A 30 GHz LOW NOISE FET AMPLIFIER

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ABSTRACT

A low noise FET amplifier has been developed for the 27.5 to 30 GHz communications band using a new 1/4 m gate GaAs FET device. The 3-stage amplifier exhibits a maximum noise figure of 3.2 dB across the 27.5 to 30 GHz band with an associated gain of 23 ±0.5 dB.

INTRODUCTION

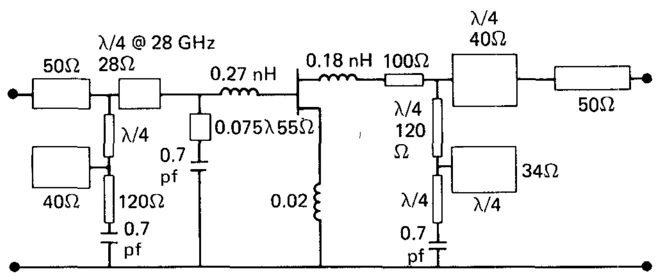
Recently, several FET amplifiers[1,3,4] operating in the 26.5 to 40.0 GHz frequency range, have demonstrated low noise figures, high gains and wide bandwidths. In addition, significant improvements in device noise figure and gain have been achieved at frequencies ranging from 12 to 34 GHz.[5,6] An all FET receiver operating at 30 GHz[2] and a 60 GHz FET amplifier[7] have been reported, thereby establishing GaAs FET technology at millimeter-wave frequencies. This paper presents a low noise FET amplifier which achieves a new level of performance at 30 GHz.

GaAs FET DEVICE

The GaAs FET devices used in this amplifier development consists of two E-beam defined 1/4 x 30 μm gate fingers in an interdigital structure with the source metallization pattern surrounding the active area.[6] Two different channel materials, doped VPE layers (lots DFET6 and DFET7) and silicon implanted undoped VPE buffer layers (lots DFET4 and DFET5), were used to fabricate the devices. Identical implantation schedules were employed for all implanted wafers with an implantation energy and dosage of 100 keV and 7 x $10^{12}cm^{-3}$, respectively. This implantation yielded a peak carrier concentration of approximately 1.3 x $10^{17}cm^{-3}$ after capless annealing at 840°C. The VPE material has a doping range from 2.8 to 3.0 x $10^{17}cm^{-3}$.

SINGLE STAGE AMPLIFIERS

The equivalent circuit of the single stage amplifier is shown in Figure 1. The microstrip matching circuits were fabricated on 10 mil thick quartz substrates using MIC techniques. The devices and the circuits were mounted on 0.390 x 0.250 inch Kovar carriers. This basic circuit was used both for device evaluation and amplifier fabrication. The noise figure and gain of several single stage amplifiers assembled using devices from 4 different wafer lots are summarized in Table 1. Both the initial (as fabricated) and the optimized (tuned) data are listed. An average initial cascade noise figure (F_C) of 3.5 dB was achieved at 30 GHz and improved to 3.0 dB through tuning. DFET7 devices clearly show superior performance with a minimum cascaded noise figure of 2.28 dB at 30 GHz. The frequency response of the best amplifier stage is shown in Figure 2. The noise figure is 2.0 ±0.2 dB across the 26.5 to 30.5 GHz frequency band with an associated gain of 6.2 ±0.5 dB.



EQUIVALENT CIRCUIT OF TYPE 3 LNA

Figure 1. Single-Stage Amplifier Equivalent Circuit.

