Overlapping, Multiple CPW Stub Structures for High Density MMICs

Khelifa Hettak, Cornelius J. Verver, and Malcolm G. Stubbs
Communications Research Centre Canada,
3701 Carling Ave., Box 11490, Station H, Ottawa, Canada, K2H 8S2

Abstract

This paper proposes a robust option for developing a new class of very compact matching stub configurations. It demonstrates that an overlapping technique, involving different MMIC CPW stubs built into a single line section, can provide size and cost reductions up to 60%, while also providing performance enhancements. The high flexibility of uniplanar technology allows the development of possible transmission line shapes and removes a number of limitations inherent in conventional design approaches, thus providing varying degrees of miniaturization. The experimental prototypes presented in this paper demonstrate the efficiency of the design method and the feasibility of creating multistub configurations in a single line section to get ultra compact structures. The principle of achieving such high-quality circuits is detailed and is also confirmed by experimental and theoretical results which are in good agreement up to at least 40 GHz. This good agreement validates the design procedure and shows that complex circuit functions can be implemented by means of relatively inexpensive compact structures. This study was completed by producing a very compact 90° CPW branchline coupler for Ka/K-band, advanced SATCOM terminal systems operating in the 20/44 GHz frequency bands, which demonstrated that the concept can be easily used.

I. Introduction

The explosive growth in digital wireless communications products has heightened the need for RF circuits. Increased integration of circuit functions and the desire to reduce component costs drive designers to consider alternative design approaches so that these goals can be realized. Today, more attention is being given to uniplanar design concepts to minimize MMIC processing cost, reduce size and increase yield [1-4]. In light of this, this paper explores the integration of novel arrangements of multiple CPW stubs in a single line section. The aim is to show that the coexistence of multistub configurations in a single line section creates a design flexibility that leads to the realization of new, very compact geometrical configurations. The new topologies are shown in figures 1, 2 & 3. This new and powerful technique allows a large number of novel possibilities for hybrid and monolithic millimeter waves integrated circuits with high integration density.

II. Overlapping multiple stubs configuration realized in a single section of line

The technique of cascading multiple open circuit series stubs allows easy realization of a bandpass frequency response with high out-of-band rejection and low loss performance. The passband resonance of an open circuit stub occurs when the length is approximately $\lambda_g/4$ and the stopband resonance occurs when the stub length is $\lambda_g/2$, although the stopband resonance is considerably stronger than the bandpass resonance [4,5]. A typical CPW topology, shown in figure 1, consists of a cascade of alternate, quarter wavelength CPW open circuit series stubs and a quarter wavelength

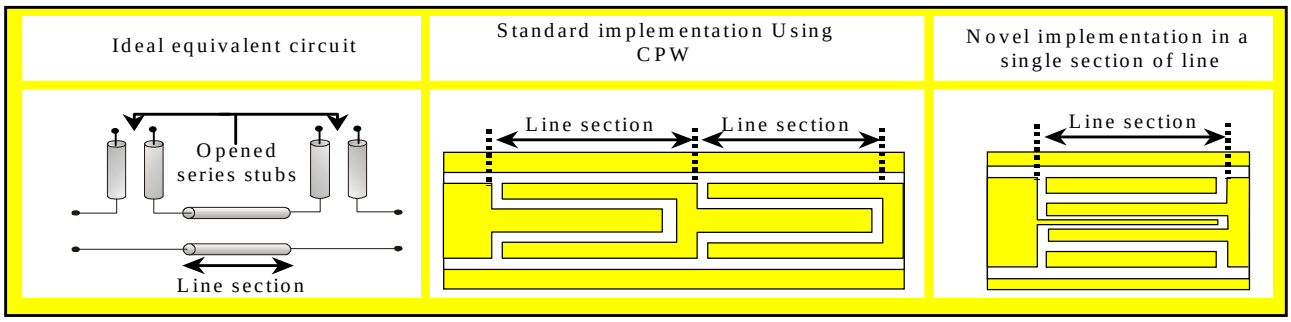

Figure 1: Comparison of standard and novel implementation of series/series multistub configurations (using the same line section). A 50% size reduction is achieved with the novel implementation.

