EXPERIMENTAL STUDY OF WIDEBAND UNIPLANAR PHASE INVERTERS FOR MICs

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Abstract

In this work, a class of novel uniplanar phase inverters are presented for hybrid and monolithic microwave integrated circuits(MICs). An extensive experimental study for characterizing frequency response of insertion loss and phase shift has been made. Measured results show that a CPW phase inverter with slotline transition has more than 2.3:1 bandwidth centered at 3.9 GHz with better than 1 dB insertion loss and 140^0 phase shift. A compact CPW phase inverter without slotline transition has also been developed that demonstrates better electrical performance than its counterpart with slotline transition. It shows more than 3.1:1 bandwidth centered at 3.5 GHz with better than 0.5 dB insertion loss and 140^0 phase shift. A new CPW phase inverter with triple strip line transition is proposed. It features more than 2.5:1 bandwidth centered at 6.2 GHz with better than 1 dB insertion loss and 140^0 phase shift.

Introduction

With the rapid advancement of system design for wireless communications aimed at low cost, compact, and low power consumption, the demand for cost-effective miniaturized hybrid/ monolithic microwave integrated circuits (MICs) has substantially been increased. In the conventional MICs, microstrip line has been used as the main building block. It is known that the microstrip-based MICs suffer from some potential drawbacks such as the difficult integration of three-terminal active devices and the dependency of electrical characteristics on substrate thickness. The uniplanar MIC technology which only uses one side of substrate was proposed to overcome such problems[1]. Uniplanar guided-wave structures consist of coplanar waveguide(CPW), slotline, and coplanar strip. They have a distinct advantage of easy inter-transition. Generally, the uniplanar technology permits a high level of integration and is well-suited for high frequency applications since it is easy to minimize the parasitic effects for both circuit element interconnection and active device integration. In the uniplanar MICs, there is no need for via holes to implement shunt passive or active components, which results in a significant simplification in manufacturing process. The easy inter-transition of uniplanar guided-

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wave structures provides a great flexibility for circuit design. Furthermore, the variation of the slot and strip widths offers additional degree of freedom in circuit synthesis once the substrate thickness is chosen. Various high-performance circuits on the base of the uniplanar technology have been developed [2,3].

In MICs, a circuit element with a 180^0 phase shift is usually required in order to achieve the cancellation of two-path signals with equal amplitude. As is well known, the phase inverter which has 180^0 phase shift is an indispensable element in some applications such as wideband ring coupler, balanced mixer, frequency discriminator, and feeding network of antenna arrays. To fully take the advantages of the uniplanar configuration, an electrical performance study of various phase inverter circuits is necessary. In this work, three types of CPW phase inverter are developed and experimentally investigated. The configurations are shown in Fig. 1. The measured results show that the phase inverters have more than one octave bandwidth with good insertion loss and phase shift. A compact CPW phase inverter without slotline transition demonstrates more than 3.1:1 bandwidth centered at 3.5 GHz with better than 0.5 dB insertion loss and 140^0 phase shift.

Circuit Description

It is well known that a 180^0 phase shift may be obtained by means of reversing field orientation with reference to ground. In MICs, reversing field orientation to the ground is usually achieved by reversing signal and ground paths. To reverse signal and ground paths, a typical approach is using balun transformer. Fig.2 illustrates the circuit model of a balun-type phase inverter. In uniplanar circuit, this type of phase inverter can easily implemented on the basis of CPW and slotline as shown in Fig.1A. It is obvious that in the balun-type phase inverter, all transmission lines must have the same characteristics impedance to maintain a good electrical performance over a broad frequency range. As it is well documented, however, the slotline is a non-TEM transmission line, and its modal dispersion is more pronounced than that of CPW. In order to overcome the shortcoming of the phase inverter with slotline transition, two new CPW phase inverter are proposed in this work. The configurations are given in Fig.1B and Fig.1C. The phase inverter shown in Fig.1B consists of two CPW sections terminated with short-circuit radial stubs, which are directly connected at the opposite side of one CPW slot. Its advantage consists in eliminating slotline transition section and minimizing the radiation loss owing to symmetrical distribution of two radial stubs. Consequently, the size of circuit can be reduced. Its bandwidth is limited only by two radial stubs. Fig.1C shows the phase inverter using a triple strip line transition. The CPW section is connected to the triple strip line. Since the CPW and triple strip line have a symmetrical filed distribution, the phase inverter eliminates the radiation loss which exists in the slotline configuration. It is noted that the parasitic coupled slot-line mode in the CPW circuit may be excited by asymmetrical discontinuities. Therefore, in practical applications, an air-bridge is needed to suppress such an unwanted mode.

