High Frequency PIN-Diode Switches for Radiometer Applications

Oliver Montes, Douglas E. Dawson, Pekka Kangaslahti, and Steven C. Reising*

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

*Microwave Systems Laboratory, Colorado State University, Fort Collins, CO

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Introduction

- Dicke switched radiometers allow for correction of gain and noise figure fluctuations in components of receiver chain.
- Accomplished using a single-pole double-throw (SPDT) RF MMIC switch.
- Switches the input of the receiver between the signal from the antenna and a signal from a matched load internal to the radiometer.
Description of Work

- Microwave switches were designed to cover three frequency ranges of 80-105 GHz, 90-135 GHz, and 160-190 GHz
- Monolithic microwave integrated circuits (MMIC) were realized in microstrip and coplanar waveguide technology
- Fabricated using Northrop Grumman’s 75-μm thick InP MMIC PIN diode process
- PIN diodes used because of low insertion loss and fast switching speeds
- Variations of each SPDT design with PIN diode sizes ranging from 3 to 8 μm were fabricated
- To date, 80-105 GHz and 90-135 GHz switches have been tested; 160-190 GHz switches have not yet been tested
PIN diodes are used as switching elements

- Provide high impedance when reverse-biased because of relatively small junction capacitance of diode
- Provide low impedance path when forward-biased because of decreased junction resistance
Shunt PIN-diode SPDT Switch Implementation

- Forward-biased diode provides RF short to ground (OFF state)
- Reverse-biased diode provides high impedance to ground and does not affect RF signal (ON state)
Series PIN-diode SPDT Switch Implementation

- Reverse-biased diode provides high impedance RF path (OFF state)
- Forward-biased diode provides low impedance RF path (ON state)
Series-Shunt PIN-diode SPDT Switch Implementation

- Implements both series and shunt diode SPDT configurations together to maximize isolation
- Eliminates the need for quarter-wave transformer (reduces size)
- This configuration was used for SPDT switch designs being presented
Design Topology

SPDT Switch Circuit Schematic
Symmetric Design

- Microstrip design
- SiN 2-layer MIM capacitors for bypass and DC blocking capacitors
- NiCr thin-film process for resistors
- Radial stubs used to provide well-defined virtual RF shorts

Measured Performance

![Graph showing Insertion Loss, Isolation, Common Leg RL, and Antenna Leg RL over a frequency range of 80 to 110 GHz.](image)
Measured Results vs. Simulated Results

- Insertion Loss vs. Frequency (GHz)
- Isolation vs. Frequency (GHz)
- Antenna/Reference Leg Return Loss vs. Frequency (GHz)
- Common Leg Return Loss vs. Frequency (GHz)
Asymmetric Design

- Same technology as symmetric design (microstrip, SiN 2-layer MIM capacitors, etc.)
- Antenna and Common legs aligned and Reference leg at a 90° angle
- More practical implementation for radiometer receiver since “input” and “output” are aligned

Measured Performance

Asymmetric design variation with integrated 50-Ω reference termination

Insertion Loss

Common Leg RL (Integrated Ref. Load Version)

Isolation

Common Leg RL

Antenna Leg RL
Post-Fabrication On-Chip Tuning of Isolation

- Higher frequency measurements demonstrated isolation was optimized for higher frequency
- By increasing effective electrical length of shunt diode radial stubs, optimal isolation was lowered to frequency range of interest

Tuning ribbon added to shunt diode radial stub

**Measured Performance**

- Isolation (Un-tuned)
- Isolation (Tuned)
Symmetric Design

Same technology as 80-105 GHz design (microstrip, SiN 2-layer MIM capacitors, etc.)

Preliminary tuning of shunt diode radial stub demonstrates decrease in isolation optimal frequency

Measured Performance

- Insertion Loss
- Isolation
- Antenna Leg RL
- Common Leg RL

Frequency (GHz)

Loss (dB)
Symmetric Design

- Coplanar waveguide design
- SiN 2-layer MIM capacitors for bypass and DC blocking capacitors
- NiCr thin-film process for resistors

Simulated Performance

- Insertion Loss
- Common Leg RL
- Antenna Leg RL
- Isolation

160-185 GHz MMIC Switch
## Results

<table>
<thead>
<tr>
<th>Switch</th>
<th>Insertion Loss</th>
<th>Return Loss</th>
<th>Isolation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-105 GHz</td>
<td>&lt;2 dB</td>
<td>&gt;15 dB</td>
<td>&gt;15 dB</td>
<td></td>
</tr>
<tr>
<td>80-105 GHz (Asymmetric)</td>
<td>&lt;2 dB</td>
<td>&gt;18 dB</td>
<td>&gt;15 dB</td>
<td>Isolation &gt;20 dB from 85-103 GHz after on-chip tuning</td>
</tr>
<tr>
<td>90-135 GHz</td>
<td>&lt;2 dB</td>
<td>&gt;15 dB</td>
<td>&gt;8 dB</td>
<td></td>
</tr>
<tr>
<td>160-190 GHz</td>
<td>&lt;2 dB</td>
<td>&gt;20 dB</td>
<td>&gt;20 dB</td>
<td>Simulated Results Only</td>
</tr>
</tbody>
</table>
Summary

• Dicke switched radiometers allow for correction of gain and noise figure fluctuations in components of receiver chain after the switch

• RF switches were designed to cover three frequency ranges, 80-105 GHz, 90-135 GHz, and 160-190 GHz

• Realized as monolithic microwave integrated circuits (MMIC) using microstrip and coplanar waveguide technology

• To date, 80-105 GHz and 90-135 GHz switches have been tested; 160-190 GHz switches have not yet been tested
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