20 GHz BAND GaAs-FET WAVEGUIDE-TYPE AMPLIFIER

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Abstract

Negative conductance reflection-type GaAs-FET amplifier was studied. Calculation showed a packaged GaAs-FET could be operated at high frequency than 20 GHz. An amplifier with 17 dB gain at 20 GHz was obtained using a packaged GaAs-FET mounted in a waveguide circuit.

Introduction

According to recent GaAs-FET development, 80GHz f_{max} is available today. However, its practical application at the high frequency band is rather limited by the existence of parasitic reactances. In addition, considering the reliability assurance, it is to be desired that the device should be packaged, which further imposes restrictions on the extent of practical application. The present paper describes the results of the study on the feasibility of applying a packaged GaAs-FET, whose f_{max} is 55 GHz, to a high gain amplifier at 20 GHz band.

The resonant frequencies caused by the combination of parasitic inductances of bonding wires and parasitic /intrinsic capacitances of the GaAs-FET used in the study are in the high frequency region. The GaAs-FET possesses sufficiently high g_m at these high frequencies. The above indicates the possibility of realizing a negative conductance one-port device at high frequency band.

In order to examine the possibility, a calculation was carried out for a one-port device model, showing that the negative conductance could be expected in 20 GHz band. Further, a reflection-type amplifier was constructed to confirm the possibility.

GaAs-FET Performance as One-Port Device

A simplified model of GaAs-FET, which was assumed to be as shown in Fig. 1, was used in the study. An external circuit was added to the Gate-Source port. In order to obtain a preliminary insight into the functions of self resonances, two types of Gate-Source termination were examined. In one type, the Gate-Source port is open circuited, while, in the other, it is short circuited with respect to radio-frequency.

The admittance looking into the left from a-a' is calculated as follows, when the Gate-Source port is open circuited,

$$Y=\frac{G\,[1-(f/f_1)^2]+jB\,[1-(f/f_2)^2]}{[1-(f/f_3)^2]-a(f/f_4)^2[1-(f/f_5)^2]+jb[1-(f/f_6)^2]} \qquad (1)$$

where f_i's are self resonant frequencies which are given in Table 1 together with G, B, a and b.

Since usually f_4 is larger enough and b is smaller enough, compared with the other corresponding parameters, the second and the third terms of the denominator of Y may be neglected as the first approximation, thus obtaining the following,

$$Y\fallingdotseq G\,\frac{[1-(f/f_1)^2]}{[1-(f/f_3)^2]}+jB\,\frac{[1-(f/f_2)^2]}{[1-(f/f_3)^2]} \qquad (2)$$

which indicates the existence of negative conductance in the frequency region between f_1 and f_3.

From the first approximation, the admittance looking into a packaged GaAs-FET from the Drain-Source port is expected to possess negative conductance characteristics in a certain frequency region if the Gate-Source port is properly terminated.

Results of calculation for some special cases are shown in Fig. 2. Figure 2(a) shows the frequency characteristics of Y when the Gate-Source port is open circuited, while Figure 2(b) shows that of Y when the Gate-Source port is short circuited. Capacitive termination of the Gate-Source port is effective to obtain negative conductance characteristics.

Experimental Result

In order to confirm the possibility of using the negative conductance characteristics in amplifier application, a reflection-type amplifier was constructed. A packaged GaAs-FET (NEC V244) was mounted in a waveguide circuit.

Figure 3 shows the waveguide mount structure. The Gate-Source port is directly coupled to a waveguide cavity by arranging the Gate stem to form a coupling loop antenna. The Drain stem forms a loop antenna coupling with input/output waveguide. The remaining part of FET is mounted in a window which is made on the common boundary wall of the cavity and input/output waveguide. The dimensions of the window considerably influence the amplifier performance, as it forms a part of the feedback element. In order to adjust the effect, a tuning stub is inserted into the window.

Figure 4 shows an external view of the reflection-type amplifier using the above waveguide mount. The input/output waveguide is connected to a circulator through tuning stubs in order to separate input power and output power. Gain and bandwidth are optimized by adjusting these stubs.

Figure 5 shows the frequency characteristics of the amplifier gain. The center frequency is 19.9 GHz and the bandwidth is 450 MHz for ± 0.5 dB gain variation.

Figure 6 shows the output power vs. input power at center frequency.

Figure 7 shows the noise figure frequency characteristics of the amplifier.

A 17 dB gain and noise figure of less than 13 dB were obtained, proving the possibility of applying a packaged GaAs-FET to a negative conductance reflection-type high gain amplifier at 20 GHz band.

