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LCP Ultra-Wideband Self-Packaged Microstrip to Stripline Transition With Multilayer Balun Demonstration

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***Abstract*—An Ultra-wideband (UWB) microstrip to stripline transition using liquid crystal polymer (LCP) technology for multilayer circuits with self-packaging feature is presented in this paper. The proposed design is light in weight, cost effective and remarkably miniaturized. In order to validate this approach, a prototype is designed, simulated and fabricated. In addition, this packaged transition is tested on a new multilayer balun to account for any losses introduced to the hosted balun further ensuring the significance of this work.**

Keywords—transition, multilayer, microstrip (MS), stripline (SL),UWB balun, broadside-coupling, liquid crystal polymer (LCP).

I. Introduction

Recently, the development and application of multilayer circuit technology has been an increasingly interesting topic being widely discussed in wireless communications [1]. It is an interconnect structure typically including stripline configurations and via holes. Multilayer circuits introduce some requirements which need to be addressed such as: reliable interconnection, broad bandwidths and low insertion losses [1]. Multilayer configurations also introduce the advantage of having miniaturized, multifunctional, electrical shielding and small profile structures [2].

In order to have a very efficient multilayer circuit performance, a well-designed interface comprising good transitions and interconnections is essential. In multilayer circuits, the transition between the interface (microstrip) and the inner layers (stripline) is accomplished by connecting one line at the top layer to another line located in the inner layers. Typically, coplanar waveguide (CPW) and microstrip structures are utilized as interfaces whereas stripline structures as the hosted design [2]. Microstrip structure is a very good candidate to be employed as the interconnecting interface to inner layers as a result of its simplicity of transition and low propagation loss [3].

On the other hand, stripline provides an excellent choice of being free of dispersion and radiation as well as having lower and upper ground planes which may be used as grounds for other structures within the design [2]. Ultra-wideband (UWB) impulses transmission in planar circuits require low parasitic radiation and dispersion transmission lines in which both conditions are satisfied using real TEM stripline structures [4]. Striplines are increasingly found in multilayer circuits in addition to those designed as feeding networks for antennas that comprise stripline topology such as: stripline slot antennas.

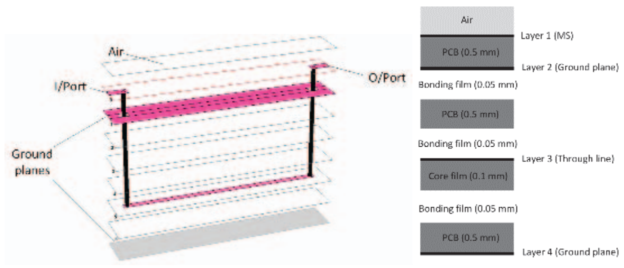
In [1], the proposed design requires the usage of too many blind vias making the fabrication extremely difficult i.e. impractical solution. On the other hand, in [2], some very expensive technologies are required namely LTCC for the application of that design. A vialess design is introduced in [3]. Yet, some remarkably expensive tools are required for this fabrication and production of through via holes for the elimination of parallel plate excitation. In [4], non-reliable connections to stripline layers can be observed as a consequence of using through via holes resulting in poor performances. A CPW interface is proposed in [5] in which the realization of the design is not simple, has some size constraints as well as lacking the advantageous stripline inner layers having pure TEM transmissions.

To address the previously discussed issues, Liquid crystal polymer (LCP) multilayer technology is adopted in this paper which offers the optimal solution for the aforementioned constraints. LCP offers outstanding electrical and physical properties including: low loss tangent, miniaturization, very good packaging flexibility, low cost, integration availability and an interesting thermal conductivity.

The main objective of this paper is to present a new inexpensive UWB microstrip to stripline transition design providing a pure TEM mode propagation for the hosted design. Moreover, this new design offers a solution for the issues associated with [6] in which poor performances are obtained due to not having TEM propagation structures. A multilayer broadside coupled balun is introduced in this paper as an application example for the proposed transition design demonstration.

