DESIGN AND PERFORMANCE OF A NEW MULTI-OCTAVE HIGH-GAIN AMPLIFIER

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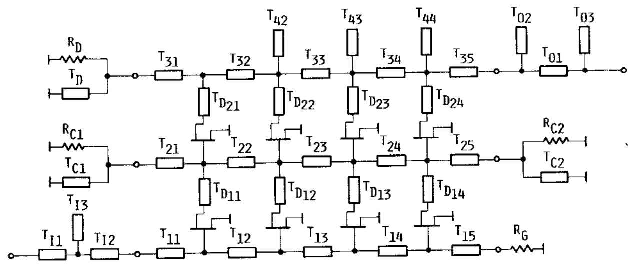
ABSTRACT

Experimental results obtained from a number of typical representatives of a new type of amplifier are discussed. Gains of G = 16.3 +/- 0.9 dB at a maximum reflection loss of RL = -11.3 dB between 2.3 GHz and 20.3 GHz and G = 18.3 +/- 1.1 dB between 2.5 GHz and 18 GHz were achieved in single stage units. The maximum noise figures of the respective modules are F = 6.6 dB and F = 6.3 dB from 2.5 GHz to 18 GHz. A two-stage amplifier yielded G = 33 +/- 1.0 dB and RL = -10.0 dB from 2.5 GHz to 20.5 GHz with a maximum noise figure of F = 7.1 dB across the 2.0 - 18.0 GHz frequency band.

INTRODUCTION

The paper describes a new type of amplifier that makes simultaneous use of the additive and multiplicative amplification process in one and the same module. In its most general form the device consists of an array of m rows and n columns of transistors. However, the amplifier module discussed in the following is limited to a 2x4 array (m=2, n=4) as shown in Figure 1. It basically is composed of two tiers of active devices linked together by transmission line elements thereby forming a network of a two-dimensional lattice. The four idle ports of the resulting six-port are terminated into loads that aid in shaping the gain, secure stable operation, and provide highly efficient dc biasing. An in depth discussion of the amplifier's principle and theory, as well as important design considerations are contained in the literature [1]. The advantage of the new device over the equivalent cascaded distributed amplifier using the same type and number of active devices is its smaller size. In addition, better reflection coefficients and lower noise figures have been measured and can be expected.



DESCRIPTION OF CIRCUIT COMPONENTS

T_{In} - INPUT MATCHING TRANSMISSION LINE ELEMENTS

T_{On} - OUTPUT MATCHING TRANSMISSION LINE ELEMENTS

T_{1n} - GATE LINE TRANSMISSION LINE ELEMENTS

T_{2n} - CENTER LINE TRANSMISSION LINE ELEMENTS

T_{3n} - DRAIN LINE TRANSMISSION LINE ELEMENTS

T_{D1n} - TRANSFORMING TRANSMISSION LINE ELEMENTS (1. TIER)

T_{D2n} - TRANSFORMING TRANSMISSION LINE ELEMENTS (2. TIER)

T_{4n} - DRAIN LINE OPEN-CIRCUIT SHUNT STUBS

R_G - GATE LINE TERMINATION

R_{Cn} - CENTER LINE TERMINATIONS

R_D - DRAIN LINE TERMINATION

T_{Cn} - CENTER LINE SHORT-CIRCUIT SHUNT STUBS

T_D - DRAIN LINE SHORT-CIRCUIT SHUNT STUB

Fig. 1 Schematic of the two-tier matrix amplifier.

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DESIGN AND EXPERIMENTAL RESULTS

A photograph of the first version of our amplifier module is shown in Figure 2. In this case it is realized on 10 mil. thick quartz and has the dimensions 0.5x0.24 inches. Due to the rather wasteful use of substrate material, especially in the input circuit, the unit's size could be easily reduced to 0.275 x 0.24 inches. All eight transistors are of the same type, incorporating 0.25x200 μm gates and are manufactured on vapor

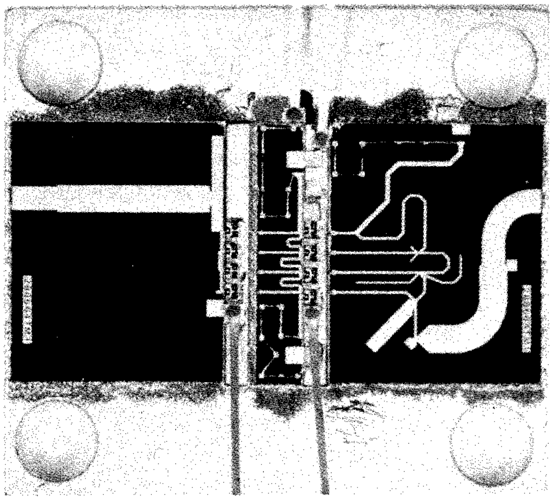

Fig. 2 Two-tier matrix amplifier on quartz (1.version).

