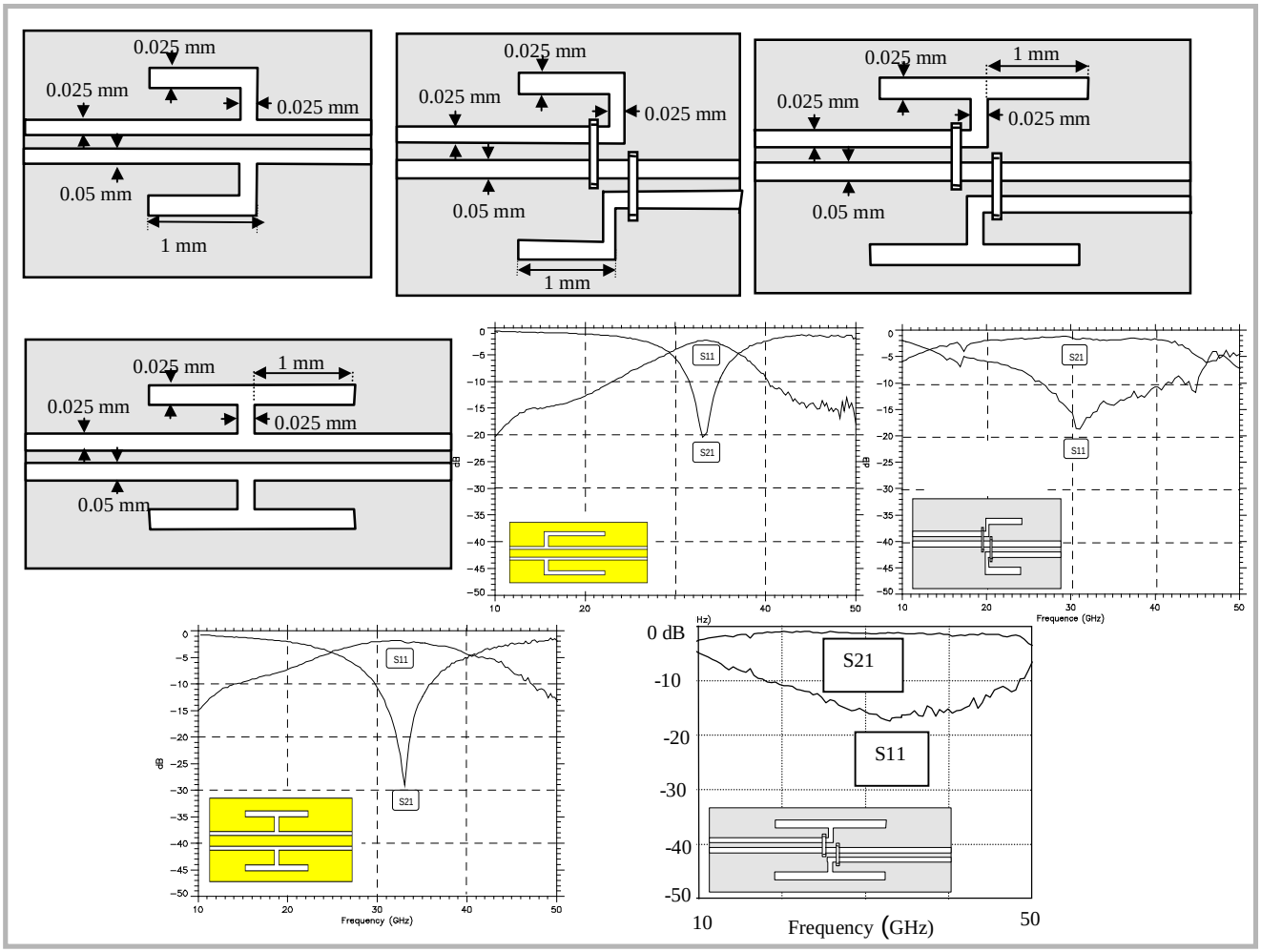

Fig. 4 The top views of the tested stubs

Conclusion

Microwave and millimeter-wave integrated circuits using uniplanar technology yield innovative and high performance components and subsystems. This study is focussed on the design of a new topologies of short-end shunt stubs in slotline form with the purpose to provide a firm foundation for passive and active monolithic and hybrid integrated circuits upon which real systems can be designed. A principle way achieving high quality circuits is detailed and confirmed by the experimental results which show that these uniplanar techniques have a major part to play in the miniaturization of MMICs in the future. Furthermore, this study confirms the ability of slotline ring resonator to switch between two possible behaviour states (bandpass-bandstop) depending of the considered configuration (series-parallel). The high flexibility that uniplanar technology offered gives rise to the possibility of a multiplicity of possible shapes which removes a number of limitations inherent to the conventional shunt stubs approach and provide varying degrees of miniaturisation. Alternatively to non symmetric short end CPW shunt stub conventional, several other advantages can be gained from this new kind of stubs as pointed out in the paper. Lastly ,the results of the new shunt stubs study indicate potential applications in the emerging wireless communications industry in general, and in the design of low cost uniplanar microwave and millimeter wave circuits such as filters, mixers, and antennas in particular.

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