TABLE I.
SINGLE STAGE LNA PERFORMANCE
SUMMARY @ 30.0 GHz

DEVICE	INITIAL N.F./GAIN (dB)	INITIAL F_c (dB)	OPTIMIZED N.F./GAIN (dB)	OPTIMIZED Fc (dB)
DFET7 4A	2.10/5.35	2.76	1.90/6.90	2.28
11A	2.20/5.50	2.87	2.00/6.45	2.48
13	2.36/5.54	3.01	2.17/6.44	2.65
2D	2.7/5.0	3.5	2.3/6.8	2.75
10C	2.25/5.39	2.90	2.30/6.90	2.78
21	2.0/5.8	2.7	–	–
3B	2.26/5.10	3.00	1.97/5.00	2.65
DFET5 9A	2.47/6.16	3.03	2.50/6.50	3.03
DFET4 19	2.68/5.04	3.50	2.30/6.79	2.75
2A	4.2/7.1	–	3.0/7.0	3.5
1A	3.57/5.60	4.40	3.10/7.35	3.60
DFET6 6	3.40/6.19	4.11	2.90/7.56	3.33
5	3.6/5.9	4.4	2.8/6.0	3.4
3C	2.7/5.9	3.4	–	–
17A	3.0/5.0	3.9	3.2/8.9	3.5*
AVERAGE	2.76/5.63	3.5	2.5/6.8	3.0

*GAIN TUNE

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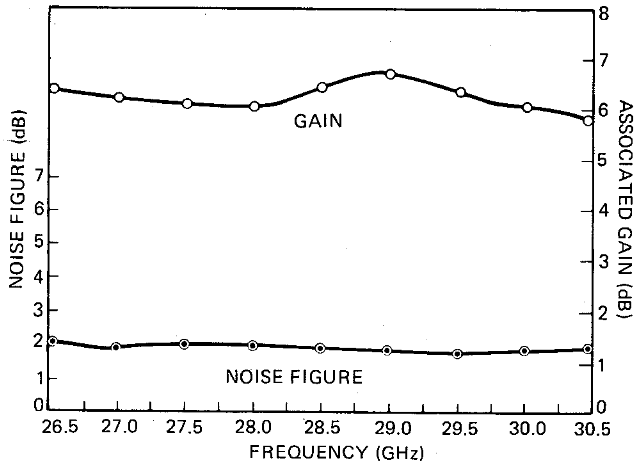

Figure 2. Single-Stage Amplifier Performance.

AMPLIFIER DESCRIPTION

One of the key elements in this effort was the development of a simple, low-loss, repeatable waveguide-to-microstrip transition for Ka-band frequencies. Our approach consists of a simple E-field probe orthogonal to the axis of the waveguide. This approach, though not "in-line", has the advantages of simplicity, low loss and excellent repeatability. The insertion loss of two back-to-back transitions including a 0.3 inch length of microstrip line is 0.5 to 0.6 dB over the 26.5 to 32 GHz band. Neglecting microstrip line losses, this translates into a dissipation loss of less than 0.2 dB per transition.

A photograph of the 3-stage low noise amplifier is shown in Figure 3. The single-ended amplifier stages are cascaded directly without isolation. The amplifier circuitry is mounted in a channel, below cutoff, which is oriented perpendicular to the waveguide input and output ports. E-field probes at the input and output provide transitions from the waveguide to the microstrip transmission line. External waveguide isolators are employed for minimum loss and VSWR. The top cover (not shown) shields the MIC circuitry and completes the waveguide-to-microstrip transition circuit.

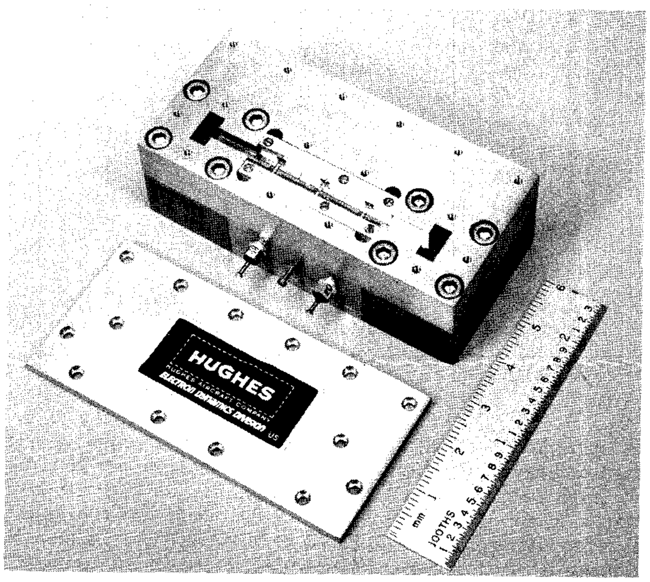

Figure 3. Three-Stage Low Noise Amplifier.

