HIGH POWER BROADBAND, 35 GHz WAVEGUIDE SWITCH USING A MONOLITHIC DIODE ARRAY

Albert L. Armstrong*, Dana E. Wheeler**, and Joel Goodrich***

* Capitol Technology Corp. Latham, NY
** M/A-COM Millimeter Co. Burlington, MA
***M/A-COM Semiconductor Products Co. Burlington, MA

ABSTRACT

A monolithic array of silicon diodes has been utilized to fabricate a 35 GHz single throw waveguide switch with over 400 W peak and 20 W average power capability. The switch provides 23 dB isolation, 60 nanosecond switching speed, under 1 dB insertion loss and 1.6:1 VSWR over the 26.5 to 40 GHz waveguide bandwidth. A double throw version handles 40 W average power and has a 25% bandwidth.

INTRODUCTION

With the development of high power sources at Ka-band and higher frequencies, there is a need for high power, broadband, solid state control components. The silicon window switch described in this paper provides a significant advancement in total RF performance. Prior work addressed fast speed at 95 GHz over a narrow 1% bandwidth (3). The current work provides broadband capabilities at 35 GHz.

DESIGN

The control element developed is an array of PIN diodes fabricated into a window of silicon. The window is placed across the waveguide and acts as a transparent or reflective barrier to the RF energy. The diodes are configured in a series/parallel connection for the RF signal (see Figure 1 and 2). Thus, the individual diodes can be designed for switching speed or capacitance independently of the power requirements. For example, peak power requirements can be met by stacking several diodes.

The component should be able to switch in times down to 20 nanoseconds (1) depending upon the driver. Such times have been demonstrated in other programs (2,3) which used similar diode arrays.

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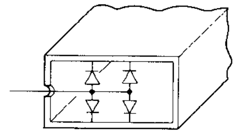

FIGURE 1 CONCEPTUAL WINDOW CONTROL ELEMENT

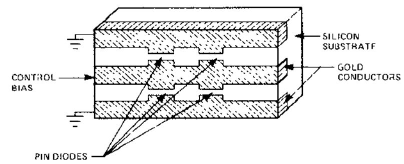

FIGURE 2 WINDOW CONTROL ELEMENT WITH FOUR DIODES

The peak power is limited by breakdown of the air in the high electric field region external to the diode I-region. A peak power of 400 W is readily met by stacking 16 diodes.

The average power capability is determined by the maximum temperature rise which occurs in the center of the window. The temperature rise is computed from the dissipated power times the thermal resistance. A shunt resistance placed across a waveguide will dissipate 20% of the incident power when the isolation is 19 dB. The 4 W dissipated power is computed to cause less than 120 degrees C rise for a window thickness of 100 μm.

The insertion loss is mainly reactive and therefore a function of the tuning circuitry. The isolation is determined by the bias current and the series/parallel diode configuration. If there are 16 diodes in each of 8 parallel columns, a current of 8 mA per diode is computed to provide 21 dB isolation. This results in a total current of 1A.

A photograph of the silicon control element fabricated according to the above design is shown in Figure 3. The perimeter of the structure is at ground potential. The control bias is applied to the large pad on one end. The diodes are very narrow horizontal slits in the vertical column.

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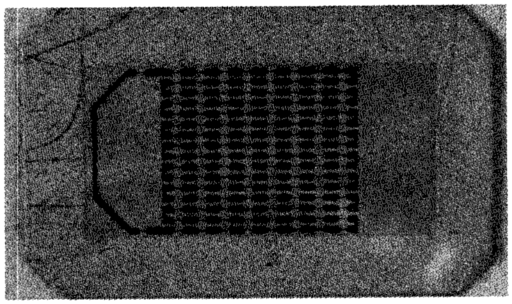

FIGURE 3 SILICON CONTROL ELEMENT

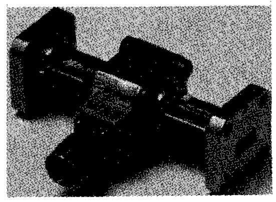

FIGURE 4

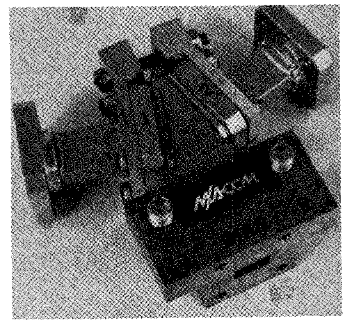

FIGURE 5

FABRICATION

The silicon control element consists of alternate rows of the NIP and PIN diodes. All the p-type regions are connected on one side to ground. The n-type regions are likewise all connected to a common bias pad on the opposite end of the element.

To fabricate the element, alternate channels are etched and doped n-type. The remaining channels are etched and doped p-type. All channels are then back filled with gold to provide conductive paths for the control bias current. A gold beam lead is also provided on the periphery of the element to facilitate mounting.

The switch component is assembled by simply placing the control and tuning elements between WR-28 waveguide flanges and shims. Photographs of the single throw and double throw components are given in Figure 4 and 5 respectively.

TEST RESULTS

RF performance of the single throw switch is presented in Figure 6. High power tests of 3 kW peak, 30 W average for periods of 15 minutes caused no degradation.

Preliminary test results of a partially tuned (no input port tuning) double throw switch have shown similar performance over a reduced 25% bandwidth (see Figure 7).

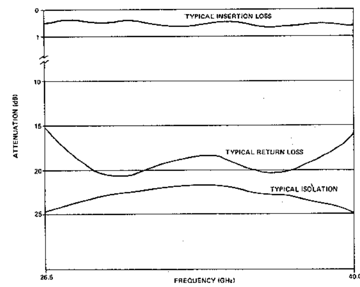

FIGURE 6 RF PERFORMANCE, SINGLE THROW SWITCH

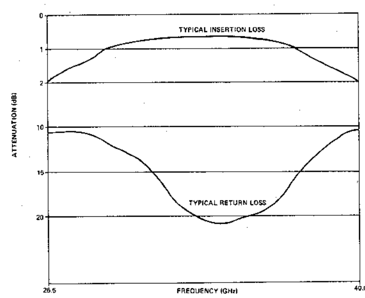

FIGURE 7 RF PERFORMANCE, DOUBLE THROW SWITCH

CONCLUSION

Monolithic diode arrays have been shown to provide significant advancement in RF performance for high power millimeter control components.

Useful application of these techniques at other frequencies from 9.5 GHz to 95 GHz are currently being realized.

ACKNOWLEDGEMENTS

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