A 55-105 GHz PIN Diode SPDT Switch

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***Abstract*—A single pole double throw switch (SPDT) realised with PIN diodes and using a commercial process is presented. The switch is characterized between 55-112 GHz and achieves minimum insertion loss of 2.8 dB at 85.2 GHz.**

***Keywords*—PIN diode, RF switch, millimeter-wave integrated circuits, monolithic microwave integrated circuits**

I. Introduction

RF switches are used in wireless and radar systems to switch an antenna between transmitter/receiver modules. Phase shifters, switched filter banks and beam forming in active antennas also require RF switches. A W-band SPDT switch realised with GaAs vertical PIN diode featuring reduced series resistance is presented in [1]. Another example of a single-pole triple-throw switch implemented in a coplanar waveguide (CWG) and using GaAs PIN diode is presented in [2]. For applications requiring large bandwidths traveling wave PIN switches can be realised, as demonstrated in [3]. PIN diodes can also be used to realise switches at high mm-wave frequencies for applications where very low-loss is essential. A radiometer with internal calibration source and InP PIN switch is demonstrated at 95 GHz in [4].

As beamforming is becoming the preferred architecture for radio access points the $\lambda/2$ constraint on element spacing requires front-ends integrated with low insertion loss and high isolation switches at increasingly higher frequencies. This paper presents a SPDT switch realised with a commercial GaAs process from WIN Semiconductors. The process, named PIH1-10, combines enhancement-mode pseudomorphic high-electron-mobility transistor (pHEMT) with monolithic PIN and Schottky diodes.

II. Switch design

The structure of the switch is shown in in Fig. 1 where an 8x8 um^2 PIN diode is used as a switching component in shunt configuration. The series ON state resistance of the PIN diode limits the isolation in the OFF state arm. Therefore to achieve reasonable isolation, two shunt diodes are used in each arm, at the expense of increased insertion loss.

A. Diode characterization

Fig. 2 shows the measured and modeled IVC and differential resistance vs. bias voltage of the 8x8 um^2 PIN diode. The extracted series resistance at ON state at bias 1.8 V is 8.2 Ohm.

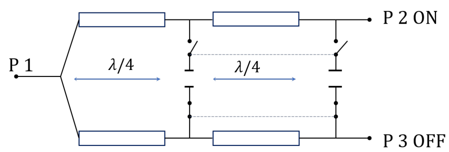

Fig. 1: SPDT switch configuration. PIN diodes can be used as switching components.

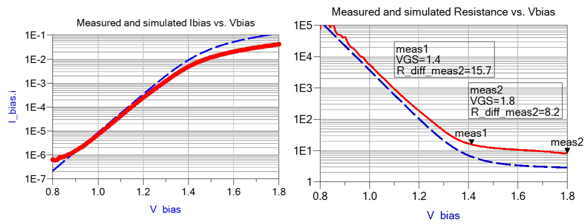

Fig. 2: **Left:** measured (red) and modelled (blue dash) diode IVC. **Right:** measured (red) and modeled (blue dash) differential resistance.

RF measurements were also performed for the ON and OFF states of the 8x8 um^2 PIN diode for frequencies between 70 kHz and 121 GHz.The extracted, from the RF measurements, ON state resistance is 10 Ohm and OFF state capacitance is 23 fF.

B. Switch using ideal components

A schematic of the SPDT switch using 8x8 um^2 diode and ideal components is shown in Fig. 3. The circuits uses loss-less transmission lines, perfect bias decoupling and grounding of the diodes. The simulated performance of the ideal switch is shown in Fig. 4 with a loss of only 0.4 dB and isolation of 30 dB at 86 GHz. However, transferring the design to real layout using microstrip line resulted in unacceptable deterioration of the insertion loss and isolation, in addition to decrease of the bandwidth. The main issue is grounding of the diodes, which would require the use of a thru substrate via (TSV). The TSV has considerable electrical length at higher frequencies associated with the 100-um thick GaAs substrate. Therefore, a CPW is used to realise the switch as the ground of the CPW is at the same level as the diode and a nearly perfect grounding of the diode can be achieved at mm-wave frequencies.