0-7803-6540-2/01/$10.00 (C) 2001 IEEE

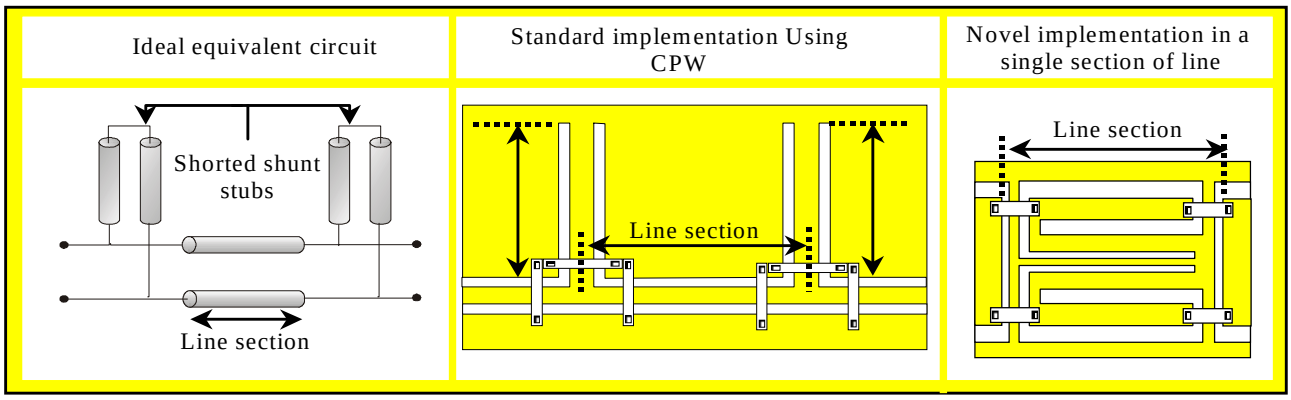

Figure 2: Comparison of standard and novel implementation of shunt/shunt multistub configurations (using the same line section). More than a 50% size reduction is achieved with the novel implementation.

