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A Compact Differential Coupler Using Substrate Integrated Suspended Slot Line (SISSL)

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Abstract

In this paper, a differential coupler using substrate integrated suspended slot line (SISSL) is proposed. It uses a strip-slot hybrid coupler to obtain compact size. A high level of common-mode suppression is achieved. The proposed SISSL differential coupler has advantages of compact size, self-packaging, and low loss.

1 Introduction

Directional coupler is a widely used passive component in the RF and millimeter-wave circuit and system. Recently, differential or balanced couplers have received much attention since they can better suppress the environmental noise and reduce the crosstalk and electromagnetic interference [1-4]. Slot line [5] is a differential/balanced transmission line with the inherent ability to suppress common-mode noise, and has been widely used to design differential filters [6] and dividers [7]. But the slot line-based circuit has radiation loss, and it usually requires a metal box for packaging.

In [8], the slot line is embedded and suspended in the air cavity of the substrate integrated suspended line (SISL) platform [9], and this new form of slot line with shielding boundary is named as substrate integrated suspended slot line (SISSL). SISSL has advantages of low loss and self-packaging as compared with the slot line with open form. Two differential branch-line couplers are designed in [8], but the circuit size is a little large.

In this paper, a compact differential coupler based on SISSL platform is proposed. It uses a strip-slot hybrid coupler and has a compact size. The SISSL differential coupler has a wide operational bandwidth for the differential-mode, and good common-mode suppression is also obtained.

2 Circuit Design

Figure 1 shows the three-dimensional view of the proposed compact SISSL differential coupler. It has five boards named as board1 to board5, and ten metal layers from M1 to M10. By using via holes and metal layers, the multi-layer circuit is self-packaged. The main circuit is designed on M5 and M6, and it is EM-shielded.

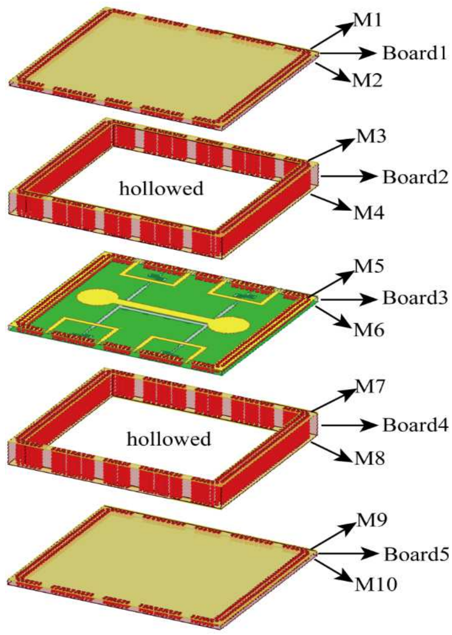

Figure 1. Three-dimensional view of the proposed compact SISSL differential coupler.

Figure 2 shows the planar view of the differential coupler. It has eight single-ended ports, forming four pairs of differential ports. The SISSL is designed on M6 and the shielded microstrip is designed on M5. The inner core circuit is a strip-slot coupler [10], which is composed of a strip on M5 and slot line on M6. This type of hybrid coupler features a compact size as compared to the traditional branch-line coupler. At the ports of the strip-slot coupler, transitions from SISSL to differential shielded microstrip are used [8]. The common-mode suppression is obtained by using the inherent nature of the operation of slot-line.

For the strip-slot coupler, the length of the coupling region is about a quarter guided wavelength. It is noted that the slot line in the coupling region is meandered as seen in Figure 2 (c), and it has a longer physical length than that of the strip line. This is mainly because the dispersion characteristics of strip line and slot line are different [10]. The board material in this paper is same as that in [8], and the center frequency is chosen as 7 GHz. The design method can refer to [10] and [8]. The detailed dimension values are provided in Figure 2 (b) and (c).

