A G-Band Multi-Chip MMIC T/R Module for Radar Applications

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***Abstract*—In this paper, we describe the design and measurements of a MMIC amplifier-based multi-chip Transmit/Receive (T/R) Module for radar applications in G-Band (140-220 GHz). The module is design with InP HEMT MMIC power amplifiers for the transmit channel and InP MMIC low noise amplifiers for the receive channel. Arrays of these 150 GHz T/R modules could be used for applications such as automotive radar and landing radar.**

I. Introduction And Background

THE applications for multi-chip MMIC modules at high frequencies are steadily increasing. Recently, a Q-band (38-50 GHz) MMIC polarimetry receiver has been developed using state of the art low noise amplifiers (LNAs) [1], for application to detection of the cosmic microwave background radiation in astrophysics. At E-Band (60-90 GHz), a multichannel receiver for imaging radar was reported [2], and at W-Band (75-110 GHz), a dual-channel receiver was demonstrated [3]. At higher frequencies, the complexity of multichip modules in the literature is somewhat reduced, presumably due to the smaller variety of components commercially available above 140 GHz. However, excellent results of a two-chip power amplifier module in G-band (140-220 GHz) with 20 mW output power were demonstrated in 2006 [4].

In our previous work, we have discussed the concept of a transmit/receive (T/R) module for G-Band for use in planetary landing radar [5], and demonstrated components for use in such a module. Millimeter-wave radar offers several advantages over optical sensors for planetary landing, in terms of ability to sense through dust or spacecraft engine plumes, and even more importantly, ability to measure precision altimetry and velocimetry data from a single sensor, as well as the possibility of hazard detection. Using high frequencies such as G-Band (140-220 GHz) allows for a very small antenna size compared to lower frequency systems, which reduces the overall size and mass of the radar instrument. In the current work, we discuss a prototype G-Band T/R multi-chip module which we have designed and fabricated using WR5 waveguide and state-of-the art MMIC amplifiers. We present measurements on the separate transmit and receive modes and discuss future improvements to the modules.

II. Results

In Fig. 1, we show a drawing of a split-block waveguide module with the lid removed to show the chip cavities where the MMICs reside. The input waveguide is at the center of the

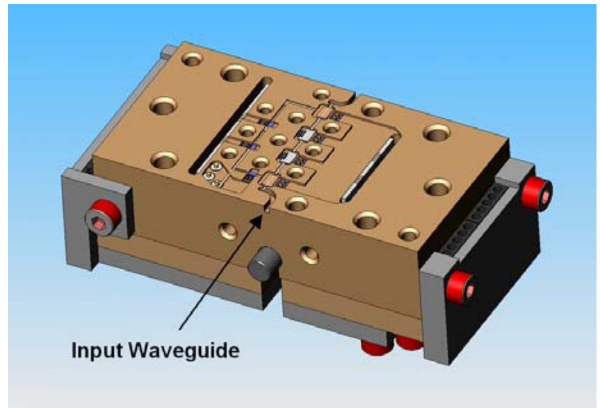

Fig 1. 3D drawing of T/R Module with lid removed, showing input and output waveguides and chip channels.

drawing. The multi-chip module contains two branches: one for the transmit mode and one for the receive mode. The two branches will eventually be separated by a single-pole-double-throw (SPDT) switch, which is in development. A photo of the completed module is shown in Fig. 2, and is approximately 2 inches tall. For our experiments, we have fabricated two modules, and populated one for Transmit mode and the second for Receive mode, and have tested them separately. The final version will have both transmit and receive paths populated with a switch between them.

To test the module, we populated the first module for transmit mode with two MMIC power amplifier chips, described in [5]. Each had approximately 7 dB peak gain around 150 GHz as determined with on-wafer S-parameter measurements. The chips were separated by microstrip

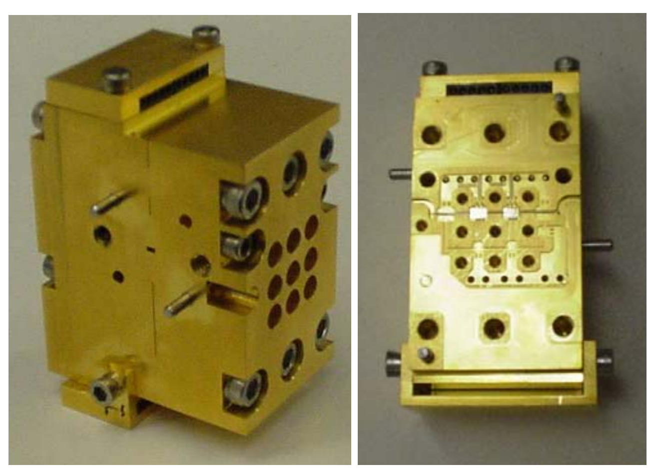

Fig. 2. Right: Photo of G-Band T/R Module showing input WR5 waveguide. Left: Lid removed to show chip cavities.

transmission lines made of alumina, and a WR5 E-plane probe was used to transition from the microstrip mode to the waveguide mode. Wire-bonds connect the transmission lines to the chips. DC connections were made via feedthroughs mounted through the module and connected to bias boards with external multi-pin connectors. In Fig. 3, we show the chip channel and S-parameter data obtained from the transmit-path. We have obtained 14 dB of gain from 148-150 GHz, with return loss better than -5 dB over the 140-170 GHz range.