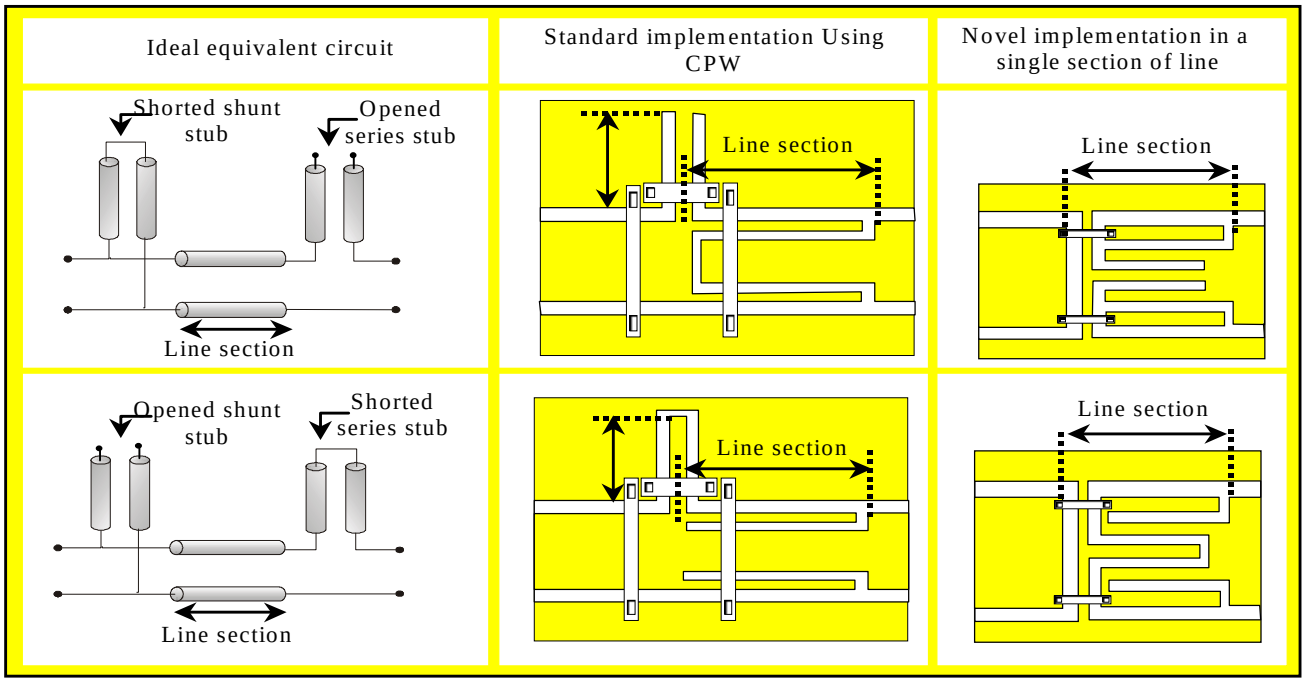

Figure 3: Comparison of standard and novel implementation of shunt/series multistub configurations (using the same line section). A 50% size reduction is achieved with the novel implementation.

CPW connecting line [5]. However, if this configuration is designed conventionally, it is very large and expensive when incorporated into MMIC's, which can be a major drawback when designing an MMIC based system. Therefore, miniaturizing such a structure without affecting the performance is highly desirable.

One technique of particular interest, is the ability to integrate both CPW series stubs within the center conductor of the same CPW line section (figure1). Using this approach, the size can be significantly reduced compared to standard topologies. This attractive technique expands the design freedom and provides an opportunity for designing original structures with high integration densities. It is worth stressing that the proposed overlapping is entirely responsible for the major reduction in size ,shown in figure 1, and is not possible using other realizations such as microstrip technology.

By expanding the above idea and by exploiting the flexibility of the uniplanar technology, many other novel miniature structures are feasible. For example, instead of using the standard CPW shunt stub printed in the ground plane [6], a more compact geometry can be achieved by locating the shunt stubs in the center conductor [7] and by allowing overlapping with other CPW shunt stubs. This work has shown the concept to be a key approach to designing miniature geometrical configurations and is

illustrated by the circuit presented in figure 2. It shows the possibility of building a cascade of alternate quarter wavelength CPW short circuited shunt stubs separated by a quarter wavelength CPW line using only one CPW line section. This results in a significantly higher degree of compactness.

Finally, due to the wide range of flexibility and scope for innovation that uniplanar technology offers [1], alternative configurations which appear to have some merit take advantage of the coexistence of CPW shunt and series stubs built in the same CPW line section. An illustration of this is shown in figure 3. The T-junction structure can be easily constructed as a combination of CPW shunt stub printed inside a series CPW stub, both of which are also printed within the center conductor of a single section of CPW line. This provides both low loss and longitudinal symmetry, and introduces more flexibility in the layout.

Thus, compared to classical implementation, the advantages that may be derived from the use of the proposed approach are: additional degrees of design freedom, lower insertion loss, high compactness and a major reduction of the number of air bridges. Moreover, figures 1, 2 & 3 give an indication of the possibilities for using this uniplanar technique to generate extremely compact forms highly desirable in millimeter wave circuitry.

It is worthwhile noting 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 using CPW. Thus, the choice of characteristic impedances is mainly dictated by manufacturing constraints and the realization of multiple stubs within the center conductor as described can be readily accommodated.

III. Simulated and experimental validation

Two novel CPW multistub configurations were designed for operation in the millimeter wave region to demonstrate the effectiveness of the method for achieving ultra compact structures (Figure 4). These CPW shunt and series stub configurations were fabricated on a 600µm thick GaAs substrate. It has previously been shown that the flexibility of the Agilent ADS Momentum™ software [8] makes it an attractive tool for the analysis and design of these complex circuits and very good agreement between the full-wave analysis and experimental results were observed as shown in figure 5. This study confirms that a CPW shunt stub can be easily configured inside a CPW series stub within the same CPW line section. This demonstration opens up the possibility of using such configurations as building blocks for future filter design.

