Sub-THz MMIC Switches Key Enablers for Sub-THz Wireless Systems

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[Summary] The development of wideband MMIC switches that operate from DC to Sub-THz frequencies represents a significant leap forward in maximizing the potential of the electromagnetic spectrum. The ability to seamlessly cover such a broad frequency range is crucial for a variety of advanced applications, as it allows for greater flexibility and efficiency in Sub-THz communication systems: imaging, sensing, and instrumentation. Miniaturizing and integrating multiple components, including the switch, onto a single compact chip enhances the overall system performance, enabling more versatile and reliable Sub-THz solutions. DC to Sub-THz switches are central to overcoming the challenges of broad-spectrum operation, in particular improvements in insertion loss, isolation, and bandwidth are key. These advancements are set to unlock new possibilities and propel the next generation of RF technologies forward.

1 Introduction

This report presents detailed measurements of a Sub-THz MMIC switch operating from DC to 145 GHz. The ability to achieve such broad-bandwidth operation is crucial for a variety of advanced applications, including high-speed communication systems, precision imaging, sensing, and sophisticated instrumentation. As the demand for faster data transmission and higher-resolution imaging continues to grow, the development of switches that can seamlessly operate from DC to Sub-THz spectrum becomes increasingly important. These wideband switches enable more versatile, compact, and efficient solutions, paving the way for the next generation of RF and microwave technologies. The following measurements demonstrate the key performance parameters of this Sub-THz switch and underscore its potential impact on the future of RF applications.

2 Technology

Wideband switch design faces trade-offs in technology selection, with GaAs PIN diodes offering low insertion loss but limited integration capabilities, and InP HBT-based switches providing high frequency and linearity advantages at the cost of isolation and power consumption. pHEMT technologies also offer integration options, but not for Sub-THz frequencies. This report focuses on using InP DHBT-based switches for integration with amplifiers and multipliers, utilizing a multi-metal layer structure to improve isolation and manage RF and DC components.

3 Design

A Single-pole-single-throw (SPST) switch from DC to 145 GHz is designed in InP HBT-based technology. The switch features either reflective or absorptive off-state.

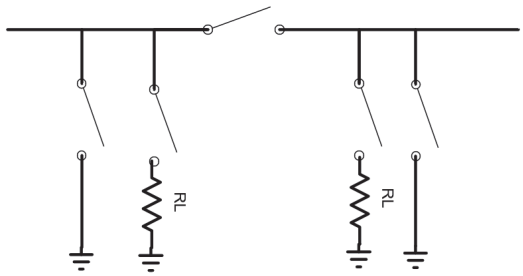

Figure 1 Representation of an SPST reflective, absorptive Sub-THz switch.

4 Measurements

Upon visual inspection of the chip layout, it was found that the top layer doesn't have visual defects. However, the very bottom metal layer had some yield issues that were noticed on multiple chips. This caused some switching states to either not function at all or poorly connect. This matter is still under investigation but the diverse design of multiple switches on the same chip shown in Figure 2 was able to point out some manufacturing flaws. It was found that the same layout implementation showed different results on the same chip.

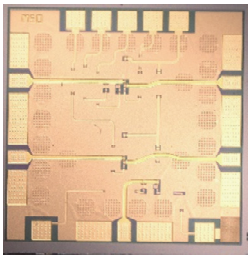

Figure 2 1×1 mm multi-switch chip module.

Some poor connections were visible from the top layer, those sections were discarded from this measurement.

Another section of the switch had minimal reliance on the bottom layer which resulted in consistent results. Dies with manufacturing flaws were not tested.

Figure 3 shows the section of the absorptive and reflective terminations using the same size transistors. Each transistor in Figure 3 was biased and tested individually to compare current dissipation with simulated values.

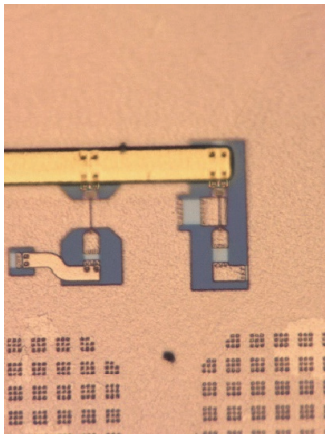

Figure 3 Absorbative and reflective termination.

Biasing the switch to the designed operation points showed the correct current and power consumption.

A TRL calibration was used to calibrate the probes across the band of measurement. The switch is probed for s-parameters in Figure 4 minimizing insertion loss in Sub-THz switches is crucial for maximizing the performance and range of these systems, particularly in applications where signal strength is a key factor for successful data transmission and reception. Two different switches were tested for insertion and return loss. In Figure 5 we have a consistent result for insertion loss for the Thru state when comparing two different switches. The Isolation measurement for both reflective and absorptive states is shown to maintain isolation of 15 dB below across the board. It was evident that the reflective state had 1 dB better isolation for the same bias conditions.