Conclusion

As a practical means of amplifier application using packaged GaAs-FET at high frequency band above 20 GHz, a negative conductance reflection-type amplifier was studied. The possibility of a high gain amplifier at 20 GHz band, using a packaged GaAs-FET, whose f_{max} is 55 GHz, was explained by calculation. Applying the GaAs-FET to a waveguide circuit , a reflection-type amplifier with 17 dB gain at 20 GHz was obtained. Refining the waveguide mount configuration and the Gate-Source port termination properly, a high gain amplifier at higher frequency band may be feasible by using the state-of-the-art GaAs-FET.

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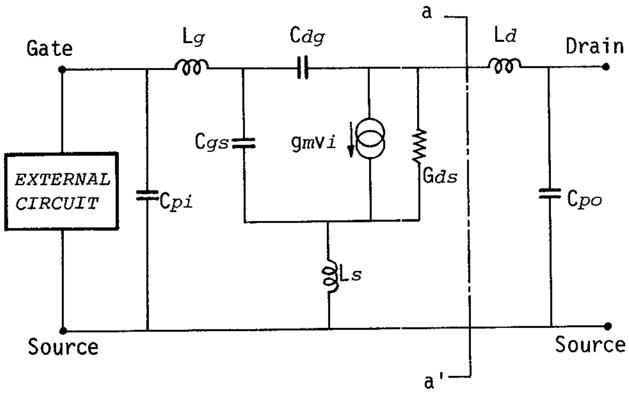


Element Values

g_m=25mmho, G_{ds}=2.5mmho,
L_g=L_d=0.2nH, L_s=0.1nH,
C_{dg}=0.05pF, C_{gs}=0.2pF, C_{pi}=C_{po}=0.25pF

Fig. 1 Simplified model of packaged GaAs-FET

Table 1 Parameters of Eq.(1)

$$2\pi f_1 = [\ (L_g+L_s)(\bar{C}_{dg}+C_{gs})C_{pi}/(\bar{C}_{dg}+C_{gs}+C_{pi})\ ]^{-1/2}$$

$$2\pi f_2 = [\ (L_g+L_s)C_{gs}C_{pi}/(C_{gs}+C_{pi})\ ]^{-1/2}$$

$$2\pi f_3 = [\ L_gC_{pi}(C_{dg}+C_{gs})/(C_{dg}+C_{gs}+C_{pi})\ ]^{-1/2}$$

$$2\pi f_4 = [\ L_sC_{gs}\ ]^{-1/2}$$

$$2\pi f_5 = [\ L_gC_{dg}C_{pi}/(C_{dg}+C_{pi})\ ]^{-1/2}$$

$$2\pi f_6 = [\ L_gC_{pi}(C_{dg}+\bar{C}_{gs})/(C_{dg}+C_{gs}+C_{pi})\ ]^{-1/2}$$

$$G = G_{ds}(\bar{C}_{dg}+C_{gs}+C_{pi})/(C_{dg}+C_{gs}+C_{pi})$$

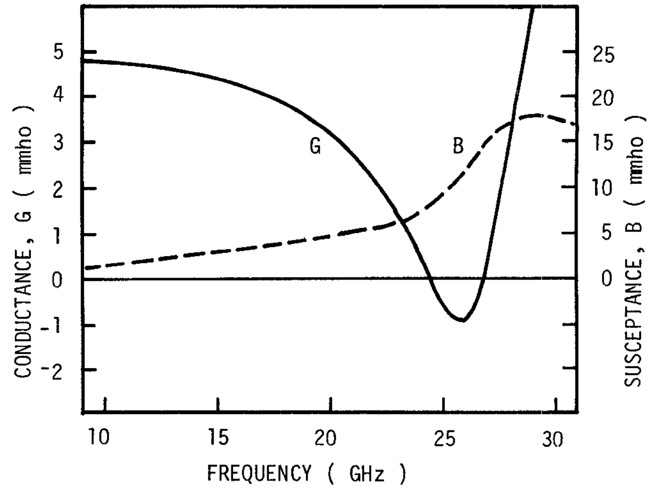
$$B = 2\pi f\ [\ C_{dg}(C_{gs}+C_{pi})/(C_{dg}+C_{gs}+C_{pi})\ ]$$

