60 AND 70 GHZ (HEMT) AMPLIFIERS

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Abstract: This paper describes the design and development of 60 and 70 GHz High Electron Mobility Transistor (HEMT) amplifiers. The 60 GHz amplifier exhibited a gain of 4.5 to 6.5 dB across the frequency band 56 to 62 GHz and had an associated noise figure of 6.0 dB measured at 57.5 GHz. The 72 GHz amplifier achieved a gain of 4 to 5 dB with a bandwidth of 2.5 GHz, with an associated noise figure of 7.8 measured at 71.0 GHz.

Introduction

High Electron Mobility Transistor (HEMT) amplifiers have been constructed at frequencies up to and including 40 GHz [1], that have resulted in performance superior to that of GaAs MESFET amplifiers. With the recent improvements in the performance of HEMT devices through reductions in the device parasitics, it is now possible to construct amplifiers at even higher frequencies of operation. These improvements include shorter gate lengths, reduced gate and source contact resistances and optimized doping profiles. This paper describes the design of 60 GHz and 70 GHz single stage and multiple stage amplifiers.

Device Fabrication

The superior performance of the HEMT device is attributed to its carrier transport mechanism, where the carrier transport in the 2-dimensional electron gas closely resembles that of undoped GaAs which has little or no impurity scattering [2]. As shown in Figure I the HEMT has a structure similar to that of a GaAs MESFET, where the HEMT utilizes a heterojunction between the GaAs and AlGaAs instead of the doped epitaxial layer. The 2-D electrons have 2X the mobility and travel at twice the velocity as those in the MESFET, and exhibit lower thermal noise thus achieving higher transconductance, higher cut-off frequency and lower noise figures than the GaAs MESFET.

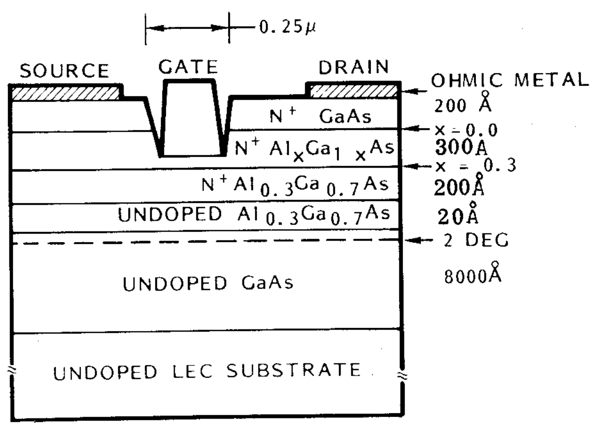

FIGURE I HEMT Cross Section

Circuit Design and Construction

The 60 GHz and 70 GHz amplifiers were designed utilizing the expertise and construction techniques gained during the development of the 36-40 GHz amplifiers. The high frequency of operation of these amplifiers necessitated the development of waveguide to microstrip transitions to facilitate assembly and test of the individual amplifier stages. In Figure II are shown two transitions placed back-to-back with a small length of interconnecting 50 microstrip line. Insertion loss and return loss for this pair of transitions are shown in Figure III. The transitions were fabricated on 0.005" thick highly polished fused silica substrate with the circuit pattern produced on the chrome gold metallization utilizing the methods of photolithography and chemical etching [3].

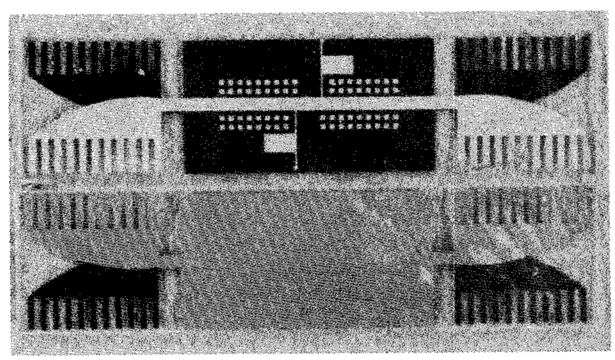

FIGURE II 60-70 GHz Transitions

In Figure IV the amplifiers were constructed in two parts using invar, with the lower section of the housing containing the bottom waveguide portion, input/output substrates, amplifier circuitry and biasing components, while the upper section contains the amplifier cavity, waveguide components and lid to

