Reconfigurable Substrate Integrated Waveguide

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Abstract— In this paper, a new substrate integrated waveguide (SIW), which is called reconfigurable substrate integrated waveguide (RCSIW) is proposed. RCSIW is derived from SIW and tunable technology which is widely used in microwave system. It is realized by replacing the side-wall metal posts of SIW with several grounded varactors which are employed to make the SIW tunable. The cutoff frequency and propagation constant can be reconfigurable by controlling these varactors. A RCSIW is designed to test these properties with the input and output of microstrip line. Ansoft HFSS was used to get the characteristics of RCSIW. The results show the reconfiguration of RCSIW.

1. INTRODUCTION

Substrate integrated waveguide (SIW) has been interested by researchers around the world and widely used in microwave and millimeter wave circuit and system. A simple reason is that SIW, as a combination of waveguide and planar circuit, has a lot of attractive properties such as low cost, low profile, high power capacity and easy to integrate with planar circuits [1–4]. And there are some planar structures based on SIW, such as half-mode substrate integrated waveguide (HMSIW) [5], quarter-mode substrate integrated waveguide (QMSIW) [6], ridge substrate integrated waveguide (RSIW) [7], folded substrate integrated waveguide (FSIW) [8], corrugated substrate integrated waveguide (CSIW) [9] and so on.

Reconfigurable technologies are required in many microwave systems, such as multiband wireless communication and wideband radar systems. Varactors, micro-electromechanical systems (MEMS) and piezoelectric transducers and ferroelectric components are common reconfigurable technologies. Due to the high tuning speed and reliability, diode varactors are widely utilized in the design of configurable devices [10–12].

HMSIW and QMSIW structures, due to their open side, are very suitable to place varactors, which makes them be employed with reconfiguration technologies conveniently. The concept of HMSIW which is forming by bisecting SIW along a fictitious quasi-magnetic wall was proposed in [7]. As an improved structure, HMSIW keeps most of the excellent performance of SIW, while both the waveguide width and the size of the structure are reduced by nearly a half compared with the SIW. Since its birth, the characterization of the propagation properties of HMSIW has been studied in [13]. Because the center symmetrical plane of the HMSIW can also be equivalently regarded as a quasi-magnetic wall for some particular modes, the HMSIW can be further bisected into two parts again along the symmetrical plane. Hence, a QMSIW is realized. The field distribution of the QMSIW is almost the same as the field distribution of the original SIW [6]. QMSIW has only 25% size of SIW, meanwhile, the advantages of SIW has been inherited.

In this paper, a new SIW structure with electrically tunable technology is been proposed, and we call it reconfigurable substrate integrated waveguide (RCSIW). It is realized by replacing the side-wall metal posts of SIW with several grounded varactors. The cutoff frequency and propagation constant of RCSIW can be tuned by changing the capacitance of the varactors. The characteristics of RCSIW are presented in Section 2, conclusions are presented in Section 3.

2. CHARACTERISTICS OF RCSIW

In this section, we investigate the electric field, modes, insertion loss, cutoff frequency and propagation constant of RCSIW. RCSIW is designed with substrate F4B, which $h = 0.764\,\text{mm}$, $\varepsilon_r = 2.55$, and $\tan\delta = 0.001$. Ansoft HFSS is used as an aided designer to simulate and explore the properties of SIW structures.

2.1. Dominant Mode of RCSIW

Figure 1 shows the configuration of RCSIW, microstrip line is employed to make the measurement convenient. Microstrip-RCSIW transition is used to match the RCSIW and microstrip line. To construct a RCSIW, first, two gaps are cut on the top of SIW, after that, several varactors are

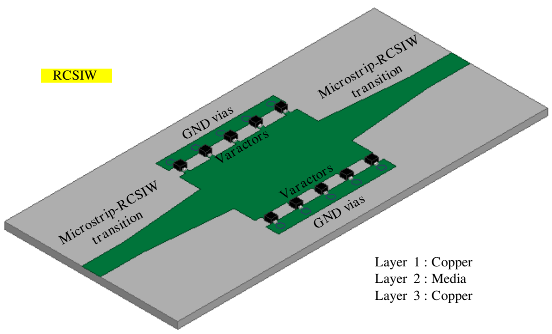


Figure 1: Configuration of the proposed RCSIW.

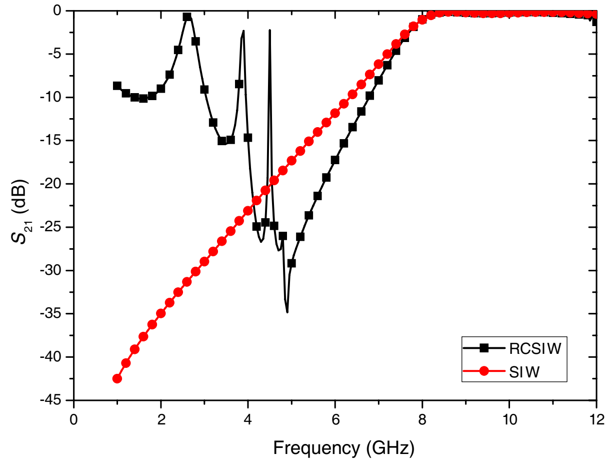
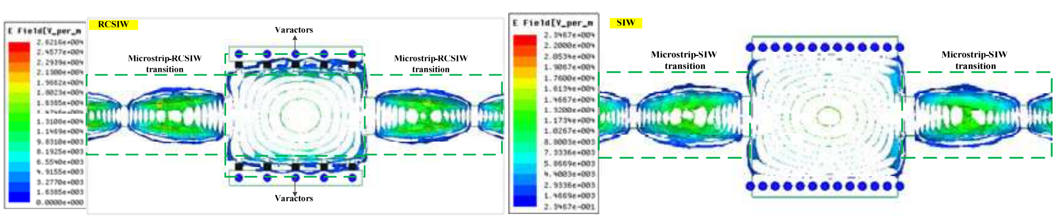


