A Design of V-band Reconfigurable SPDT Switch/Power Divider Based on Slotted SIW

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Abstract—In this paper, a novel reconfigurable single-pole double-throw (SPDT) switch/power divider (PD) employing substrate-integrated waveguide (SIW) technology is presented for V-band applications. By controlling the dc-bias of PIN diodes, the proposed reconfigurable function can be achieved. Simulations show that, when functioned as a SPDT switch, the circuit exhibits an isolation of larger than 32 dB and an insertion loss of less than 1.4 dB from 58-62 GHz. On the other hand, a minimum insertion loss of 0.9 dB is calculated at 60 GHz when functioned as a 3-dB PD. The total area of the device is $3\lambda_0 \times 2.36\lambda_0$.

I. INTRODUCTION

As a key component in various measurement equipments and communication systems, microwave switch can be used for signal routing between different transceiver paths. Currently substrate-integrated waveguide (SIW) technology is very promising for millimeter-wave applications due to its advantages of low loss, compact size and easy integration with RF circuitries [1]. Based on SIW technology, microwave switches with various implementations have been reported in recent years, such as mechanical control switches, magnetic control switches [2] and electronic control switches [3]-[4]. The operating frequencies of these SIW switches are usually below 20 GHz. With the rapid development of modern communication, single-functional designs cannot meet the continuous demands since their characteristics are fixed and inflexible. To this end, the research on reconfigurable devices becomes a challenging task [4]. The existing reconfigurable SIW devices are mainly polarization-reconfigurable or frequency-reconfigurable, rarely in function-reconfigurable.

In this paper, a V-band reconfigurable SPDT switch/PD is proposed based on SIW technology. The proposed device can be functioned as SPDT or PD, with low loss and high isolation.

II. STRUCTURE AND DESIGN

A. SPST Switch

Fig. 1 depicts a V-band SPST switch based on SIW. As shown, a rectangular-ring slot is etched on the top SIW surface to cut off the surface current. A “H-type” metal strip is located inside the rectangular-ring slot, with two pairs of PIN diodes connected to the metal surface of SIW.

A simplified equivalent circuit model is also given in Fig. 1, where the latitude and longitude paths of the slot can be modeled as series and parallel loads, respectively. 1) When under forward bias, the PIN diode acts like a series connection of a small inductance and a small resistance. Since the central strip is connected to the SIW surface, the incident wave will propagate (“ON-state”). It should be mentioned that the leakage waves radiated from the longitude paths of the slot can be effectively suppressed because of symmetry of structure. 2) When under reverse bias, the PIN diode acts like a series connection of a small inductance and a small capacitance. In this case, the central strip is isolated and the incident wave will be reflected (“OFF-state”).

B. Reconfigurable SPDT Switch/PD

Based on the previous SPST switch, a V-band reconfigurable SPDT switch/PD can be implemented. As illustrated in Fig. 2, this circuit consists a Y-junction SIW PD, two SPST switches and two bias circuits. The SPST switch is integrated in each PD arm and the bias circuit is connected to the “H-type” strip...
TABLE I
OPTIMIZED PARAMETERS FOR THE RECONFIGURABLE SPDT/PD:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>a (mm)</th>
<th>d (mm)</th>
<th>s (mm)</th>
<th>t (mm)</th>
<th>W1 (mm)</th>
<th>W2 (mm)</th>
<th>W3 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>1.9</td>
<td>0.2</td>
<td>0.4</td>
<td>0.17</td>
<td>1.3</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Parameter</td>
<td>L1 (mm)</td>
<td>L2 (mm)</td>
<td>L3 (mm)</td>
<td>Lg (mm)</td>
<td>D (mm)</td>
<td>L (mm)</td>
<td>W (mm)</td>
</tr>
<tr>
<td>Value</td>
<td>1.7</td>
<td>2.2</td>
<td>2.5</td>
<td>0.4</td>
<td>0.4</td>
<td>15</td>
<td>11.8</td>
</tr>
</tbody>
</table>

through a gap (Lg). To filter spurious RF signals from the dc bias, a high-low impedance low-pass filter (LPF) is adopted.

1) When the upper switch is “ON-state” and the lower switch is “OFF-state”, the device will function as a SPDT switch and the incident EM wave will propagate through port 1 to port 2; 2) When the upper switch is “OFF-state” and the lower switch is “ON-state”, the device will function as a SPDT switch and the incident EM wave will propagate through port 1 to port 3; 3) When both switches are “ON-state”, the device will function as a PD and the incident EM wave will be divided equally to port 2 and port 3.

III. SIMULATION RESULTS AND DISCUSSION

In this paper, a 0.17-mm thick silicon dioxide is employed as SIW substrate with dielectric constant of 3.9 and loss tangent of 0.0005. The length (L) and width (W) of the substrate are 3λ0 and 2.36λ0, respectively. Beam-lead PIN diodes (MA4AGBLP912, M/A-COM Technology) are selected for switching RF on or off. A full-wave electromagnetic simulation software CST Microwave Studio is used for circuit optimization. For this purpose, the parasitic parameters of the PIN diodes are included in simulations. The optimized parameters of the structure are listed in Table I.

Fig. 3 gives the simulated S-parameters of the optimized SPST switch. As shown, the return loss (“ON-state”) is greater than 10 dB, and the insertion loss (“ON-state”) is less than 0.85 dB from 58 – 62 GHz. The isolation (“OFF-state”) is greater than 33 dB from 56 – 62 GHz.

Fig. 4 shows the simulated S-parameters of the optimized reconfigurable SPDT switch/PD with port 1 excitation. As shown, the insertion loss (SPDT switch) is less than 1.4 dB and the isolation (SPDT switch) is greater than 32 dB from 58 – 62 GHz. The calculated insertion loss (3-dB PD) is 0.9 dB at 60 GHz.

Fig. 5 gives the E-field distributions of the designed reconfigurable SPDT switch/PD at 60 GHz. It can be clearly observed that the device can be functioned as either a SPDT switch or a 3-dB PD.

IV. CONCLUSION

This paper presents a V-band reconfigurable SPDT switch/PD based on SIW technology by controlling the dc-bias of the PIN diodes. Simulations show that the proposed device exhibits a high isolation and low loss, which makes it very promising for millimeter-wave T/R or multiple-beam antenna applications.

REFERENCES