Progress In Electromagnetics Research Letters, Vol. 73, 133–136, 2018

A New Microstrip-to-Microstrip Vertical Transition Structure for Ultra-Wideband (UWB) Applications

Lihua Wu[1] and Chengpei Tang[2, *]

Abstract—A new microstrip-to-microstrip vertical transition structure for ultra-wideband (UWB) applications is proposed in this paper. The transition consists of a low impedance microstrip ring stub and a couple of slotline square multiple-mode resonators (MMRs) on the common ground plane. The low impedance microstrip ring stubs are realized by the connection of three single stubs in parallel, and the high-impedance section of slotline SIR is realized by the connection of four single stubs in series. The simulated and measured results are in good agreement, showing good wideband filtering performance with ultra-wideband fractional bandwidth.

1. INTRODUCTION

Ultra-wideband (UWB) radio technology has attracted much attention since the U.S. Federal Communications Commission (FCC) allocated a frequency range with a bandwidth of 7.5 GHz (3.1 $\sim$ 10.6 GHz) for unlicensed radio applications. Many applications have been developed based on UWB technology such as short-range broadband communication, radar sensing, and body-area networking [1]. On one hand, to meet the needs in advancement of microwave integrated circuits, proper combination of different planar structures is always preferred to achieve optimal performance in system or module. On the other hand, the vertical microstrip transitions are essential to building compact microwave circuits in multilayer designs. Traditionally, the categories to achieve microstrip vertical transitions are as follows: transitions based on the via [2], slot-coupled or cavity-coupled transitions [3–7]. Transitions based on a via exhibit a low-pass behavior. However, as the operating frequency increases, the performance is degraded. Both slot-coupled and cavity-coupled transitions are band-pass circuits, and two or three transition poles are achieved in the passband through changing the shape and electrical size of the slot.

In this paper, a new microstrip-to-microstrip vertical transition structure for ultra-wideband (UWB) applications is presented. The proposed slot-coupled category is introduced to achieve microstrip UWB vertical transition. This paper analyses the relationship between the impedance of the stubs and the bandwidth of the transition, and design a new UWB microstrip vertical transition structure. Finally, the performance of the proposed microstrip-to-microstrip vertical transition is measured.

2. CIRCUIT DESIGN

The configuration and physical size of the proposed microstrip-to-microstrip vertical transition are shown in Fig. 1(a) and Fig. 1(b). Port 1 is located on the top-layer of the structure and port 2 at the bottom layer. The ground plane, which includes the half-wavelength slotline SIR, is at the mid-layer of the structure. The half-wavelength slotline square multiple-mode resonator (MMR) can generate a

Received 6 December 2017, Accepted 30 January 2018, Scheduled 5 March 2018
* Corresponding author: Chengpei Tang (elechengpeitang@aliyun.com).
[1] School of Intelligent Robot, Open University of Guangdong, Guangzhou 51009, China. [2] School of Intelligent Engineering, Sun Yat-sen University, Guangzhou 510006, China.