II. Design and Analysis of Through Line and Balun

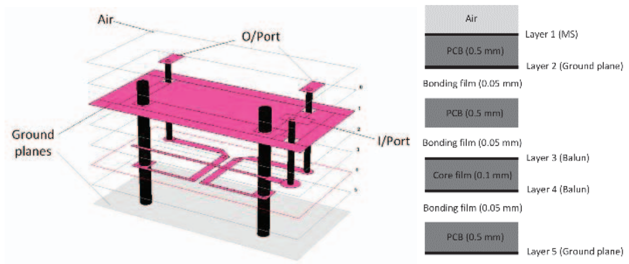
Fig.1 illustrates the 3-D view of the design as well as the layer stack of the multiple layers implemented. Layer (1) presents the interface of the hosted design to the outer system in which it contains the microstrip lines (MS) typically designed to match a *50 ohms* impedance which corresponds to a width of *1.2 mm*. These MS lines are connected to *0.5 mm* via holes which links them to the hosted stripline (SL) also designed to match a *50 ohms* impedance located in layer (3). The via holes go through a slot with *0.25 mm* separation gap at each side of the via hole as seen in layer (2) which acts as the ground plane for MS and the upper ground plane for the SL. Finally, layer (4) is the lower ground plane in regards to the SL located in layer (3).



(a) (b)

Fig. 1. (a) 3-D view of the proposed transition design and (b) cross section of the layers stack implemented.

Fig.2 demonstrates the balun design implemented for illustration purposes of the proposed MS to SL transition design. It follows the same design previously presented in Fig.1 where the only difference being that layer (3) and (4) are etched on the same substrate to provide high precision required for the broadside coupled quarter wavelength lines of the balun. In addition, the grounding via holes used in here are *1.0 mm* wide in contrast with the feeding lines' via holes being *0.5 mm* in width.

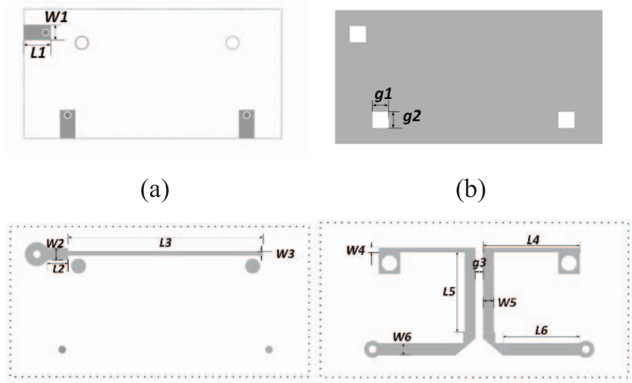


(a) (b)

Fig. 2. (a) 3-D view of the proposed Balun design and (b) cross section of the layers stack implemented.

In Fig.3, each of the layers used within the stack are shown individually with the corresponding dimensions. Final dimensions are: L1=2.5, W1=1.2, g1=g2=1.0, L2=1.4, W2=0.8, L3=13.1, W3=0.3, L4=6.3, W4=0.3, L5=5.2, W5=0.7, L6=5.0, W6=0.8 and g3=0.5 (all dimensions are in millimeter).

Two different types of substrates were utilized in this design namely: printed circuit board (PCB) and liquid crystal polymer (LCP). The PCB is Rogers RO3003 with a dielectric constant of *3.0* and a loss tangent of *0.0025* whereas LCP substrates have almost the same characteristics as the PCB. Note that the LCP core film has a different melting temperature of *315°* compared to *280°* of the bonding film in which a multilayer lamination process was developed for this prototype fabrication.



(c) (d)

Fig. 3. Balun multilayer design. (a)Layer1.(b) Layer2.(c) Layer 3.(d) Layer 4.

III. RESULTS AND DISCUSSION

Based on the previous discussion, an LCP ultra-wideband microstrip to stripline transition was designed, simulated and finally fabricated covering the bandwidth between *0-14* GHz. Moreover, a demonstrating balun example deploying the proposed UWB transition was also designed with a center frequency of *6.2* GHz and a fractional bandwidth *>100%*. The proposed multilayer components were fabricated in house and tested as well using N5225A PNA Microwave Network Analyzer. Fig. 4 presents the simulated and measured scattering parameters (S-parameters) responses of the proposed transition design. The simulated return loss is better than 17 dB and insertion loss is 0.3 dB whereas the measured return and insertion losses are 12 and 1.5 dB respectively.

