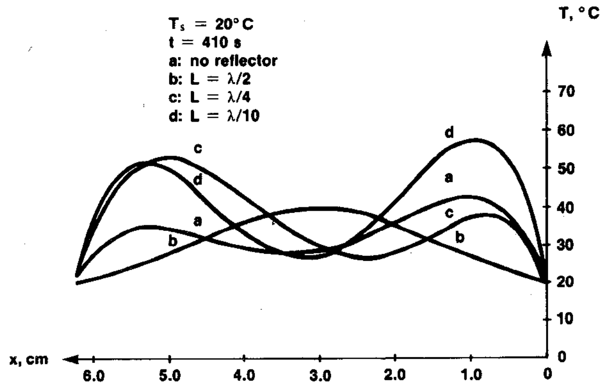


Fig. 12. Temperature profile in a homogeneous slab in the absence (curve $a$) and in the presence of a reflector (curves $b, c, d$). Boundary conditions: $T_s = 20.0\,°C$. Irradiation time: 410 s.

puted at $t = 410$ s after the beginning of the heating process. It is evident that a preferential heating by the microwaves of a certain region in the material may be achieved by adequately selecting the distance between the reflector and the slab boundary.

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# On Temperature Characteristics for a GaAs Monolithic Broad-Band Amplifier Having Resistive Loads

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*Abstract* —**Temperature characteristics for a GaAs monolithic broad-band amplifier having resistive loads were investigated. It was demonstrated that gain versus temperature characteristics for the amplifier are self-compensated and that the bandwidth for the amplifier becomes narrow when ambient temperature increases.**

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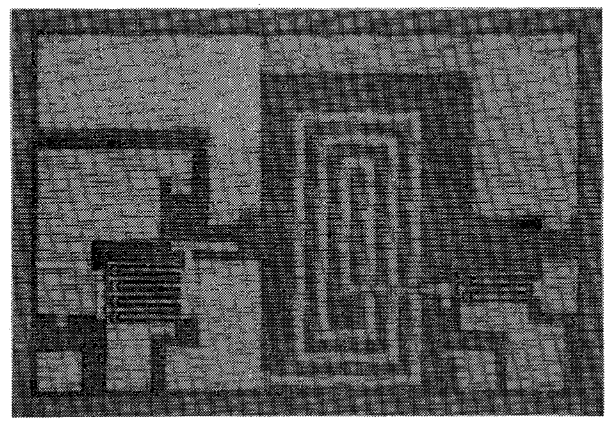

Fig. 1. Chip photograph for GaAs monolithic broad-band amplifier.

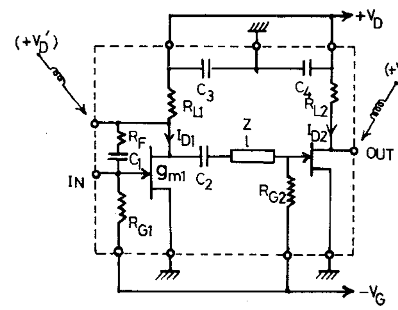


Fig. 2. Equivalent circuit for the amplifier.

## I. Introduction

To realize low-noise, broad-band amplification, GaAs monolithic amplifiers having resistive loads, which are formed by GaAs active layers, have been developed [1]–[6]. To apply the amplifiers to real systems, such as mobile radio systems, temperature characteristics for the amplifier are very important.

This paper reports the results of an investigation on temperature characteristics for the amplifier having resistive loads. It is demonstrated that gain versus temperature characteristics for the amplifier are self-compensated and that the bandwidth for the amplifier becomes narrow when ambient temperature increases.

## II. Theoretical Prediction

Figs. 1 and 2 show a chip photograph for the GaAs monolithic broad-band amplifier [2] and its equivalent circuit. The amplifier was fabricated on a Cr-doped semi-insulating LEC GaAs substrate. To fabricate FET's and resistors uniformly, an ion implantation technique was used. FET active (n) layers were formed by $^{30}Si^+$ ion implantation to the substrate in selected areas with energy $E = 70$ keV and dose $D = 3\times10^{12}$ cm$^{-2}$. Resistive ($n^+$) layers were formed by a double ion implantation. Conditions for the ion implantation are $E = 130$ keV, $D = 3\times10^{13}$ cm$^{-2}$ and $E = 60$ keV, $D = 1.5\times10^{13}$ cm$^{-2}$. Dopant for the $n^+$ layers is $^{30}Si^+$. After the ion implantations, the substrate was coated with a CVD-$SiO_2$ film and annealed at 800°C (20 min) in an $H_2$ ambient.

