MILLIMETER WAVE MMIC SWITCH DESIGN

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Introduction

Welcome to the project poster for the Millimeter Wave MMIC Switch Design project. In this poster, we will provide a comprehensive overview of the project, discuss the mathematical background behind the switch design, present the results obtained, and draw insightful conclusions based on our findings. This project represents a significant endeavor in the field of high-frequency switch design, with a focus on millimeter wave frequencies.

Overview

The Millimeter Wave MMIC Switch Design project focuses on the development of a high-frequency switch that operates in the millimeter wave range. This switch is an essential component in various applications, including wireless communication systems, radar systems, and satellite communication. The objective of this project is to design a switch that offers low insertion loss, high isolation. The design results were made with the ADS EM simulation program. In addition, WR-12 size waveguide module and Vivaldi antennas are designed with microstrip lines to measure chip.

Mathematical Background

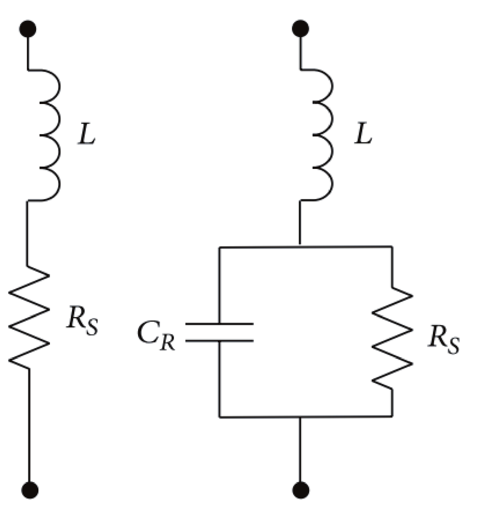

Figure-1 Forward Bias and Reverse Bias Models

$$R_s = \frac{W^2}{(\mu_n+\mu_p)\,Q}\,(\Omega) \qquad (1)$$

where :

$Q = IF \; x \; \tau \; (in \; coulombs)$
$W = I \; region \; width$
$\tau = carrier \; lifetime$
$IF = forward \; bias \; current$
$\mu n = electron \; mobility$
$\mu p = hole \; mobility$

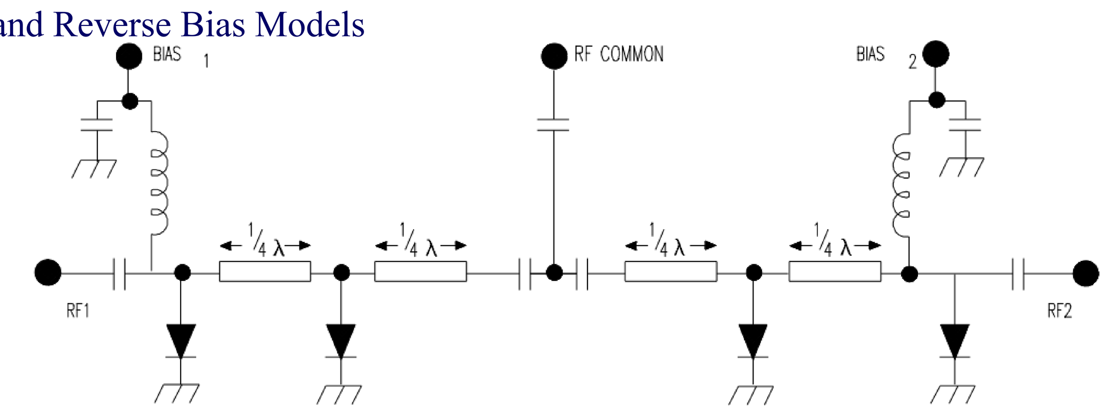

Figure-2 Shun-Shunt Quarter Wave Topology

Additionally, the reverse bias model of pin diode is given in the right circuit in figure-1. The capacitor of this circuit is calculated as follows:

$$C_R = \frac{\varepsilon A}{W} \qquad (2)$$

Where:

$\varepsilon = dielectric \; constant \; of \; silicon$
$A = area \; of \; diode \; junction$

Figure-2 showcases a band-limited shunt multi-throw switch design that overcomes this difficulty. It consists of two cascaded quarter-wavelength sections, each terminated by a shunt diode. This arrangement ensures that the OFF branch maintains a high input impedance at the common port (connected to the signal source). This prevents the impedance of the ON arm from being burdened, as it would typically occur in other configurations.