Experimental Results

To demonstrate the usefulness of the proposed phase inverter and also to reveal its electrical properties, an extensive experimental study has been made to determine the potential operating frequency bandwidth. Experimental samples were fabricated on a 1.27 mm-thick RT/Duroid 6010 (ε_r=10.2) substrate. For 50Ω CPW feed line, slot and central strip widths are 0.33 mm and 0.8 mm, respectively. A Wiltron test fixture (model 3680V) is used in our experimental setup. The Thru-Reflect-Line (TRL) calibration technique is implemented on an HP 8510C network analyzer [4]. The reference plane in the test setup is set up at the middle of the circuit so as to eliminate the phase difference which is produced by the physical length of the circuit. Fig.3 shows the measured frequency response of insertion loss and phase shift for the phase inverter with the slot line transition shown in Fig.1A. These results indicate that the 1 dB insertion loss bandwidth is located in the 2.3-5.8 GHz frequency range while the 140^0 phase shift bandwidth is in the 1-5.4 GHz frequency range. A 180^0 phase shift appears at 2.86 GHz. It is obvious that the bandwidth is limited by the intrinsic slotline cutoff frequency and series resonant frequency of the short-circuit radial stub. The insertion loss comes from the CPW and slot impedance mismatch and air-bridge discontinuity reflection as well as slotline mode radiation.

Fig.4 shows the measured frequency response of insertion loss and phase shift for the phase inverter without slot line transition shown in Fig.1B. The experimental insertion loss is less than 0.5 dB in 1.8-5.9 GHz frequency range. The 140^0 phase shift bandwidth is located in the 1-5.3 GHz frequency range. It is noted that the phase shift at 1 GHz is larger than 154^0. As expected, the CPW phase inverter without the slotline transition has better insertion loss performance than its counterpart with the slotline. Fig.5 shows the measured frequency response of insertion loss and phase shift for the phase inverter with the triple strip line transition shown in Fig.1C. It has more than 2.5:1 bandwidth centered at 6.2 GHz with better than 1 dB insertion loss and 140^0 phase shift.

Conclusions

Three types of uniplanar phase inverter have been developed. An experimental study was performed. Measured results show that a CPW phase inverter with slotline transition has more than 2.3:1 bandwidth centered at 3.9 GHz with better than 1 dB insertion loss and 140^0 phase shift. The compact CPW phase inverter without slotline transition demonstrates more than 3.1:1 bandwidth centered at 3.5 GHz with better than 0.5 dB insertion loss and 140^0 phase shift. The phase inverter with triple strip line transition has more than 2.5:1 bandwidth centered at 6.2 GHz with better than 1 dB insertion loss and 140^0 phase shift. These phase inverters are promising for applications in coupler, mixer, frequency discriminator, and feeding network of antenna arrays. The proposed uniplanar configurations are in particular suitable for miniaturized hybrid/ monolithic MICs at high frequencies.

Acknowledgment

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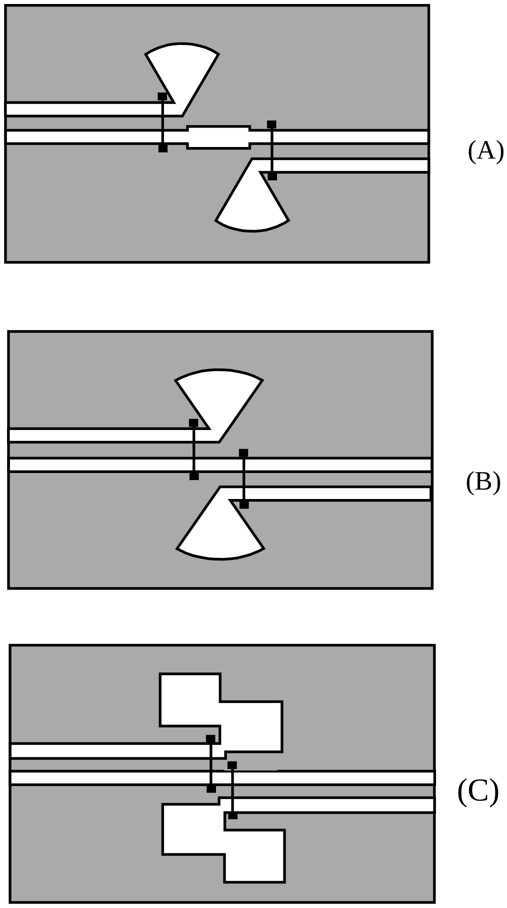