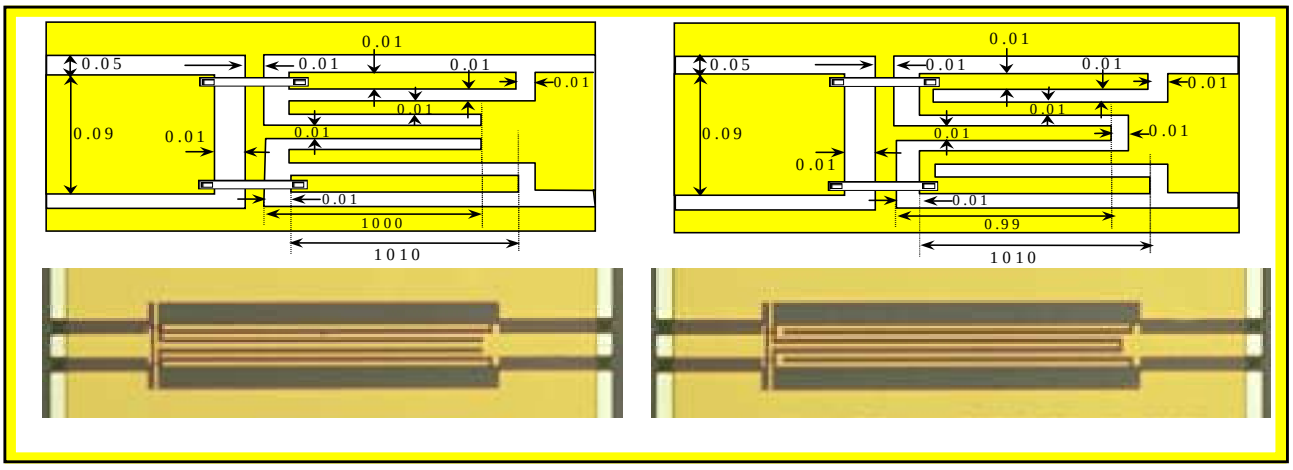

Figure 4: Top views of the tested CPW shunt stubs patterned inside series CPW stubs, all within the center conductor of a single CPW line section (unit : mm)

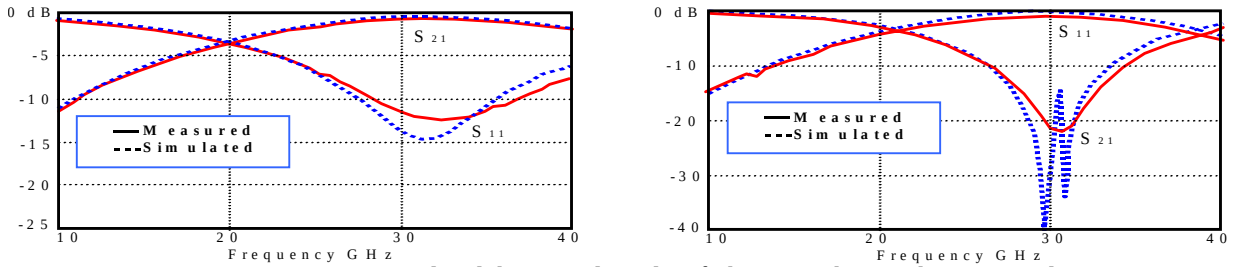

Figure 5: Experimental and theoretical results of the CPW shunt stubs integrated inside the center of CPW series stubs shown in Figure 4

IV. Example of potentiel application: Design novel very compact CPW branchline coupler

The quarter wavelength transmission lines conventionally used in branchline couplers make them very large and therefore expensive when they are incorporated into MMIC's. This can be a major drawback when designing an MMIC based system. Therefore, there is a strong desire to develop compact design approaches which can lead to high density chip layouts. In order to address this need, we have developed a new type of miniature 90° CPW hybrid branchline coupler taking advantage of the harmonious coexistence between CPW shunt and series stubs. The miniature, CPW, MMIC branchline coupler was designed based on the basic principles outlined in paper [9]. The topology is illustrated in Figure 6. Furthermore, by using CPW transmission lines in MMICs it is possible to form a compact circuit layout by the inherent decoupling of adjacent lines, yielding high flexibility in circuit design and miniaturization without scarifying performance. It is worth noting that the ability to realize shunt and series stubs within the center conductor presents a viable way of achieving MMIC size reduction. Finally, the simulated performance of this coupler using Agilent ADS, being less than 45% of the area of a standard branch line coupler, was found to exhibit high balance, good return losses, and excellent isolation (Figure 6).

Conclusion

This study has focused on several new designs of overlapping, multiple CPW stubs patterned in the center conductor of a single CPW line section. The experimental results indicate that the proposed technique may have a major part to play in the future miniaturization of MMICs. Experimental and theoretical results have been presented to verify the validity of the design and very good agreement between theory and experiment was obtained. The overlapped CPW multistubs in the same line section provides additional degrees of design freedom and results in extremely compact configuration which are attractive for passive and active monolithic integrated circuits. Finally, The successful implementation of this approach to branchline coupler circuit proved the advantages provided by this uniplanar technology.