Results

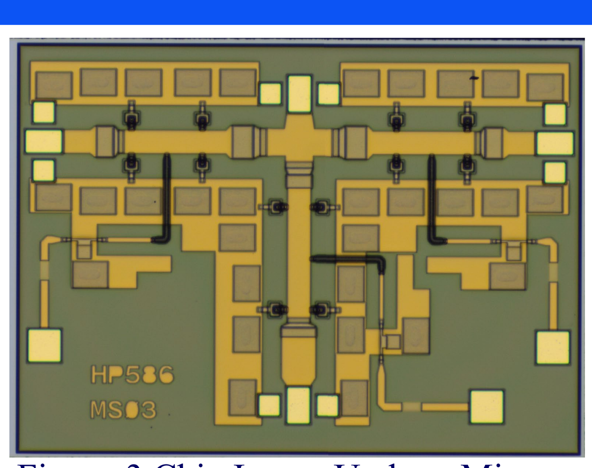

Figure-3 Chip Image Under a Microscope

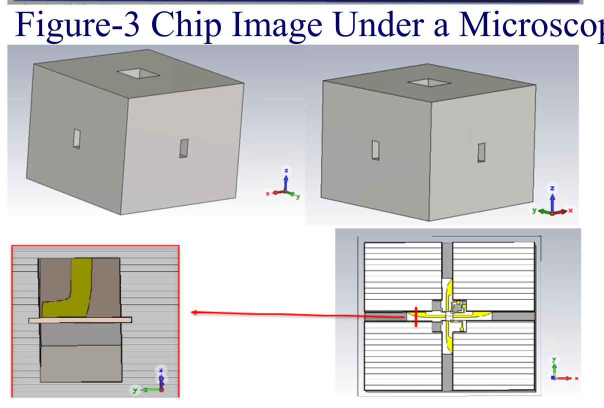

Figure-4 Designed External Module

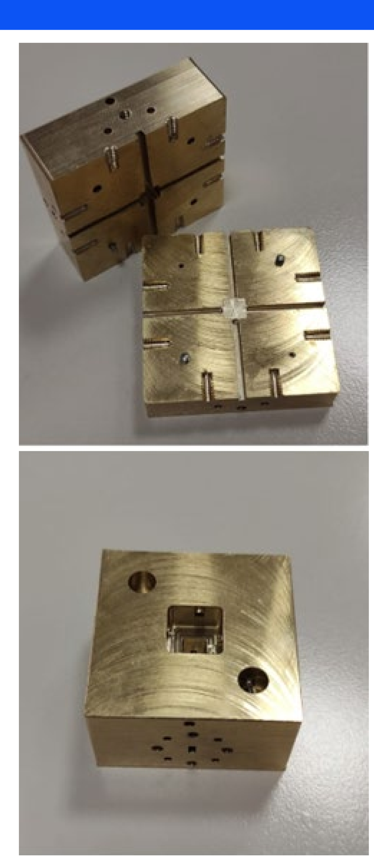

Figure-5 Manufactured WG

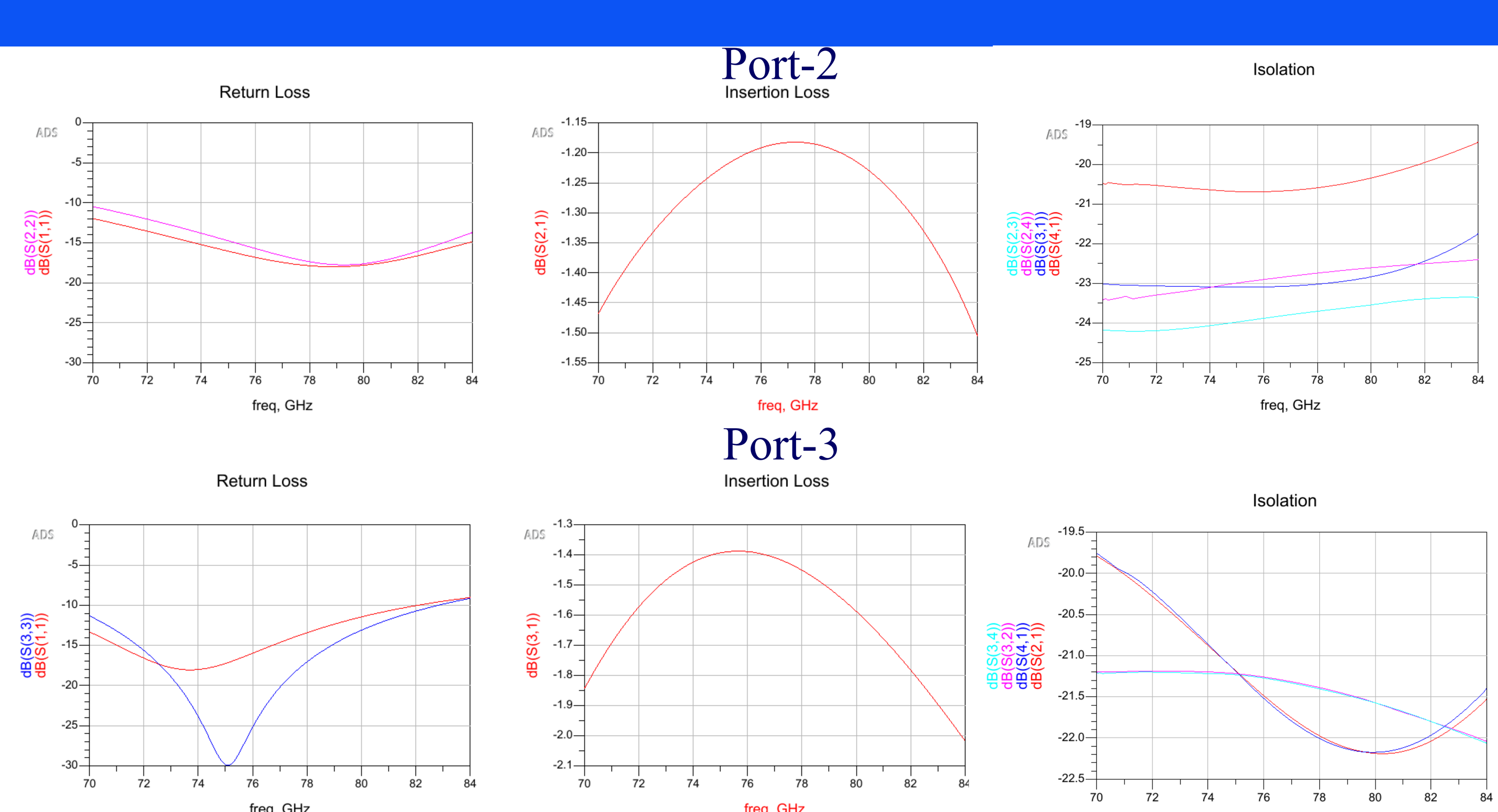

Figure-6 Return Loss, Insertion Loss and Isolation Result of Port-2&3

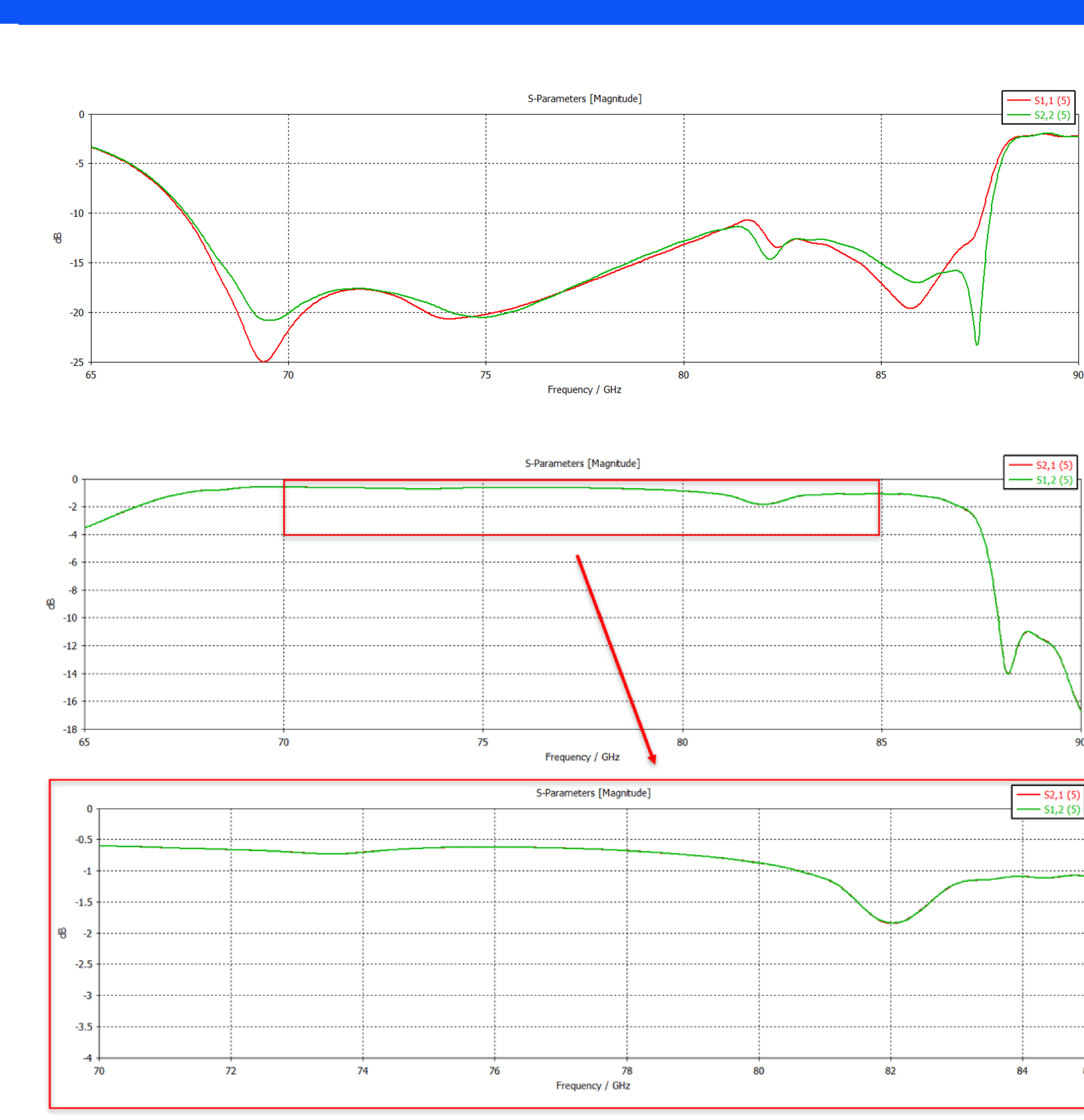

Figure-7 Insertion Loss and Return Loss Results of External Module

As a result, it is clearly seen in the layout results that the Insertion Loss value is less than 2 dB, the Return Loss value is greater than 13 dB, and an insulation value over 20 dB is provided as shown in Figure6.

The return loss results, and the insertion loss results shown in Figure-7 demonstrate the broad bandwidth and low loss characteristics of the designed waveguide module at these high frequencies. The length of the bond wires has a significant impact on these results.

Conclusions

The Millimeter Wave MMIC Switch Design project has successfully achieved its objectives of designing a high-frequency switch with exceptional performance characteristics. The set targets at the beginning of the project, such as the schematic and layout simulation results, have been successfully achieved. These targets include Frequency Range: 76-78 GHz, Insertion Loss < 2 dB, Return Loss > 13 dB, Isolation > 20 dB, Switching Speed < 80 ns.

Additionally, an additional waveguide structure was designed for measuring the 77 GHz switch, and the brass alloy part of the structure was manufactured. The designed Vivaldi antennas is going to be inserted into the fabricated brass waveguide structure using Rogers 5880 materials. The microstrip lines of these antennas are going to be connected to the RF ports of the chip using bond wires. This approach enables both the measurement of the chip's RF performance and the production of a ready-to-use product for end users.

References

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