A K-BAND 1 WATT GaAs FET AMPLIFIER

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Lumped-element impedance matching techniques were successfully adopted for K-band power GaAs FET amplifiers. The 18 GHz band two-stage amplifier provides 1.05 Watt power output at 1 dB gain compression with 8.1 dB small-signal gain, and 20 GHz band one-stage amplifier has 1.04 Watt power output with 3 dB associated gain.

Introduction

Lumped-element internal matching techniques have been adopted to realize high-power GaAs FET amplifiers in the C-and X-bands (1),(2),(3),(4). Above Ku-band, high-power FET chip width becomes comparable to a microstrip wavelength, and it becomes much more difficult to achieve uniform excitation as well as low loss matching for multi-cell or multi-chip devices with extremely low impedance.

The paper presents effective application of lumped-element impedance matching techniques to K-band power GaAs FET amplifiers. The 18 GHz band single-stage amplifier developed using the lumped-element matching techniques provides 1.25 Watt power output with 3 dB associated gain, and the 20 GHz band single-stage amplifier has 1.04 Watt power output with 3 dB associated gain. The 18 GHz band two-stage amplifier provides 1.05 Watt power output at 1 dB gain compression with 8.1 dB small-signal gain and 1.25 Watt saturated power output.

Matching Techniques and Amplifier Description

The GaAs FETs used in the amplifier are NE 869 series FETs with the graded-recess structure of 0.5μm gate length (5). The single chip consists of four cells and has 3-mm total gate width. The real part of the single chip FET input impedance is as low as 1.3~1.5Ω, and the imaginally part of it becomes inductive above Ku-band. So, it becomes difficult to realize wideband operation of the power FET amplifiers at such high frequencies.

The equivalent circuit topology for the lumped-element matched FET NE 8698 with two-chip structure of 6 mm total gate width is shown in Fig. 1. The input-matching circuit was designed, based on FET small-signal S-parameters. The lumped-element input-matching circuit consists of a series inductor and a parallel capacitor. The inductor is realized by a 30μm diameter gold bonding wire. Two wires are bonded, in parallel, on each gate pad in the FET chip because of realizing small inductance for impedance matching. The capacitor is realized on a 0.1 mm thick single ceramic substrate with 39 relative dielectric constant. A tapered microstrip impedance-transformer with low characteristic impedance, formed on a 0.635 mm thick alumina substrate for the 18 GHz amplifier, and a 0.25 mm thick alumina substrate for the 20 GHz amplifier, is incorporated into the lumped-element input circuit. This semi-lumped-element input-matching network was effectively adopted to realize low loss, uniform phase matching as well as wideband operation for a wide multi-cell and multi-chip structure.

The FET NE 8694 with single-chip structure of 3 mm total gate width has an input-matching network consisting of lumped-elements and a quarter-wavelength stepped-transformer formed on an alumina substrate.

Large-signal circuit design is required for the output-matching circuit of the power FET amplifier. The trial output-matching circuit was designed, based on the power-load impedance characteristics measurement. Then the output circuit microstrip pattern formed on a 0.25 mm thick alumina substrate was experimentally optimised by fine adjustment.

Figure 2 is a photograph of the 20 GHz band single-stage amplifier with two-chip structure. The total width of the two chips is 2.5 mm and the module is 5.7 mm long. A photograph of the 18 GHz band two-stage amplifier, consisting of the NE 8694 amplifier module and the NE 8698 amplifier module, is shown in Fig. 3. Each stage amplifier module is assembled on a separate carrier. Dc-cut capacitors and gate bias bypass capacitors have beam lead MIS structure. Drain bias bypass capacitors have chip-type MIS structure. The first-stage and second-stage modules were interconnected by a gold tape.