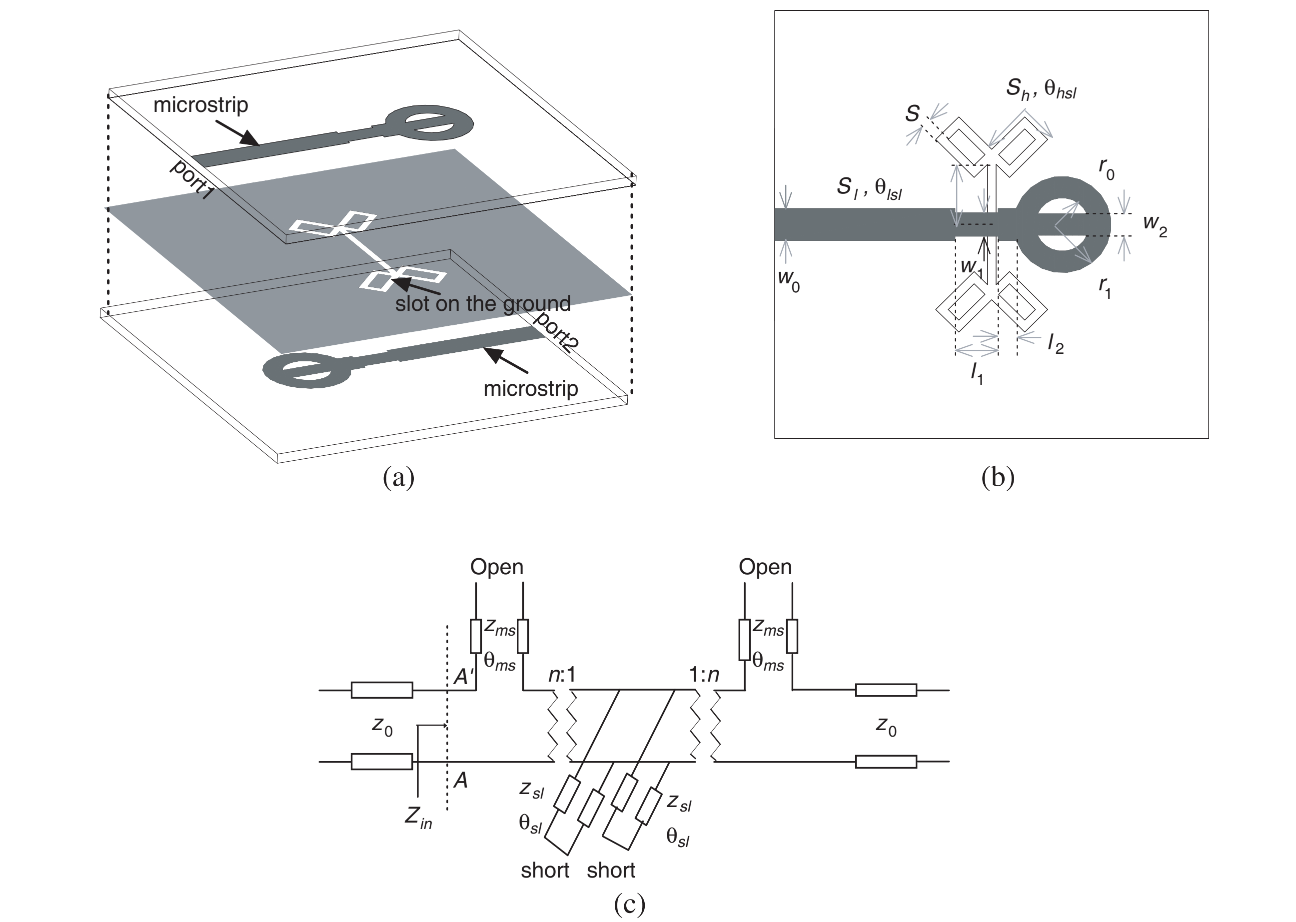

Figure 1. (a) The layout of the proposed microstrip-to-microstrip vertical transition; (b) The physical size of the proposed microstrip-to-microstrip vertical transition; (c) The equivalent of the proposed microstrip-to-microstrip vertical transition with uniform microstirp and slotline stubs.

resonant frequency in the passband. Besides, the proposed structure contains low-impedance quarter-wavelength microstrip ring stubs. As described in [8], due to the limited reliability high-impedance slotline stub and low-impedance microstrip stub, the low-impedance microstrip stub is realized by the connection of three single ring stubs in parallel, and the high-impedance section of the slotline square MMR is realized by the connection of four single square stubs in series. As described in [5], the transition has three transition poles in the passband. When the microstrip stubs and slotline stub are uniform, their equivalent circuits can be shown as Fig. 1(c). The proposed microstrip vertical transition can be expressed as (assume $\theta_{ms} = \theta_{sl} = \phi$):

$$Z_{in} = z_0 \frac{1 - j2\frac{z_{ms}}{z_0}\cot\phi - 2\frac{z_{ms}}{n^2 z_{sl}}\cot^2\phi - j2\frac{z_{ms}^2}{n^2 z_0 z_{sl}}\cot^3\phi}{1 - j2\frac{z_0}{n^2 z_{sl}}\cot\phi - 2\frac{z_{ms}}{n^2 z_0 z_{sl}}\cot^2\phi} \tag{1}$$

This equation holds if:

$$z_{ms} = \frac{z_0^2}{n^2 z_{sl}} \quad \frac{z_{ms}^2}{n^2 z_0 z_{sl}} \to 0 \tag{2}$$

It is evident that a large bandwidth can be obtained when Z_{ms} has a low value and Z_{sl} has a high value. Using slotline SIR instead of high-impedance slotline stub can control the bandwidth and impedance matching of the proposed microstrip vertical transition. The design process is aided with HFSS 13.0 simulation software. The simulated performance of the microstrip vertical transition varies

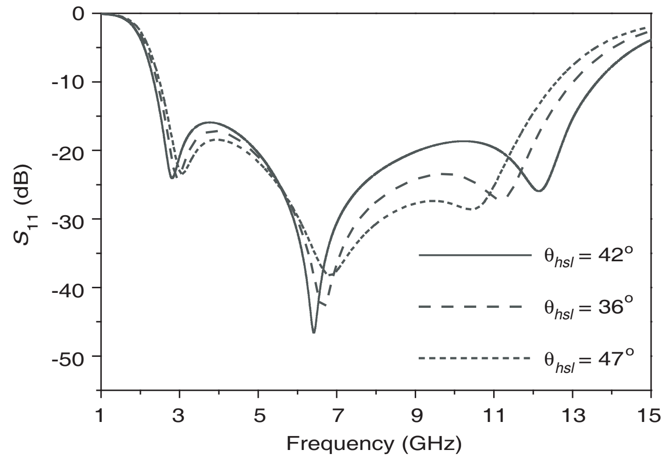

Figure 2. Simulated S_{11} varies with high-impedance slotline stub length θ_{hsl}.

with the high-impedance section of the slotlie SIR, shown in Fig. 2. It can be seen that the fractional bandwidth (FBW) moves down simultaneously with increasing θ_{hsl}. Therefore, by appropriately adjusting the slotlie SIR dimensions, the desired FBW can be achieved. Besides, the width w_1 can control the coupling coefficients between the microstrip and the slotline SIR.