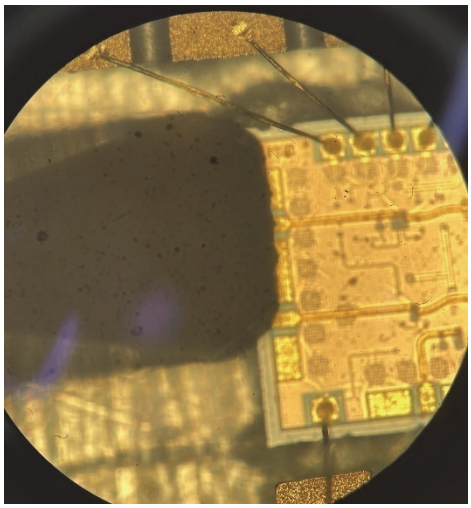

Figure 4 Biasing and probing the switch from DC to 145 GHz.

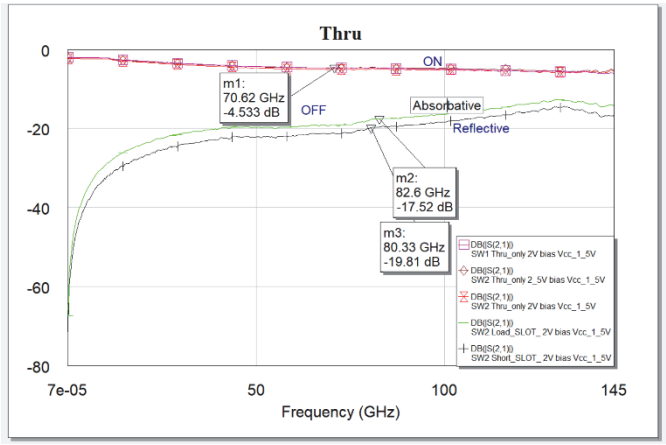

Figure 5 Insertion loss measurement (cyan, brown for 2 different switches) and Isolation (green and black for absorptive and reflective states).

Figure 6 demonstrates Thru states for multiple switches and different bias conditions. increasing the bias voltage by 0.5 volts improved the insertion loss by 0.5 dB.

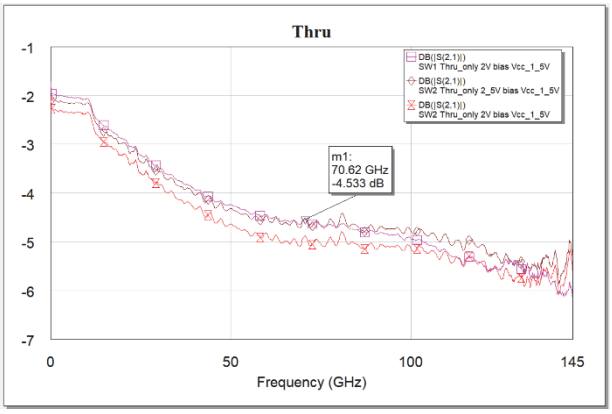

Figure 6 Insertion loss measurement at different bias conditions and different switches.

Finally, In the context of switches, especially at high

frequencies like Sub-THz or microwave bands, good return loss ensures that the switch's ports are well-matched to the system's characteristic impedance (often 50 ohms), minimizing reflections and preventing power from being reflected into the source. Return loss is maintained lower than 14 dB across the band and better than 20 dB above 80 GHz Figure 7.

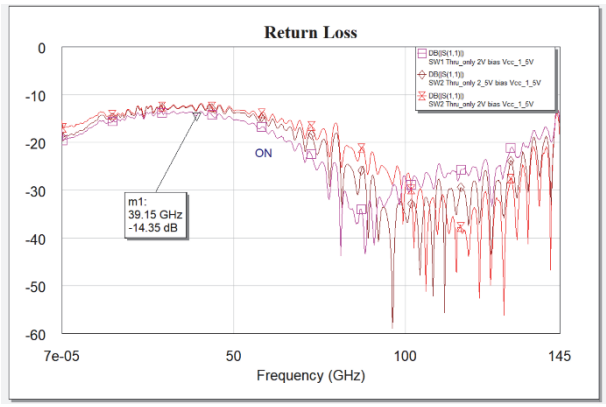

Figure 7 Return loss for ON state.

Importantly, this approach was successful in maintaining a steady insertion loss without ripples or resonances from DC to 145 GHz.

In general, designing a switch using HBT is challenging because of leakage and challenging bias conditions. This report sets the stage for the future of integrating Sub-THz switches on a chip using InP HBT technology.

5 Conclusions

This article presents the design and fabrication of an RF Sub-THz MMIC switch using InP DHBT, which produced promising results. This approach showcased significant potential for miniaturized, advanced RF systems across the DC to Sub-THz spectrum. The unique properties of InP DHBT, such as high electron mobility and thermal conductivity, enhance performance, making it a strong candidate for advanced telecommunications. This approach demonstrated that having an ultrawideband switch is possible using InP DHBT technology. While InP DHBT may not be the optimal material for isolation, this limitation adds complexity to the design process and may affect the switch's maximum operational frequency. However, the increased power handling capability of DHBT, compared to HEMT, strengthens its potential for use in front-end ultrawideband transmitters.

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