Performance

The small-signal input and output impedances of the 20 GHz band NE 8698 two-chip structure amplifier are shown in Fig. 4. The input-output responses and the power output responses versus frequency for the 18 GHz band NE 8694 single-chip amplifier, the 18 GHz band NE 8698 two-chip amplifier, and the 20 GHz band NE 8698 two-chip amplifier are shown in Fig. 5 and Fig. 6, respectively. The 18 GHz band NE 8694 amplifier has 0.8 Watt power output with 3 dB associated gain, 0.96 Watt saturated power output and 15 % maximum power-added efficiency with 5.4 dB small-signal gain. The 18 GHz band NE 8698 amplifier has 1.25 Watt power output with 3 dB associated gain, 1.68 Watt saturated power output and 12.5 % maximum power-added efficiency with 4.5 dB small-signal gain. The 20 GHz band NE 8698 amplifier provides 1.04 Watt power output with 3 db associated gain, 1.35 Watt saturated power output, and 11.0 % maximum power-added efficieny with 3.8 dB small-signal gain. The 18 GHz band NE 8698 amplifier covers the 17.7 to 18.5 GHz range with more than 1.0 Watt power output for 0.5 Watt input power level, and the 20 GHz band NE 8698 amplifier covers the 19.65 to 20.5 GHz range with more than 0.8 Watt power output for 0.4 Watt input power level.

The 18 GHz band two-stage amplifier performance is shown in Fig. 7. The amplifier provides more than 0.8 Watt power output over the frequency range from 17.7 to 18.6 GHz for 0.25 Watt input power level. The amplifier has 1.05 Watt power output at 1 dB gain compression with 8.1 dB small-signal gain, 1.26 Watt saturated power output and 13.6 % maximum power-added efficiency at 18.0 GHz. Third-order intermodulation distortion ratio, measured for this two-stage amplifier by injecting two equal-amplitude signals separated in frequency by 10 MHz, was -27.5 dB at 26 dBm total power output level. A.M. to P.M. conversion factor of this amplifier remained below 3 degree/dB for output power up to saturation.

Conclusion

Lumped-element impedance matching techniques were successfully adopted for 18 GHz and 20 GHz band power GaAs FET amplifiers. Single-stage amplifier and the two-stage amplifier were developed. The 18 GHz band two-stage amplifier provides 1.05 Watt power output at 1 dB gain compression and 1.26 Watt saturated power output with 8.1 dB small-signal gain, and the 20 GHz band single-stage amplifier has 1.04 Watt power output with 3 dB associated gain.

It was shown that the lumped-element matching techniques are remarkably effective to achieve uniform excitation and low loss matching for multi-cell and multi-chip FETs with extremely low impedance, even in the K-band.

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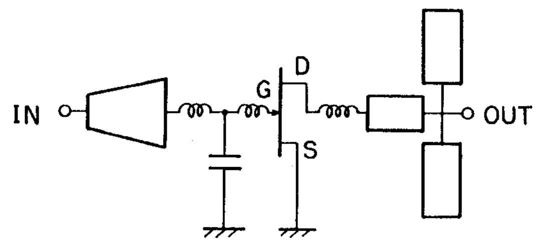

Fig. 1 Equivalent circuit for GaAs FET amplifier.

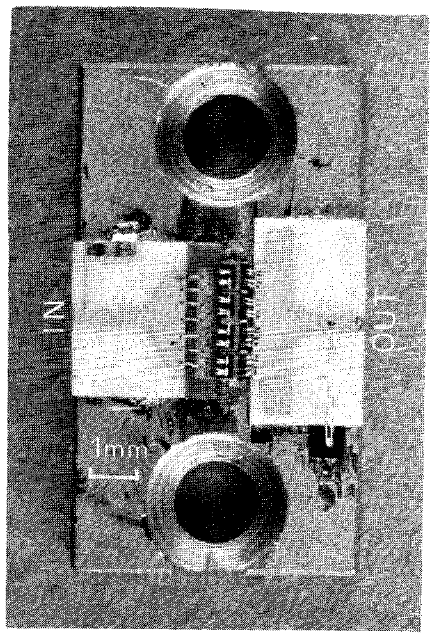

Fig. 2 20 GHz single-stage power GaAs FET NE 8698 amplifier.