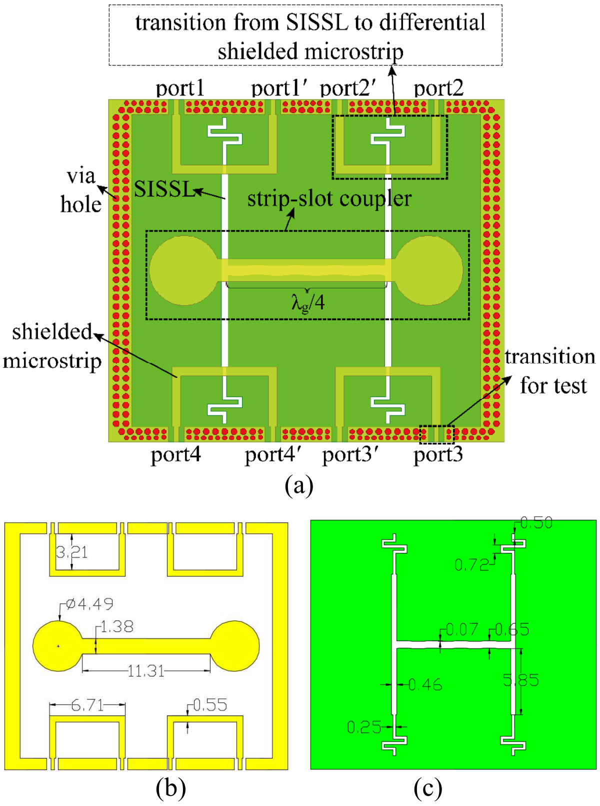

Figure 2. (a) Planar view of board3. (b) M5. (c) M6. units:mm

3 Results

The simulated response is shown in Figure 3. From 6.36 GHz to 7.66 GHz, the simulated return loss and isolation for the differential mode are both better than 20 dB, and the phase difference between two output ports is 90°±0.7°. The simulated insertion loss for the differential-mode is 0.2 dB at 7 GHz. From 6 GH to 8 GHz, the common-mode suppression and cross-mode rejection are almost larger than 30 dB. The core circuit area is 19.87mm×22.3mm.

4 Conclusions

This paper presents a compact differential coupler based on SISSL platform. It not only has good differential-mode response, but also features wideband common-mode suppression. Good properties in terms of compact size and self-packaging are obtained.

5 Acknowledgements

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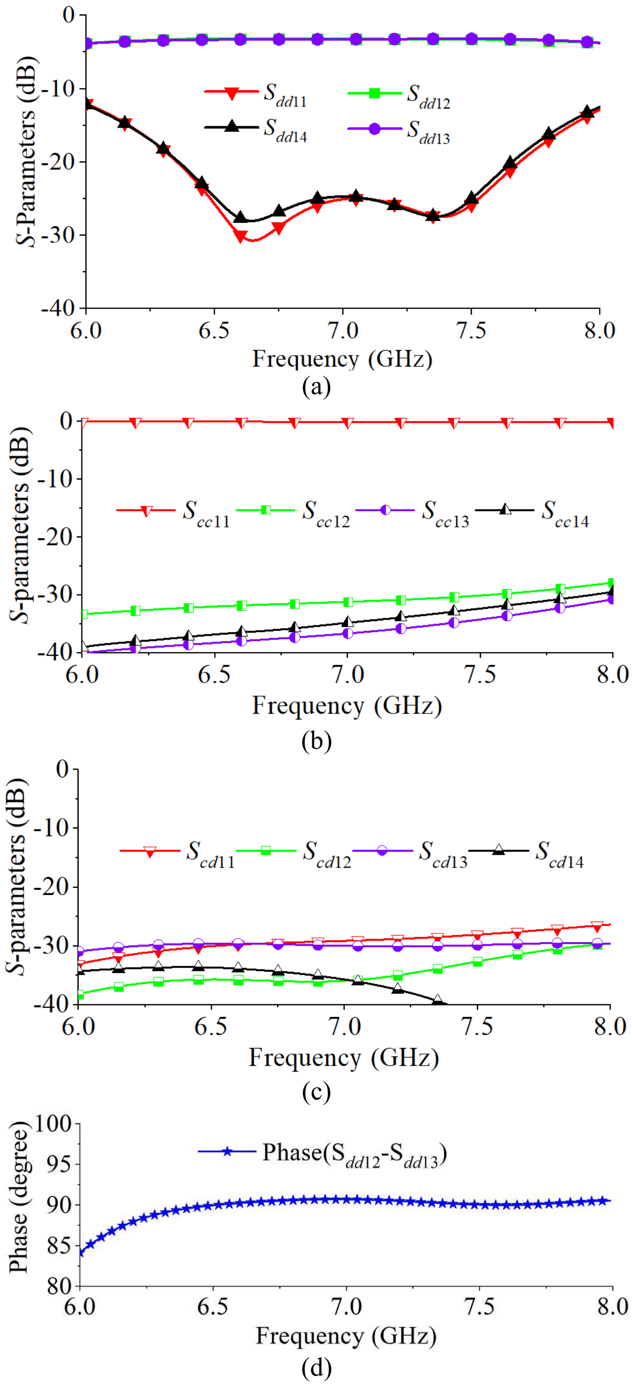

Figure 3. Simulated response of the SISSL differential coupler. (a) Differential-mode. (b) Common-mode. (c) Cross-mode. (d) phase for the differential-mode.

6 References

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