3. SIMULATION AND MEASUREMENT RESULTS

The microstrip-to-microstrip vertical transition is fabricated on Rogers Duroid 5880 with dielectric constant of 2.22 and thickness of 0.508 mm. The center frequency is designed at 7.7 GHz. The final optimized sizes of the broadband microstrip vertical transition are: $w_0 = 1.5$ mm, $w_1 = 1.1$ mm, $w_2 = 1.0$ mm, $l_1 = 2.0$ mm, $l_2 = 0.8$ mm, $r_0 = 1.25$ mm, $r_1 = 2.25$ mm, $s = 0.2$ mm, $S_1 = 3.5$ mm, $S_h = 3.8$ mm. Fig. 3 shows the simulated and measured results of the proposed microstrip vertical transition. A broad band 2.6–12.1 GHz for a return loss less than 10 dB is achieved. The insertion loss is less than 0.6 dB. The minor discrepancy between simulation and measurement results is mainly due to the reflections from the SMA connectors and the finite substrate. Fig. 4 shows a photograph of

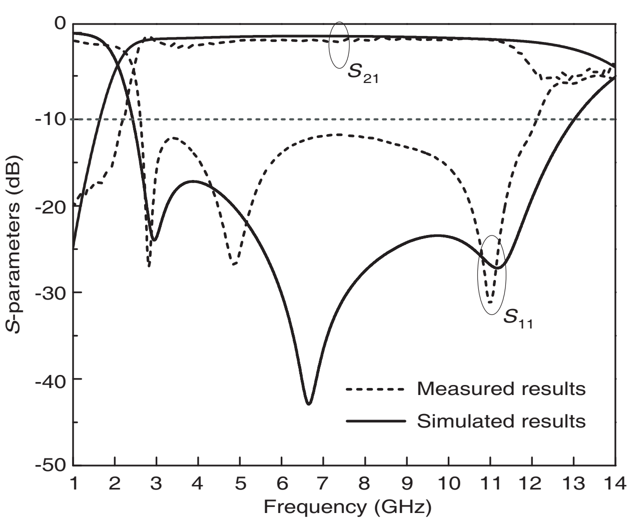

Figure 3. Measured and simulated results of the proposed microstrip-to-microstrip vertical transition.

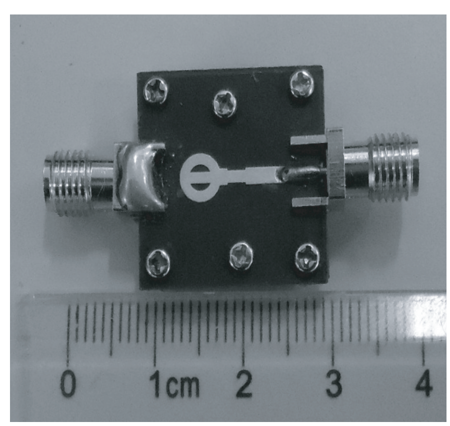

Figure 4. Photograph of the fabricated microstrip-to-microstrip vertical transition.

Table 1. Comparisons with other microstrip-to-microstrip vertical transition.

Ref.	Pass band (GHz)	FBW (3 dB)	Insertion loss (dB)	Material
[4]	$4.0 \sim 12.0$	100%	≤ 2.7	N/A
[5]	$3.1 \sim 10.6$	110%	≤ 0.7	Rogers RO4003C
[6]	$3.5 \sim 11.0$	103%	≤ 1.1	Duroid 5880
This work	$2.6 \sim 12.1$	129%	≤ 0.6	Duroid 5880

the fabricated microstrip-to-microstrip vertical transition structure. Comparisons with other reported microstrip-to-microstrip vertical transitions are listed in Table 1. It shows that our proposed microstrip-to-microstrip vertical transition has low insertion loss and ultra-wideband fractional bandwidth.

4. CONCLUSION

In this work, a new microstrip-to-microstrip vertical transition structure for ultra-wideband (UWB) applications is presented. The transition consists of low characteristic impedance microstrip ring stubs and a couple of slotline square multiple-mode resonator (MMR) on the common ground plane. This paper analyses the relationship between the impedance of the stubs and the bandwidth of the transition, and designs a wideband microstrip vertical transition. Finally, the performance of the proposed microstrip vertical transition structure is measured to validate the proposed design concept. With good passband characteristics and super compact size, the proposed new structure is attractive for the UWB wireless systems.

ACKNOWLEDGMENT

This paper is supported by the special fund of Guangdong frontier and key technology innovation (No. 2016B010108005), special fund of Guangdong applied science and technology research and development (No. 2016B010125001), Guangdong science and technology plan (No. 2016B090918110), 2015 Guangdong provincial-level information industry development special fund (Internet of Things Supports Industrial 4.0-oriented Steel Structure Intelligent Manufacturing System Development and Demonstration).

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