References

[1] T.Hirota and H.Ogawa, "Uniplanar MMIC hybrids - A proposed new mmic structure," IEEE Trans. On MTT, vol. 35, pp. 576-581, June 1987.

[2] M. Muraguchi, T. Hirota, A. Minakawa, K. Ohwada and T. Sugeta, "Uniplanar MMIC's and their applications, " IEEE Trans on MTT, vol 36, pp. 1896-1901, Dec. 1988.

[3] M. Naghed, B. Hopf and I. Wolff, "Field theoretical broadband modeling of coplanar lumped elements and their application in (M)MIC bandpass filters , " 26 rd EuMC 1996, pp 991-995

[4] T.M. Weller and L.P. Katehi, "Miniature stub and filter designs using the microshield transmission line, " IEEE MTT-S Digest., 1995, pp. 675-678

[5] K.Hettak, N. Dib, A. Sheta, S.Toutain, "A class of novel nonradiating uniplanar series resonators and their implementation in original applications" IEEE Transactions on MTT, vol.46, pp. 1270-1276, September 1998.

[6] K.Hettak, G. Delisle and M. Boulmalf, "Simultaneous realization of millimeter wave uniplanar shunt stubs and Dc block, "IEEE MTT-S Digest, pp. 809-812, 1998.

[7] K. Hettak, N. Dib, A. Omar, G. Y. Delisle, M. G. Stubbs, S. Toutain, "A Useful New Class of Miniature CPW Shunt Stubs and its Impact on Millimeter-Wave Integrated Circuits," IEEE Trans. On MTT, vol. 47, pp. 2340-2349 Dec. 1999

[8] Agilent Technologies Advanced Design System v1.3, Palo Alto, CA, 1999

[9] T. Hirota, A. Minakawa, and M. Muraguchi, "Reduced-Size Branch-Line and Rat-Race Hybrids for Uniplanar MMIC's," IEEE Trans. On MTT, vol. 38, pp. 270-275, Mar. 1990.

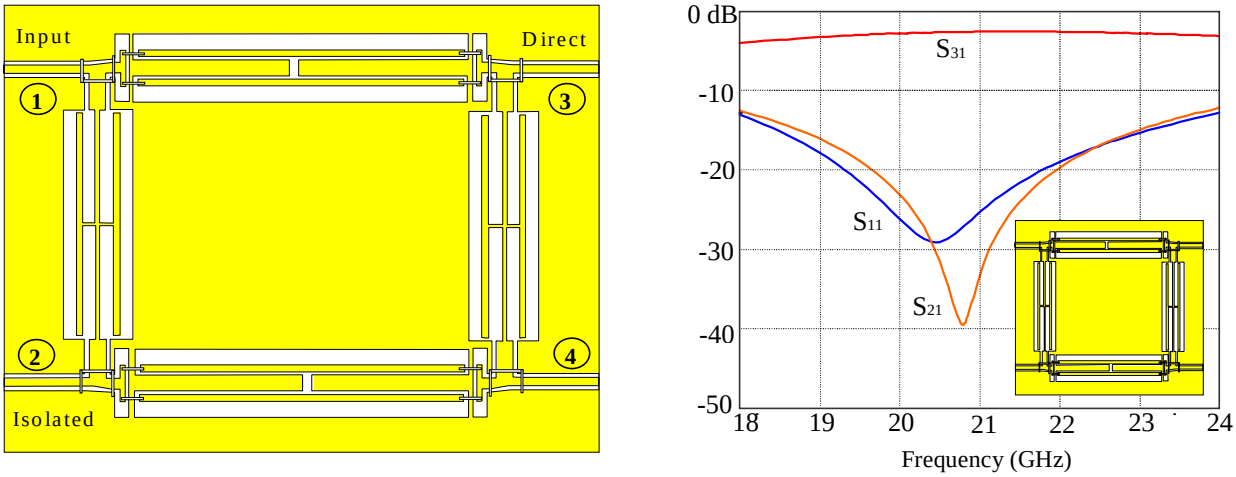

Figure 6: A new class of miniature 90 ° CPW hybrid couplers and its simulated performance