To estimate the gain versus temperature characteristic for the amplifier, voltage gain $Av(T)$ for the first-stage-FET circuit in

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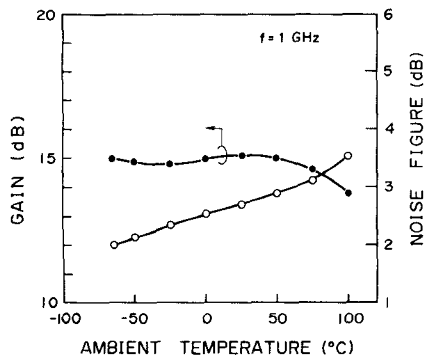


Fig. 3. Gain versus ambient temperature characteristics (noise figures are also plotted).

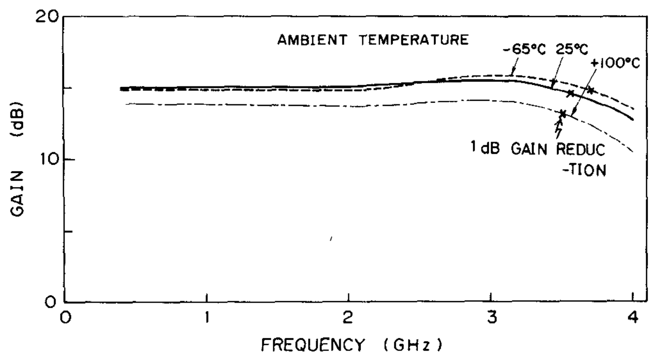


Fig. 4. Gain versus frequency characteristics measured at −65, +25, and at +100°C.

Fig. 2 is approximately calculated as

$$Av(T) \simeq \frac{R_{L1}(T)/R_F(T) - g_{m1}(T)R_{L1}(T)}{R_{L1}(T)/R_F(T)+1} \tag{1}$$

where the drain conductance for the FET was neglected for simplification. In (1), since both transconductance $g_m(T)$ and resistance $R_L(T)$ are functions of temperature $T$, voltage gain $Av(T)$ becomes a function of temperature.

Using sheet resistivity $R_\square(T)$ for the ion implanted $n^+$ layer, $R_{L1}(T)$ and $R_F(T)$ are represented as follows:

$$R_{L1}(T) = \frac{L_{L1}}{W_{L1}} R_\square(T)$$

$$R_F(T) = \frac{L_F}{W_F} R_\square(T) \tag{2}$$

where $L_{L1}$, $L_F$ and $W_{L1}, W_F$ are lengths and widths for the resistors, respectively. From (2), the following relation is derived:

$$R_{L1}(T)/R_F(T) = L_{L1}W_F/L_F W_{L1} = \text{const.} \tag{3}$$

Since both electron mobility and electron saturation drift velocity decrease when temperature increases, it is considered that the temperature coefficient for $g_{m1}(T)$ is negative, and that for $R_{L1}(T)$ is positive. If $g_{m1}(T) \times R_{L1}(T)$ doesn't depend strongly on temperature, voltage gain becomes nearly constant, regarding temperature.

On the other hand, high cutoff frequency $fc$ for the first-stage FET circuit is roughly approximated as (3)

$$fc(T) \approx \frac{1}{2\pi C_{SG} R_{L1}(T)} \tag{4}$$

where the parallel feedback resistor $R_F$ was neglected for simplification. $C_{SG}$ is gate–source capacitance for the second-stage FET, which is nearly constant in the ambient temperature range. Assuming the positive temperature coefficient for $R_{L1}(T)$, it is anticipated that the higher the ambient temperature becomes, the lower $f_c(T)$ becomes.

## III. Measured Temperature Characteristics

Fig. 3 shows gain for the amplifier measured under the ambient temperature range from −65 to +100°C. As seen, gain deviations between −65 and +65°C is as small as ±0.15 dB. Fig. 4 shows gain versus frequency characteristics measured at −65, +25, and at +100°C. In the figure, 1-dB gain reduction points (×) are indicated. The 1-dB gain reduction frequency becomes low when ambient temperature increases. The 1-dB gain reduction frequencies for −65, +25, and for +100°C are 3.7, 3.6, and 3.5 GHz, respectively. As shown in Figs. 3 and 4, experimental gain and the bandwidth characteristics results are in good agreement with the theoretical prediction.

Measured noise figures are also plotted in Fig. 3. Noise figures, which are not self-compensated, are within 2.7±0.75 dB in the ambient temperature range from −65 to 100°C.

## IV. Conclusion

It has been demonstrated that gain versus temperature characteristics for a GaAs monolithic broad-band amplifier having resistive loads are self-compensated and that the bandwidth for the amplifier becomes narrow when temperature increases. Experimental results are in good agreement with theoretical prediction.

## Acknowledgment

The author would like to thank T. Tsuji, T. Ozawa, and M. Ohyagi for developing the ion implantation process. He would also like to thank T. Sugiura, Y. Takayama, and H. Muta for their constant encouragement throughout this work.

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