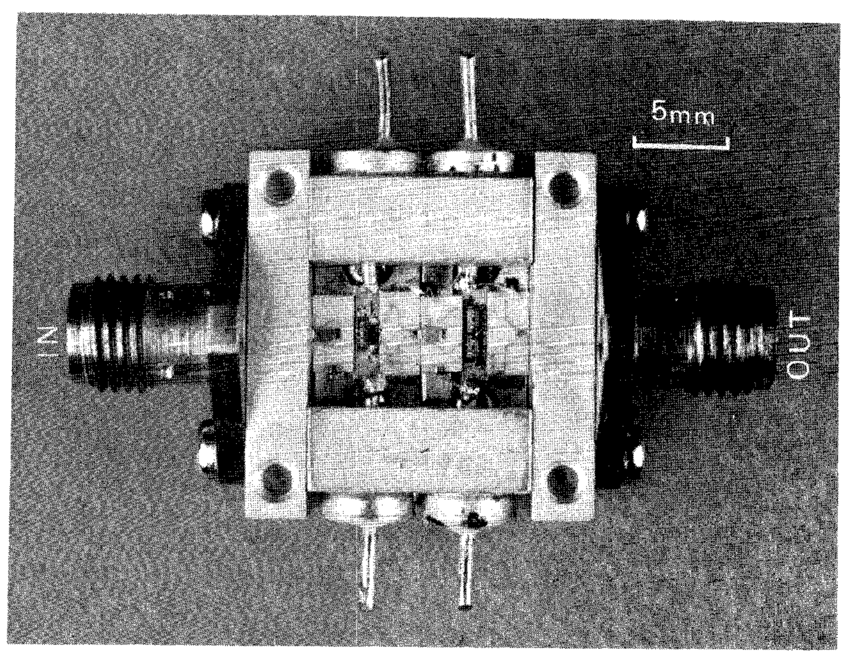

Fig. 3 Internal view of 18 GHz two-stage power GaAs FET amplifier.

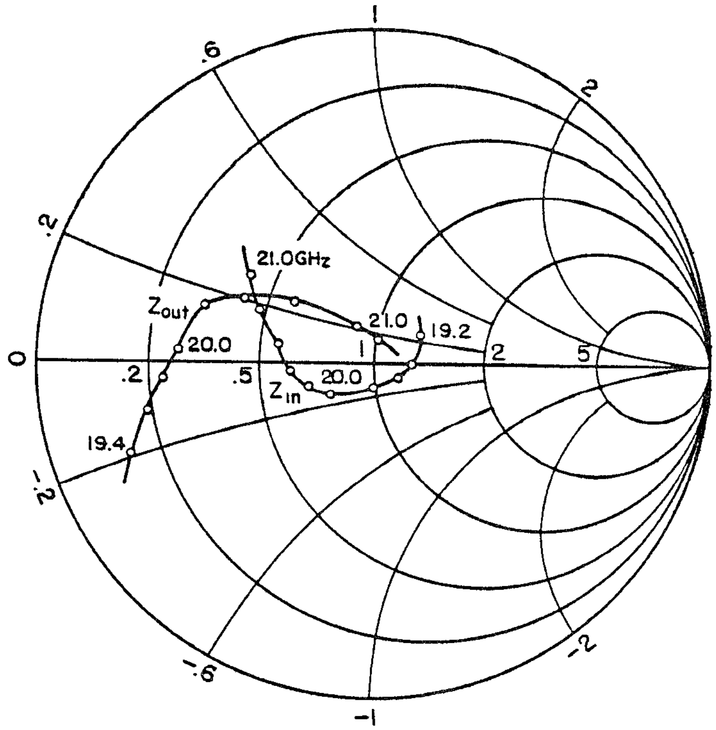

Fig. 4 Small-signal impedances of 20 GHz single-stage power GaAs FET NE 8698 amplifier.
Z_{in}: input small-signal impedance, Z_{out}: output small-signal impedance