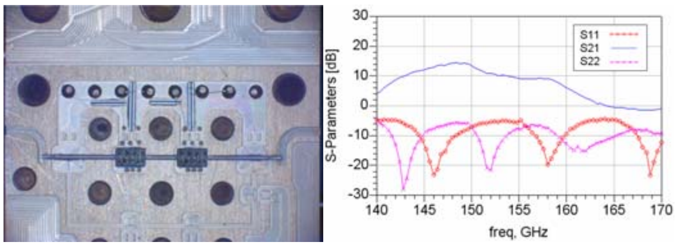

Fig. 3. Right:Transmit path of T/R Module populated with two power amplifier MMIC chips. Right: Measured transmit-path S-parameters.

We measured the Transmit module for output power and the results are shown in Fig. 4 (top). We have obtained 9.8 dBm at 152 GHz for the peak power. The power gain plot is shown in Fig. 4 (bottom), with a power gain of about 7 dB at the point of maximum output power at 152 GHz.

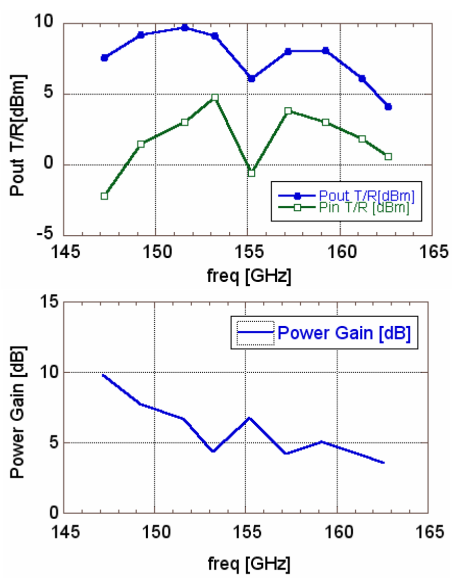

Fig. 4. Top: Output power from the Transmit module from 147-163 GHz. Bottom: Associated power gain over the same frequency range.

We populated the second module for receive mode with three state-of-the-art MMIC LNAs each having approximately 14 dB of gain from on-wafer measurements. The MMIC LNAs were separated by similar microstrip lines and wirebonds as in the transmit path. For biasing, 51 pF bypass capacitors were used close to the DC pads on the MMICs to prevent low frequency oscillations. DC connections were made via feedthroughs mounted through the module and connected to bias boards with multipin connectors on the outside of the module. S-parameter data indicate up to 25-30 dB of gain from 150-160 GHz.

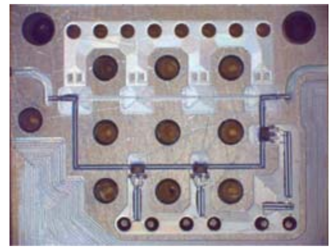

Fig. 5. Receive Channel of T/R Module populated with three low noise amplifier MMIC chips.

We have designed a four element array of the T/R modules, each using the chip cavities described in this paper for the transmit and receive chains, and show the conceptual drawings in Fig. 6. The four-element array has a maximum length of 2.36 inches, showing that a very compact design is possible for these multi-chip MMIC modules.

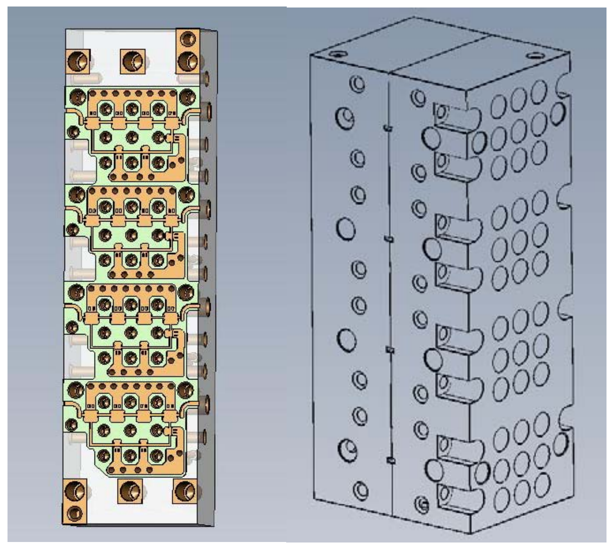

Fig. 6. Conceptual drawing of a 4 element array of T/R units, having a total length of 2.36 inches,with the 4 input waveguides shown at right.

References

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