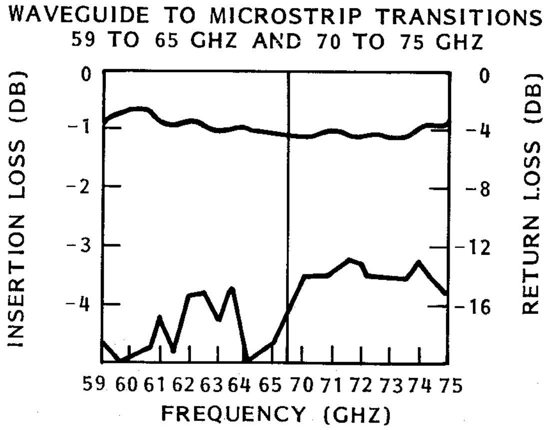

FIGURE III Insertion Loss and Return Loss of Transition

complete the enclosure. The amplifier cavity was designed to reduce radiation effects and eliminate the possiblity of moding. The amplifier circuitry was constructed on the same substrate as that of the transition to reduce the parasitic losses that occur at the interconnection of two substrates.

Conventional microstrip fabrication techniques were utilized [4] where the circuitry consists of distributed circuit matching elements and series low inductive gold bonding ribbons located at the gate, source and drain of the device, to reduce the parasitic inductances. Tuning is facilitated by the addition of shunt capacitive stubs to the 50 ohm transmission lines located at the input and output of the device. The bias circuitry consists of $\lambda/4$ high impedance lines with $\lambda/4$ shunt stubs for RF rejection optimized to insure out of band stability.

The amplifiers were tuned for maximum stable gain and bandwidth by tuning the output with a selective mismatch of the input. Gain and input return loss for the 60 GHz amplifier are found in Figure V. The spot noise figure at 57.5 GHz was 6.0 dB and the 1 dB compression point at 62.5 GHz was 8.5 dBm. No effort was made to noise tune this particular amplifier stage, and the noise figure was measured at maximum gain bias. A narrowband 56.0 to 57.5 GHz low noise amplifier was developed which achieved a gain of 5.5 to 6.0 dB and a noise figure of 4.6 dB after noise tuning. A two stage 54.0 to 58.0 GHz amplifier was constructed with gain and return loss as shown in Figure VI.

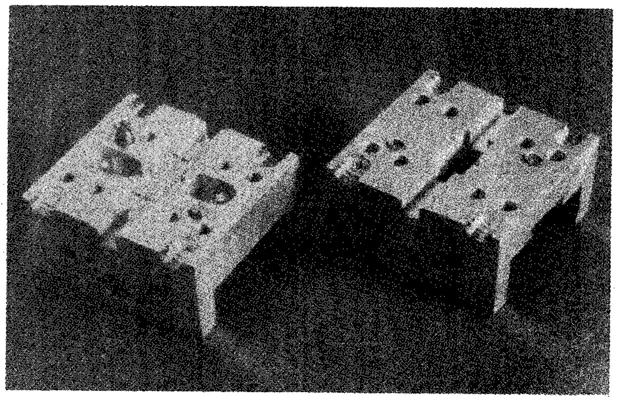

FIGURE IV Amplifier Fixtures

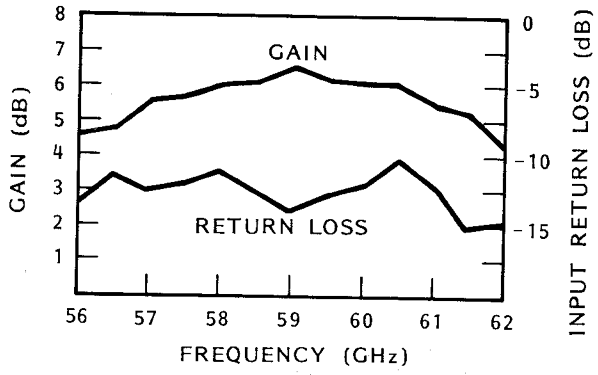

FIGURE V Single Stage 60 GHz Amplifier Gain and Return Loss.