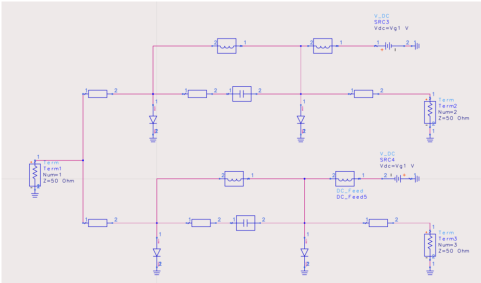

Fig. 3: Schematic of the SPDT switch.

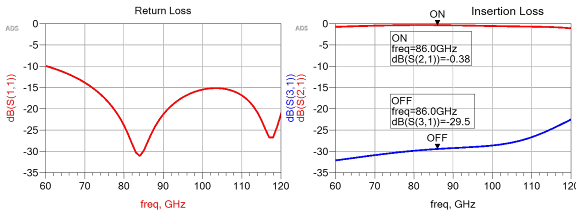

Fig. 4: **Left:** Simulated return loss of the SPDT switch realised with 8x8 um^2 diode and ideal components. **Right:** The corresponding insertion loss for the ON and OFF channels.

C. Switch design in CPW topology

The PIH1-10 process is based on a 100-um GaAs substrate with 2 metal layers in the back-end-of-line. The 2 top layers are separated by a stack of SIN and polyimide dielectrics (eps=6.9 and 3.3, respectively) and can be used to realize capacitors and inductors. Crossovers (bridges) formed in metal 2 are used at each corner of the CPW lines to suppress higher order modes. The picture of the switch and the probes used for the measurement are shown in Fig. 5.

III. Switch Performance

The switch was measured using a VNA in two frequency bands: 55-95 GHz (E-band) and 62-112 GHz (W-band). The diodes in the OFF channel were biased with 1.4 V/15 mA for the E-band and 1.8V/80 mA for the W-band measurement. As the circuit can be contacted with maximum two RF probes, all measurements were performed when one of the output channels left open-circuited that has partly deteriorated measured reflection loss and isolation as compared

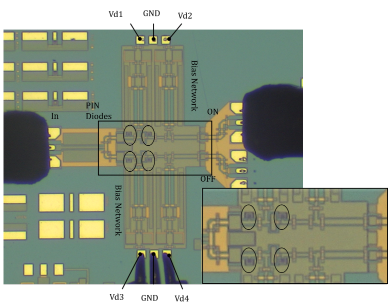

Fig. 5: Picture of the SPDT switch as it was measured. The locations of the PIN diodes are marked with circles.

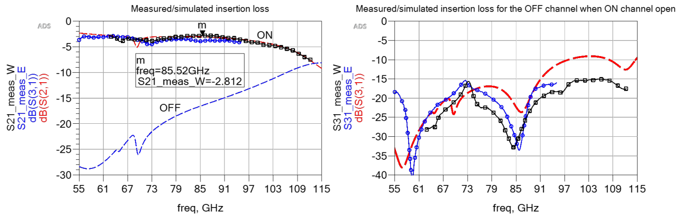

Fig. 6: Measured and simulated insertion loss (IL) of the SPDT switch. **Left:** measured E-band IL for the ON channel (blue circles), measured W-band IL (black squares); simulated IL for the ON channel (red dashed) and simulated IL (isolation) for the OFF channel (blue dash). **Right:** measured IL (isolation) for the OFF channel with the ON channel left open; simulated IL for the same configuration (red dash).

with simulations. The measured and simulated insertion loss for the ON and OFF channels is shown in Fig. 6 with the minimum loss of 2.8 dB at 85.2 GHz. The measured return loss demonstrates maximum peaks of approximately 7 dB which are due to the open OFF channel. Results are omitted here due to space limitations.

IV. Conclusion

We presented the SPDT switch realized using PIN diodes in a commercial GaAs process combining PIN/Schottky diodes with enhancement-mode pseudomorphic high-electron-mobility transistor from WIN semiconductors (PIH1-10). The switch has been characterized between 55 and 112 GHz with minimum insertion loss of 2.8 dB measured at 85.2 GHz. The isolation was not measured properly as it requires RF probing at all 3 ports of the switch. The estimated isolation varies from 26 dB at 55 GHz to 8 dB at 100 GHz.

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