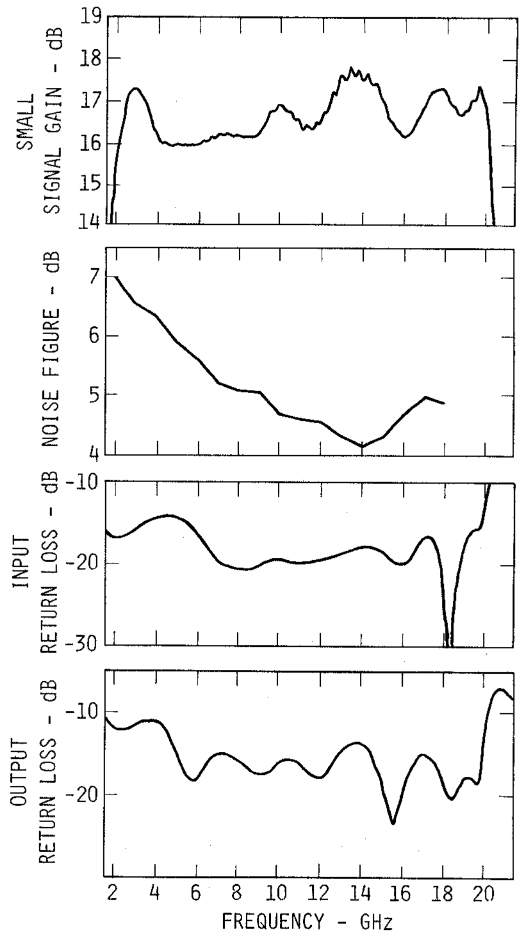

Fig. 3 Measured performance of the experimental amplifier module of Fig. 2.

phase epitaxial material whose doping is N = $4x10^{17}cm^{-3}$ with a 90% level at a depth of 0.2 μm. The unit is self-biased with only one voltage supplied to a simple voltage divider. The test results of a single module, as shown in Figure 1, are plotted in Figure 3. A small-signal gain of G = 16.3 +/- 0.9 dB at a maximum reflection loss of -11.4 dB was measured between 2.3 GHz and 20.3 GHz. Across the frequency bands 2.5-18 GHz and 8-18 GHz, maximum noise figures of F = 6.6 dB and F = 5.1 dB were recorded.

The measured data of a two-stage matrix amplifier, as we have named this device due to its regular geometric arrangement of circuit elements, are displayed in Figure 4. A small-signal gain of G = 33 +/- 1.0 dB was achieved between 2.5 GHz and 20.5 GHz. The maximum reflection loss over this band is -10 dB for the input and -11 dB for the output terminal. Maximum noise figures of F = 7.1 dB from 2.0-18.0 GHz and F = 6.1 dB from 5.0-18.0 GHz were measured. At an output power of P = 20 dBm (2.5 dB compression) and the frequency f_o = 2.5 GHz, the output power of the dominant harmonic is $P(3f_o)$ = 0 dBm. All other harmonics are more than 30 dB below the carrier for the same conditions.

A photograph of a second and improved version of the matrix amplifier module that also uses 10 mil. thick quartz is shown in Fig. 5. It measures 0.350 x 0.240 inches and employs the same type of GaAs MESFET used in the unit of Fig. 2. The measured and computed small-signal gain, as well as the noise