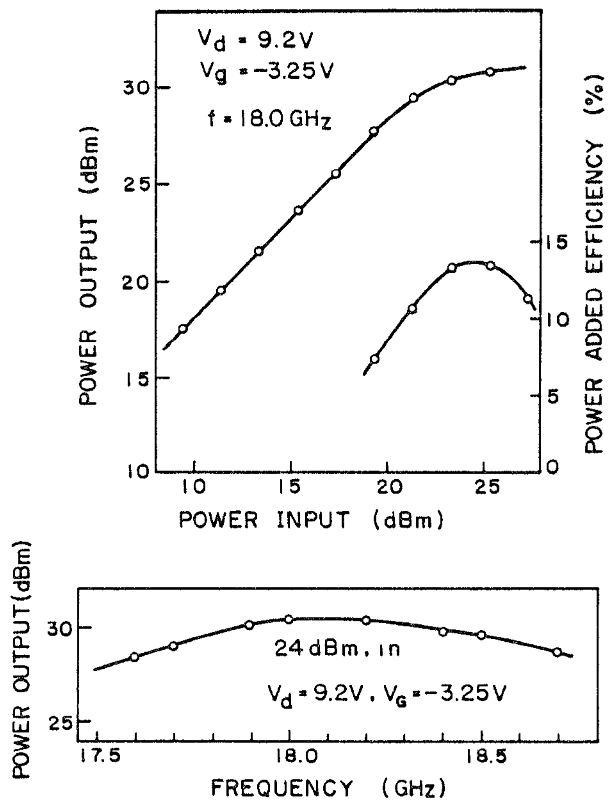

Fig. 7 Microwave performance of 18 GHz band two-stage power GaAs FET amplifier.

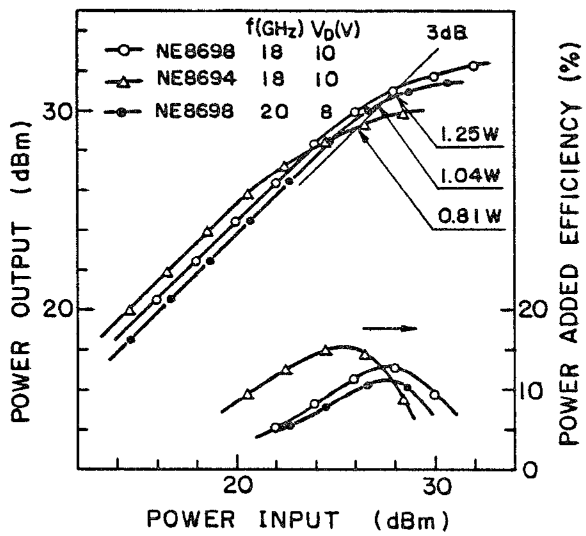

Fig. 5 Input-output responses for 18 GHz band and 20 GHz band GaAs FET amplifiers.

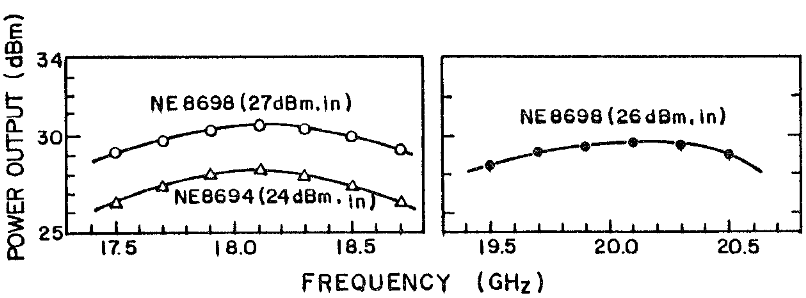

Fig. 6 Power output responses versus frequency for 18 GHz band and 20 GHz band GaAs FET amplifiers.