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A 1 WATT 28 GHz BAND AMPLIFIER USING CLUSTERED FETs

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Abstract

The clustered FET operating at Ka-band, in which four FET cells with 800 μm gate width are combined by the new 4-way monolithic combiner, has been developed. The amplifier using these clustered FETs has been demonstrated with more than 1 watt power output with 6 dB associated gain over 27.6 - 29.3 GHz.

Introduction

High power FET amplifiers operating at high frequencies are required for military and commercial systems.[1-3]

Higher power levels are usually achieved by increasing the FET device size. However, large FET cells result in lower device gain and lower efficiency at higher frequencies due to internal phase and amplitude umbalances. Therefore, FET cell size is limited, and in order to realize high power FET amplifiers, efficient cell combining techniques are required.

This paper describes the clustered FET operating at Ka-band and the 28 GHz band amplifier using it. The clustered FET consists of four 800 μm gate width unit FET cells and the 4-way monolithic combiner. The amplifier with 1 watt, 6 dB gain over 27.6 - 29.3 GHz has been developed.

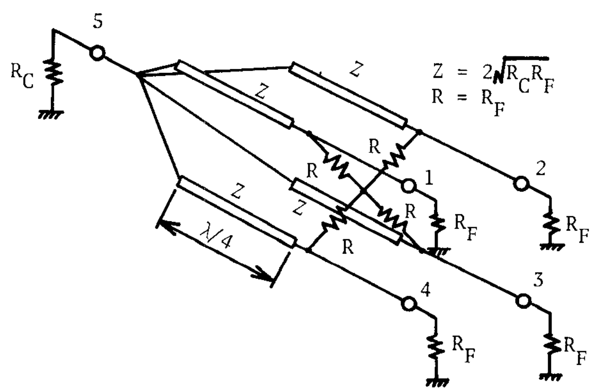

Fig. 1 4-way Wilkinson Hybrid

Clustered FET

By using Wilkinson hybrid,[4] a number of output power can be combined and it takes only one quarter wavelength. But N-way Wilkinson hybrid ($N \geq 3$) requires a common floating node as shown in Fig.1. In order to combine FET cells, planar type combiner circuits are required.

A new 4-way planar combiner shown in Fig.2 is devised. It consists of two binary combiners, in which the center ports of isolation resistors are connected by bond wire. The features of the combiner are that the length is only 1/4λ section, and that it can be easily fabricated by using monolithic technique.

In this combiner, it is necessary that the isolation resistance R is equal to the resistive impedance R_F seen from each branch-line of the combiner to output port of unit FET cell, and the bond wire is as short as possible. The resistive impedance (R_F) is very low at higher frequencies, so the isolation resistance is required to be lower. But, it is difficult to realize small

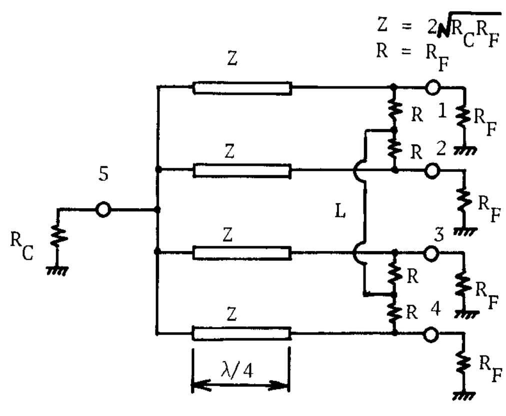

Fig. 2 New Planar Type 4-way Combiner

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epitaxicial resistors with lower resistance which are fabricated at the same time as the FET active channel. Moreover, at high frequencies, the length of the bond wire is not sufficiently shorter than wavelength, and the inductance L of the bond wire can not be neglected. Taking into account the above consideration, 4-way combiner for 800 μm unit FET cell with R_F of 4 ohm, which is also used for transformer between 4 ohm output port of unit FET cell and 15 ohm transmission line, has been designed.

Fig.3 shows calculated S-parameters of combiner. In this combiner, R is determined to be 15 ohm, that is, about 4 times of the required value (R_F). The length of the bond wire with 25 μm diameter is 0.6 mm and L becomes about 0.45 nH. R and L are not optimum values. But, S_{11} is less than -5 dB, S_{21} is less than -12 dB, S_{31} and S_{41} are less than -20 dB. These values are less than those of the combiner without isolation resistors.