$$a = (C_{dg}+C_{pi})/(C_{dg}+C_{gs}+C_{pi})$$

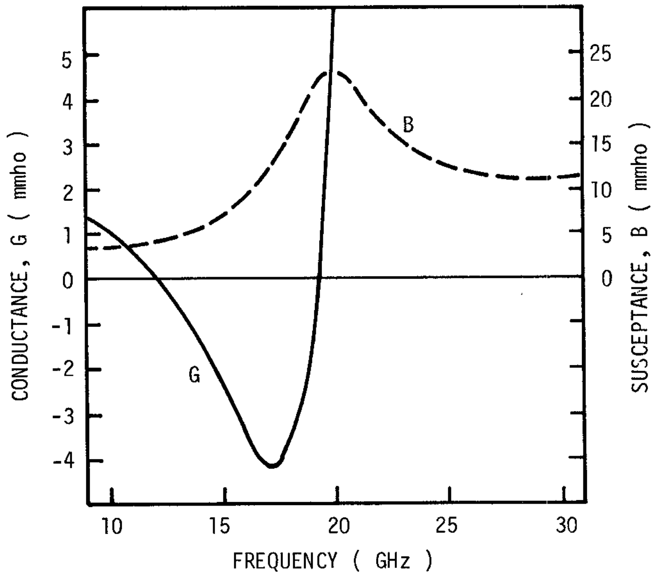
$$b = 2\pi f\ [\ L_s(g_m+G_{ds})(C_{dg}+\bar{C}_{gs}+C_{pi})/(C_{dg}+C_{gs}+C_{pi})\ ]$$

$$\bar{C}_{dg} = C_{dg}\ (1+g_m/G_{ds})$$

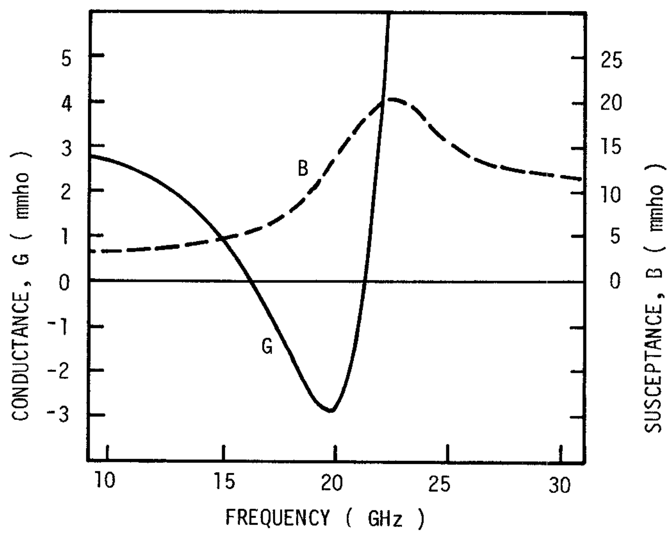
$$\bar{C}_{gs} = C_{gs}/(1+g_m/G_{ds})$$