FIGURE 1: CPW PHASE INVERTERS; (A) WITH SLOTLINE TRANSITION, (B) WITHOUT SLOT TRANSITION, (C) WITH TRI-STRIP LINE TRANSITION.

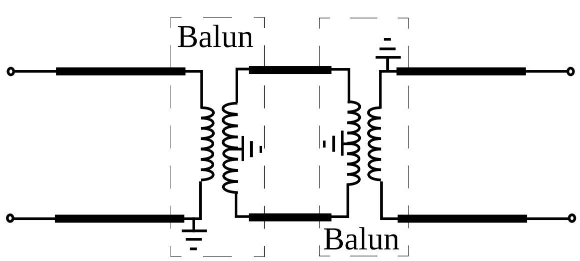

FIGURE 2: CIRCUIT MODEL OF BALUN-TYPE PHASE INVERTER.

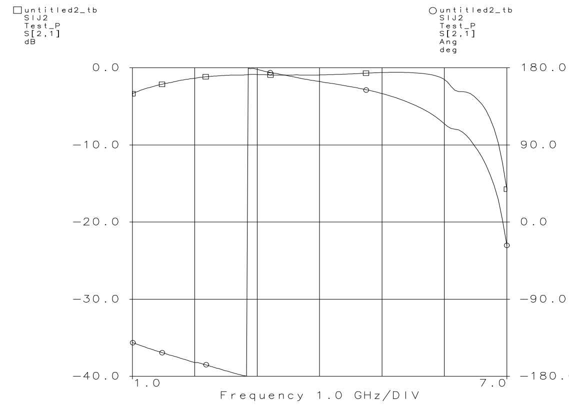

FIGURE 3: MEASURED FREQUENCY RESPONSE OF INSERTION LOSS AND PHASE SHIFT FOR FIG.1A

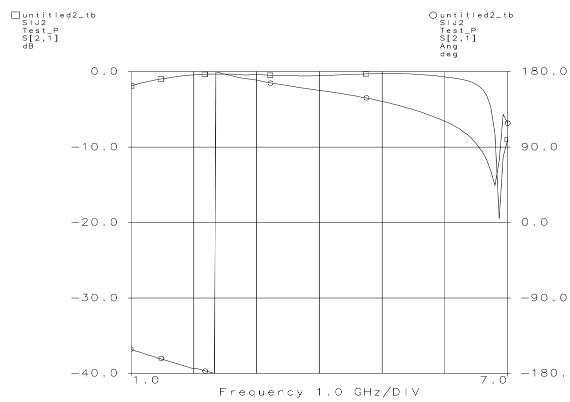

FIGURE 4: MEASURED FREQUENCY RESPONSE OF INSERTION LOSS AND PHASE SHIFT FOR FIG.1B

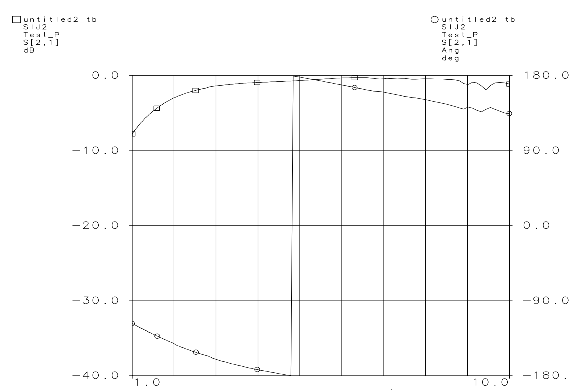

FIGURE 5: MEASURED FREQUENCY RESPONSE OF INSERTION LOSS AND PHASE SHIFT FOR FIG.1C

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