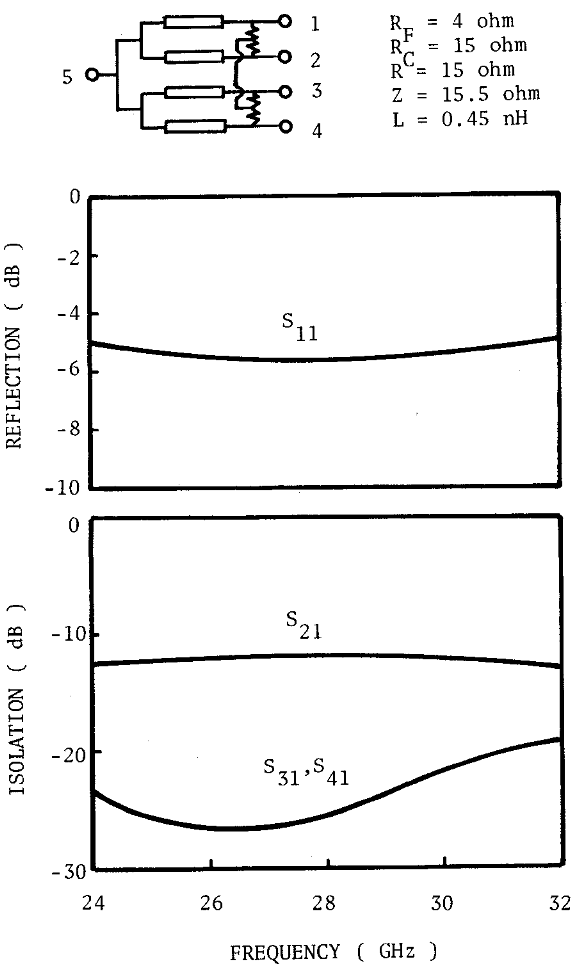

Fig. 3 Computed S-parameters of the 4-way Combiner

Fig.4 shows the photograph of the clustered FET with 3200 μm gate width, which consists of four 800 μm unit FET cells and the monolithic combiner. The chip size is 0.03 x 1.4 x 2.1 mm. The preceding 4-way combiner is used in the output of the clustered FET.

Fig.5 shows power transfer characteristic and efficiency of the typical clustered FET at 28 GHz. The measured performance is power output of 0.8 watt at 1 dB gain compression point with associated gain of 3 dB and power added efficiency of 8.3%.

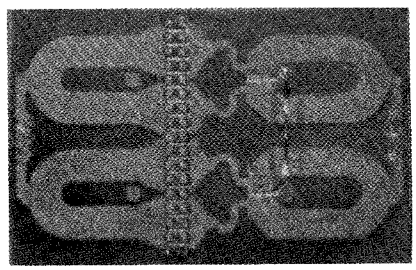

Fig. 4 Photograph of the 4-cell Clustered FET

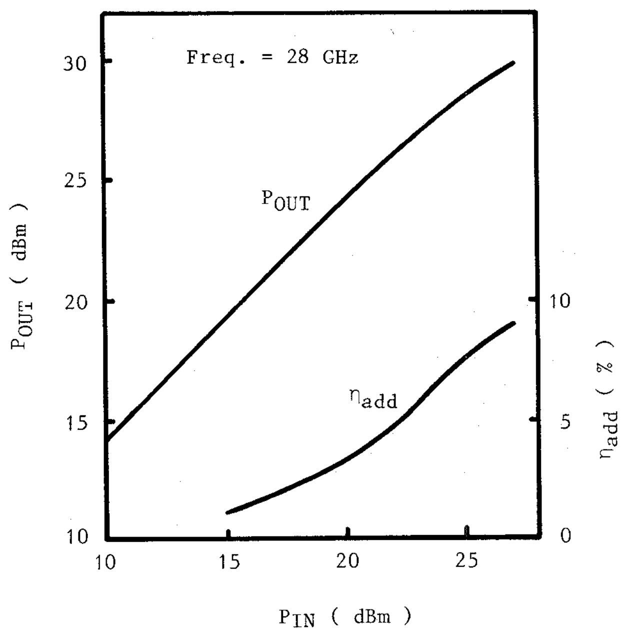

Fig. 5 Power Transfer Characteristic and Efficiency of the 4-cell Clustered FET

Amplifier

A 28 GHz band 1 watt FET Amplifier using the clustered FETs in the preceding section has been developed.

Fig.6 and Fig.7 show a schematic diagram and a photograph of the amplifier, respectively. The amplifier is a 3-stage amplifier and the last two stages are balanced. Output power of two cascaded stages are combined by microstrip branch-line couplers. The microstriplines are converted to the waveguide at both input and ouput ports of the amplifier. Each unit amplifier consists of the clustered FET, a simple matching circuit and a bias circuit. Microstripline is built using 0.25 mm sapphire substrate. The dimension of the amplifier is 14 x 40 x 70 mm.