(a) Gate-Source port ; Open

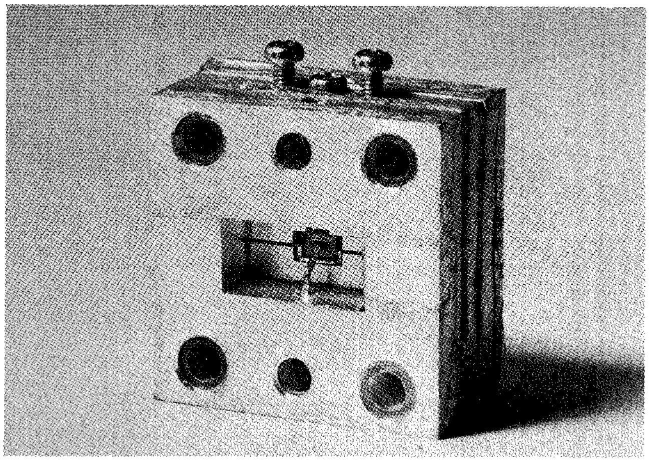


(b) Gate-Source port ; Short

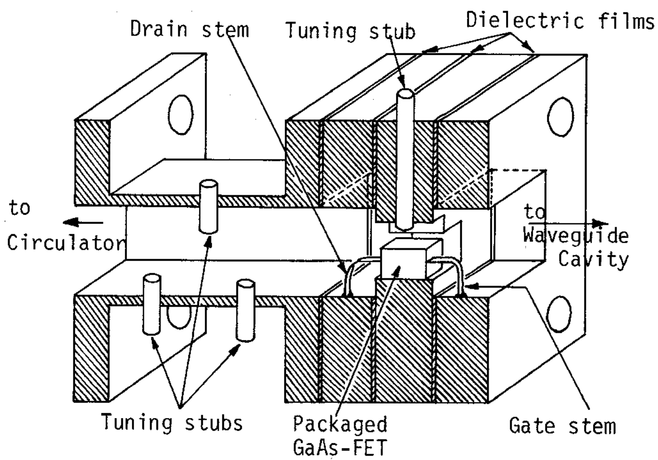


(c) Gate-Source port ; Capacitive, C=0.75pF

Fig. 2 Frequency characteristics of Y



(a) External view



(b) Cross-sectional view

Fig. 3 Waveguide mount structure

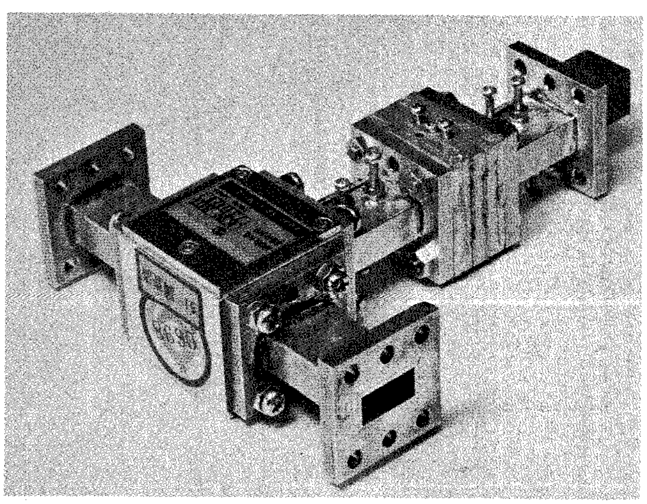


Fig. 4 External view of the waveguide-type reflection amplifier

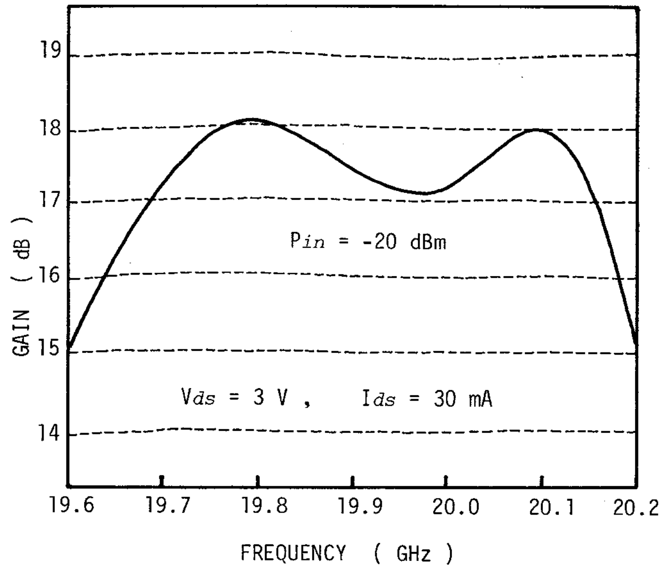


Fig. 5 Frequency characteristics of gain

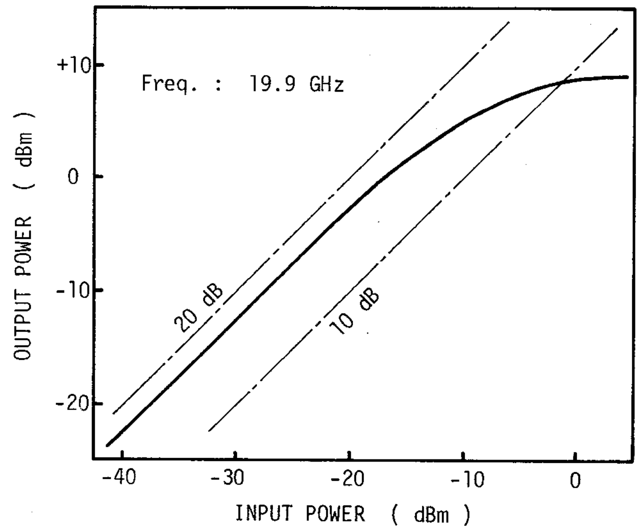


Fig. 6 Output power vs. input power

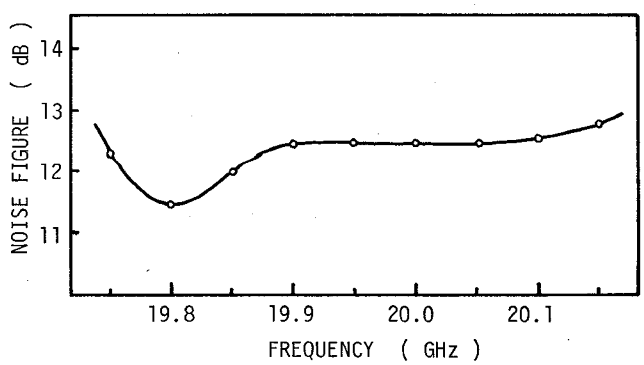


Fig. 7 Noise figure characteristics