Quasi-Optic Power Combining

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Abstract

We will report on progress in quasi-optical power amplifiers at Caltech since last year’s meeting, where we reported a 5-W, Ka-band grid amplifier with a waveguide mode converter. This year we have developed an indium-phosphide V-band grid amplifier. The amplifier has been tested both as a transmission amplifier with a waveguide mode converter on the input and output side, and as a reflection amplifier with an orthomode transducer input feed. Both show a modest gain of 2dB at 58GHz. These are single-stage amplifiers, and this indicates that it would be desirable to develop amplifiers with two stages of gain on chip.

Waveguide Mode Converters

Last year, we reported progress on a waveguide-mode converter for feeding a single-chip spatial power amplifier [1]. Previously single-chip spatial power combining amplifiers had demonstrated state-of-the-art output power levels at millimeter-wave frequencies [2]. The combining loss for 512 transistors was only 1dB. However, the chips required very large plastic lenses on both the input and the output side to focus the energy. These systems could only be used for laboratory demonstrations. Many radar and communications systems have a radiating output, so the first improvement that we worked on was to have a single-mode waveguide feed on the input side, and a radiating beam on the output side (Figure 1). In most applications the beam would feed a reflector or lens antenna. The goal for the mode-converter design is to produce a uniform power density across the grid amplifier chip so that the transistors will saturate uniformly.

Our mode converter uses a series of short steps to produce a specified amplitude and phase of higher-order modes. Previous designs had used long, tapered waveguide sections that were much larger, and suffered from spikes in the frequency response because of the interaction of the higher order modes. The mode converter is only 13mm long and would be suitable for inexpensive fabrication. At 34GHz, the maximum PAE is 22% at 5.4W output and 5.5dB gain. This is comparable to the results for a gaussian-beam feed [3].

Figure 1. Waveguide fed grid amplifier.

V-Band Grid Amplifiers

The V-band amplifiers have 100 unit cells, each containing a differential-pair amplifier. It is a single-stage design that uses the TRW 0.15µm InP power HEMT process [5]. The design uses the methodology developed by Preventza et al. [6], where the metal art of the unit cell is model is simulated with in a TEM waveguide with Ansoft’s finite-element simulator HFSS. The gate is biased by a resistor to the source.

Transmission Amplifiers

The transmission amplifier is shown schematically in Figure 2. The mode converter sections on the both the input and output are simulated with HFSS. It includes internal choke slots and DC-bias line filters. The thermal spreader is aluminum nitride, and it is set in a half-wavelength groove that helps to transfer heat to the metal waveguide. Both the input and the
output ends are standard TE10 waveguide joints. The grid was biased at 1.2V, with a drain current of 6.7A. The total length is 20mm.

Figure 2. The transmission amplifier. This is a quarter-section view. The input and output are cross-polarized.

Reflection Amplifier

The reflection amplifier is shown schematically in Figure 3. A reflection amplifier has the advantage that a surface is provided on the back for getting rid of the heat easily. The disadvantage is that the input and output pass through the spreader in the same direction, and this means that the input and output impedances need to be similar for the matching to work effectively. This probably narrows the bandwidth. The design follows the approach suggested by Michael DeLisio et al. [7]. The mode converter has to be able to perform the task of an orthomode transducer, and separate the input and output polarizations into two ports.

Results

The maximum measured small-signal gain for the transmission amplifier is 2.1dB at 58GHz. The positive gain bandwidth is 2.1%. For the reflection amplifier, the gain is 2.5dB at 58GHz, and the positive gain bandwidth is 1%. More details will be available in [4].

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References