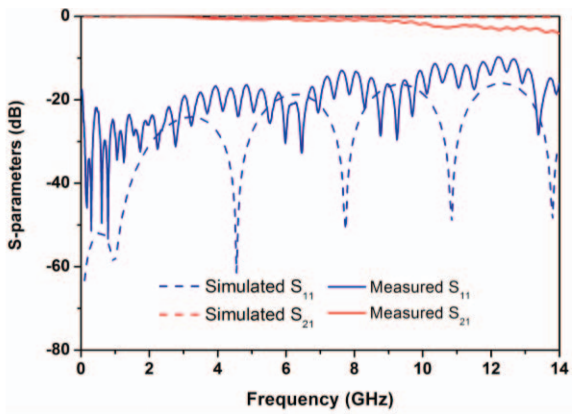
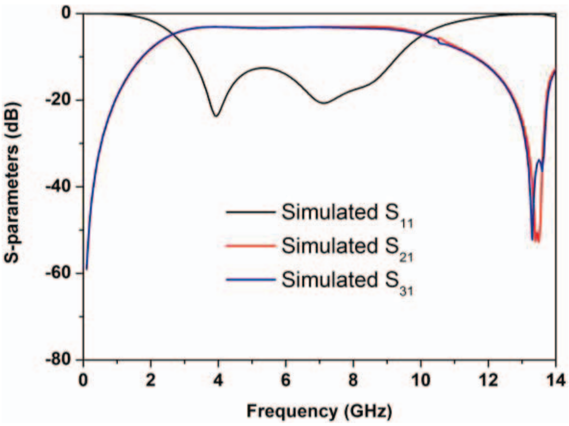


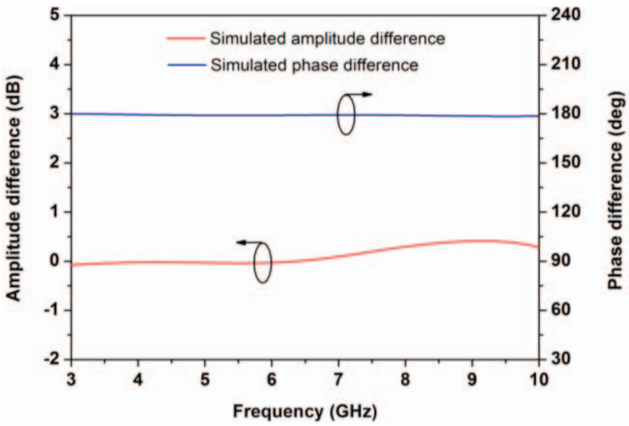
Fig. 4. Simulated and measured performances of proposed transition design.

Fig. 5 illustrates the simulated s-parameters responses as well as the amplitude and phase balances of the designed balun. The simulated return loss is better than 13 dB and insertion loss is 0.35 dB. The simulated amplitude balance is better than ±0.4 dB whereas the phase balance is ± 1.6°.

As it can be observed from the graphs that measurements generally agree with simulations with little variations caused by fabrication tolerances and the limited available tools in house.



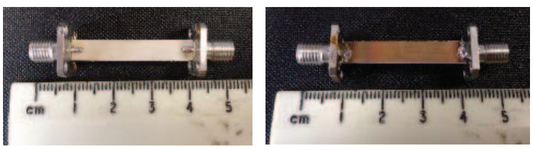
(a)



(b)

Fig. 5. Proposed balun design.(a) Simulated s-parameters. (b) Simulated amplitude and phase balances.

The photographs of the fabricated transition prototype is displayed in Fig. 6 where both sides of the design are displayed.



(a) (b)

Fig. 6. Photos of the fabricated prototype. (a) Upper side (b) Lower side.

A table with detailed performance comparison with other related transition designs in the literature is shown in Table I. One can easily see that not a single reported approach includes all the benefits or the characteristics associated with the proposed design in this paper. Thus, that confirms the outstanding significance and capability this approach introduces.

Table I: Performance comparison with other work

Ref.	BW [GHz]	Self-packaged with EM shielding	Extensive usage of via holes for unwanted modes elimination	Cost	IL [dB]	RL [dB]
[1]	0-43	No	Yes	Expensive	2.2	8
[2]	0-70	No	No	Expensive	-	17
[3]	60-110	No	Yes	Cheap	2	13
[4]	1-12	No	Yes	Expensive	1.2	8.7
[5]	0.5-20	No	No	Cheap	1.5	18
This work	**0-14**	**Yes**	**No**	**Cheap**	**0.35**	**13**

IV. Conclusion

In this paper, a new miniaturized multilayer microstrip to stripline transition using LCP technology was presented. It demonstrates an ultra-wideband performance maintaining good responses throughout the whole band of interest. As it has been shown that the design is self-packaged, light in weight with a small footprint reducing the overall cost. Simulation and measurement results show good agreement further validating the proposed design.

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