Figure 2: S_{21} of RCSIW and SIW.

placed on the gaps. In this case, there are five varactors on each side of the gap. A SIW is designed to compare with RCSIW and they have the same cutoff frequency.

Figure 2 shows the S_{21} of RCSIW and SIW. Comparing the two structures, it can be tell that, the insertion losses of SIW and RCSIW are on the same level about 0.3 dB, at the frequency of 8.2 GHz to 11 GHz. But the insertion loss of RCSIW is not so gentle compared with SIW, the insertion loss of RCSIW is 0.5 dB, at the frequency of 12 GHz. It also shows RCSIW has much more modes below the cutoff frequency, but it does not matter when the RCSIW is used to working at the waveguide dominant mode.

Figure 3 shows the electric fields of RCSIW and SIW at 8.2 GHz. The electric field of RCSIW is similar to that of SIW, when they work on dominant mode: TE_{10} mode, at the same frequency. It is shown that the width of RCSIW is a litter narrower than SIW, which is caused by the capacity



(a) RCSIW (b) SIW

Figure 3: Electric field (dominant mode: TE_{10}) of RCSIW and SIW.

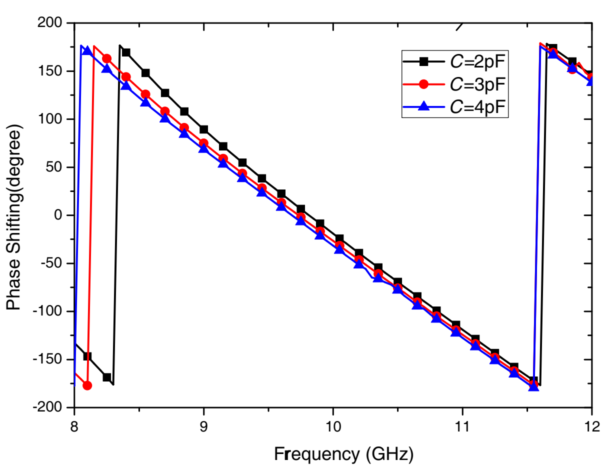


Figure 4: Phase shifting of RCSIW varied with the capacity of the loaded varactors.

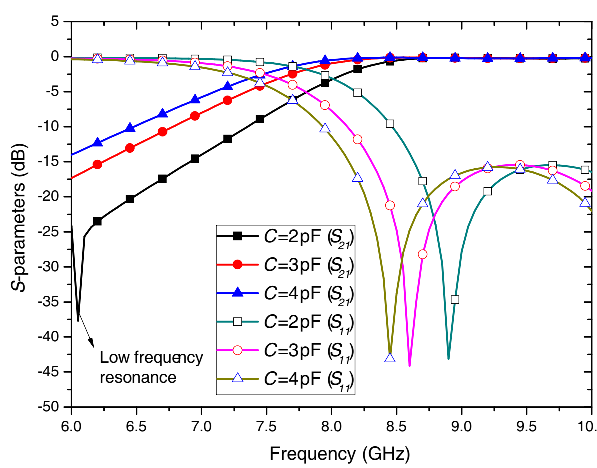


Figure 5: S-parameters of RCSIW varied with the capacity of the loaded varactors.

effect of varactors. And the varactors are placed in the two sides of the RCSIW with very low level electric field, which means the displacement current flowing through series resistance of the varactors is rather small leading a quite safe situation of the varactors.

2.2. Reconfiguration of RCSIW

In this subsection, the capacity of the varactors is tuned simultaneously to make the RCSIW reconfigurable. When the capacity of the varactors is varied from 2 pF to 4 pF, the phase of RCSIW changes 40.6 degree (shown in Figure 4). It is caused by the varactors changing the equivalence width of RCSIW, which makes the propagation constant of RCSIW reconfigurable. So RCSIW can be used in reconfigurable phase shifters.

Figure 5 shows the cutoff frequency can be tuned by controlling the capacity of the varactors. It is also caused by the changing the equivalence width of RCSIW. This property makes RCSIW to be promising in reconfigurable filters.

3. CONCLUTIONS

In this paper, a new reconfigurable substrate integrated waveguide is proposed. Varactors are employed to make the RCSIW tunable. The cutoff frequency and propagation constant of RCSIW can be tuned by changing the capacitance of the varactors, and these varactors are placed in a quite safe situation. The RCSIW structure is promising in microwave and millimeter circuits and systems.

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