AMPLIFIER PERFORMANCE

The performance of the best 3-stage LNA is shown in Figure 4. It achieved 3.0 ±0.2 dB noise figure with 23.1 ±0.5 dB associated gain from 27.5 to 30 GHz. This data includes the loss through the input and output waveguide-to-microstrip transitions and isolators. Without the transitions and isolators, the noise figure is 2.55 ±0.15 dB with a gain level of 23.8 ±0.5 dB over the 27.5 to 30 GHz band. The output power at the 1-dB gain compression point is typically +8 dBm at 30 GHz.

Several units were modified to operate over a broader frequency band. The first achieved 3.8 ±0.5 dB noise figure with 20.0 ±2.0 dB associated gain from 26.5 to 32 GHz. The second, a single stage unit demonstrated 7.0 ±1.5 dB gain from 22.5 to 39.0 GHz. A third unit using quarter-wavelength input/output matching transformers demonstrated 4.5 ±0.5 dB noise figure with 25.0 ±2.5 dB gain from 34.0 to 40.0 GHz. The performance of these units is shown in Figure 5.

CONCLUSIONS

The above results represent new levels of performance for LNAs operating from 26.5 to 40 GHz. These results clearly demonstrate the viability of GaAs FET technology at millimeter-wave frequencies, particularly for low noise receiver applications. With the continued development of GaAs technology amplifiers with sub 2 dB noise figures at 30 GHz will soon be possible.

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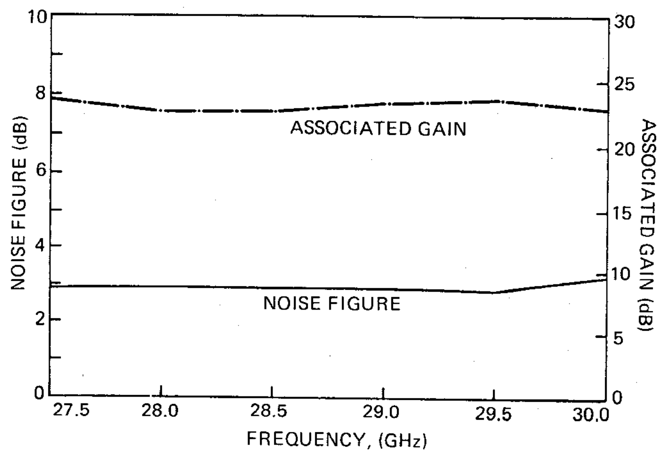

Figure 4. Frequency Response of Three-Stage LNA.

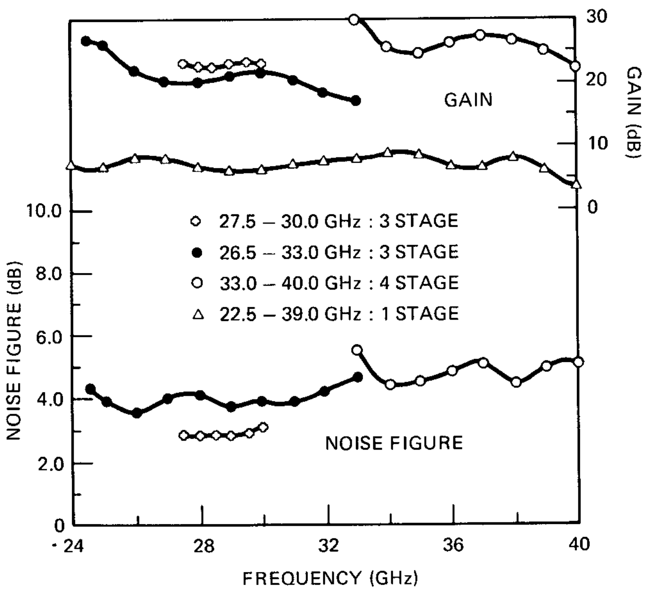

Figure 5. Ka-Band LNA Performance.

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