Fig.8 shows power performance of the amplifier. The output power of more than 1 watt with 6.5 ± 0.5 dB gain is obtained over 27.6 to 29.3 GHz frequency band.

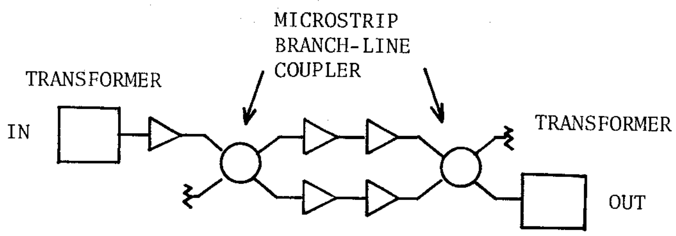

Fig. 6 Schematic Diagram of the Amplifier

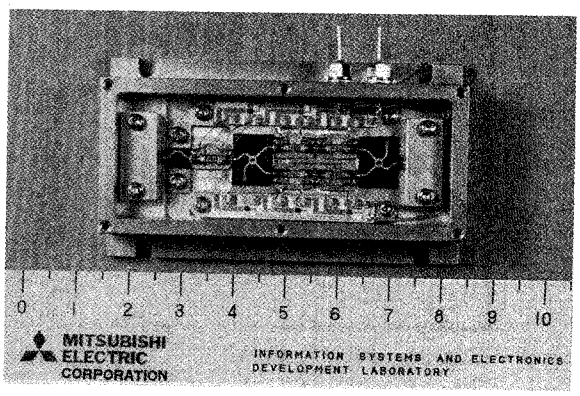

Fig. 7 Photograph of the Amplifier

Fig.9 shows power transfer characteristic and efficiency of the amplifier at 28 GHz. Output power at 1 dB gain compression of 1 watt with 8.7 dB linear gain is obtained. Saturated power is 1.5 watt and maximum power added efficiency is 4.3%.

Conclusion

A new 4-way monolithic combiner for FET cell combining at high frequencies has been devised. The clustered FET composed of the monolithic combiner and four 800 μm cells has been developed. The amplifier using the clustered FET with more than 1 watt power output over 27.6 - 29.3 GHz has been demonstrated.

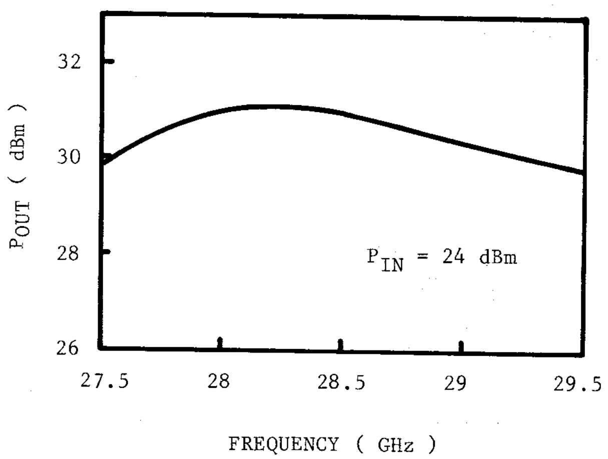

Fig. 8 Frequency Characteristic of the Amplifier

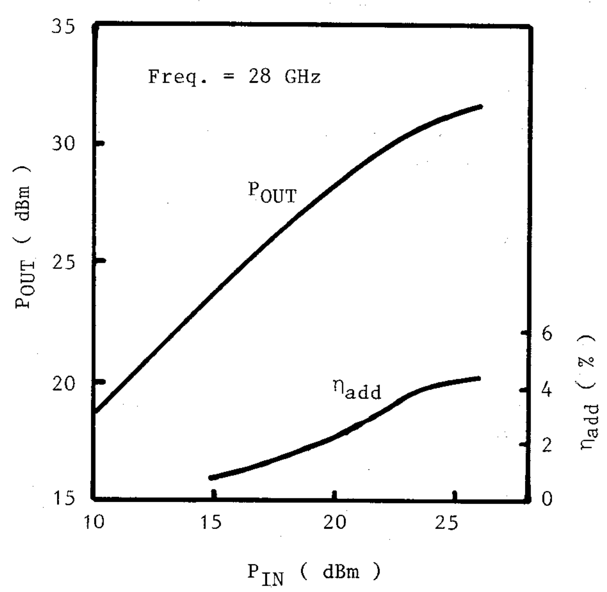

Fig. 9 Power Transfer Characteristic and Efficiency of the Amplifier

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