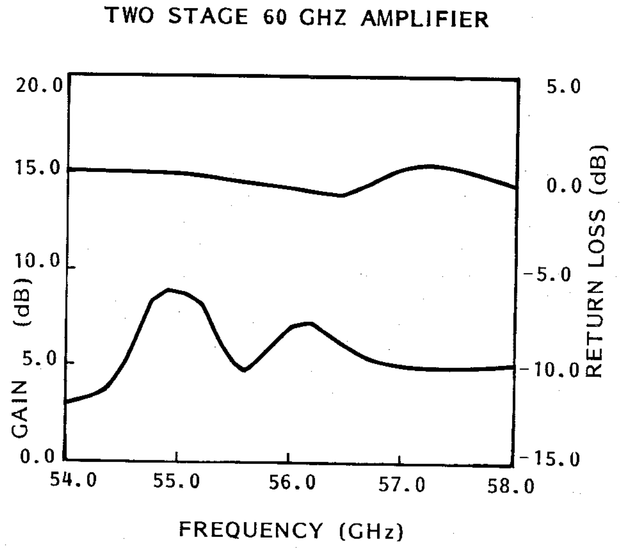

FIGURE VI 60 GHz Two Stage Amplifier

The 70 GHz amplifiers were developed as higher frequency variations of the 60 GHz design, but with the waveguide to microstrip transitions and RF circuitry optimized for the 70-75 GHz frequency band. Gain and return loss for the 69.5 to 72 GHz amplifier are shown in Figure VII. The noise figure of the amplifier was measured at 71 GHz using the well established method of the hot/cold Y-factor and found to be 7.8 dB with an associated gain of 5.0 dB, and the 1 dB compression point at 71.0 GHz was 7.5 dBm. The 70 GHz amplifier was cooled to a temperature of -20°C with the subsequent noise figure shown in Figure VIII.

By directly cascading two single stage amplifiers together, a two stage 70 GHz amplifier was constructed. Data for the two stage amplifier is presented in Figure IX. This data contains losses for two pairs of transitions. Losses that are attributed to the interstage transitions would be eliminated by utilizing microstrip techniques instead of waveguide, therefore the gain would be increased thus achieving amplifier performance suitable for use as a receiver preamplifier.

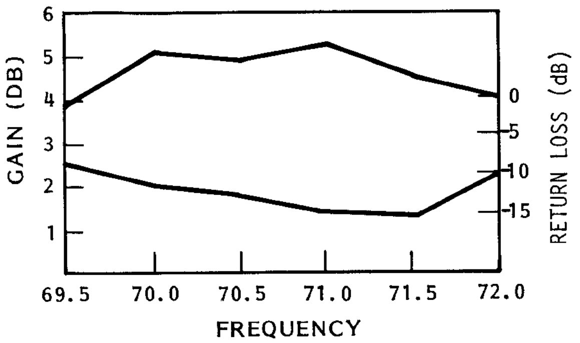

FIGURE VII 70 GHz Gain and Return Loss

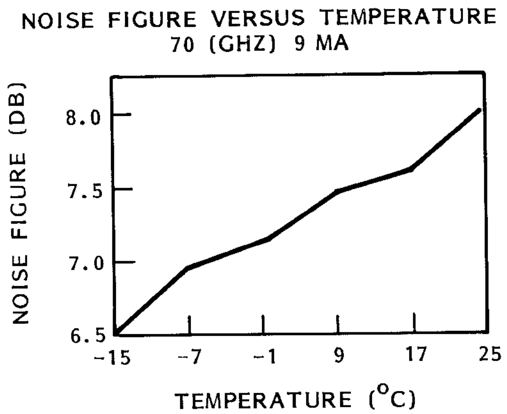

FIGURE VIII 70GHz Cooled Noise Figure
Note: Amplifier was gain tuned.

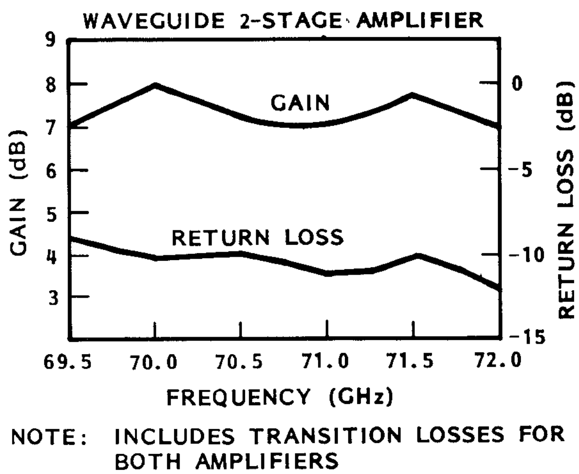

FIGURE IX 70 GHz Two Stage Amplifier

Conclusions

With the improved HEMT technology that is now available, the authors have constructed EHF amplifiers at frequencies of 60 GHz and 70 GHz, which have achieved excellent noise performance over their respective frequency bands. These amplifiers are among the highest reported frequencies that HEMT devices have been operated to date.

Further refinements of the HEMT technology will allow even higher frequencies of operation with improved gain, bandwidth and noise performance.

Acknowledgements

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Reference

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