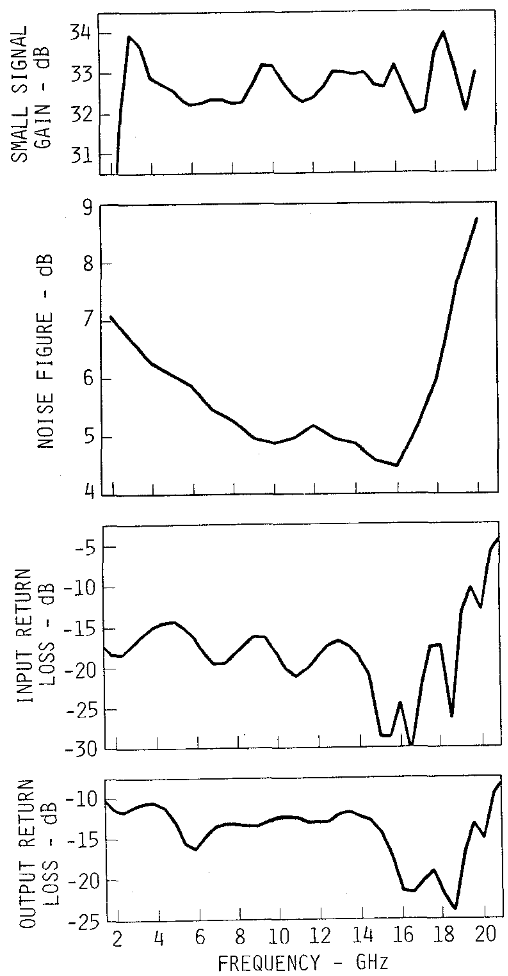

Fig. 4 Measured performance of the two-stage experimental amplifier.

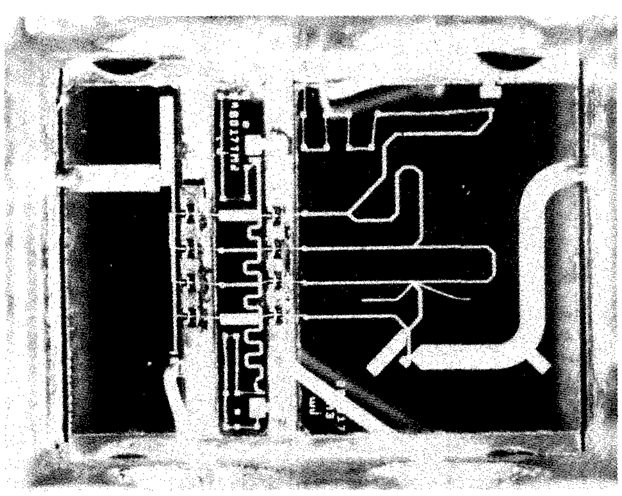

Fig. 5 Two-tier matrix amplifier on quartz (2.version).

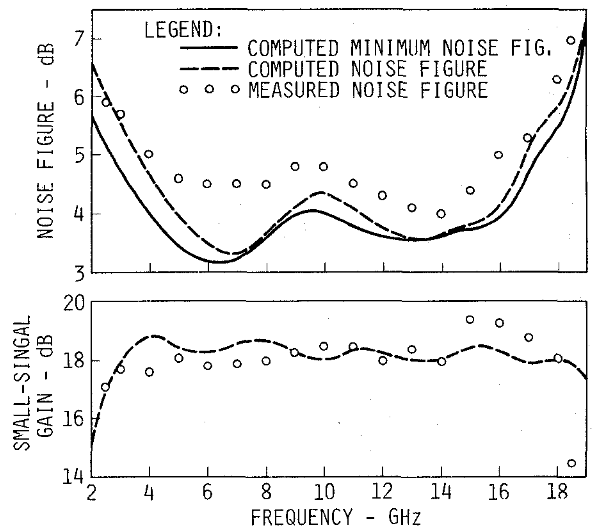

Fig. 6 Measured and computed gain and noise figures of the experimental amplifier module of Fig. 5.

figures are shown in Fig. 6. In this case, gains of G = 18.3 +/- 1.1 dB and noise figures of F ≤ 6.3 dB were measured across the 2.5-18.0 GHz band. From 4.0-16.0 GHz the maximum noise figure is F=5.0 dB with a small-signal gain of G=18.5 +/- 0.9 dB. Also plotted in Fig. 6 is the computed optimum noise figure which, analogous to that of the distributed amplifier, deviates very little from the computed actual noise figure. The dominant source of noise, except over the upper 10% of the band, is that originated by the first tier of transistors. However, above f = 16 GHz the second tier contributes the largest portion to the noise and is mainly responsible for the rapidly increasing noise figure at high frequencies. The terminations of the idle ports appreciably add to the amplifier's noise figure only over the lower 25-30% of the band. A more detailed analysis on the noise behavior of the matrix amplifier and the influence of the circuit elements on its noise figure, as well as a comparison with the noise characteristics of an equivalent two-stage distributed amplifier has been submitted for publication.

A recently designed, and significantly smaller version, of a matrix amplifier realized on 15 mil thick alumina, measures .333 x .230 inches and is shown in Fig. 7. The initial measurements of the

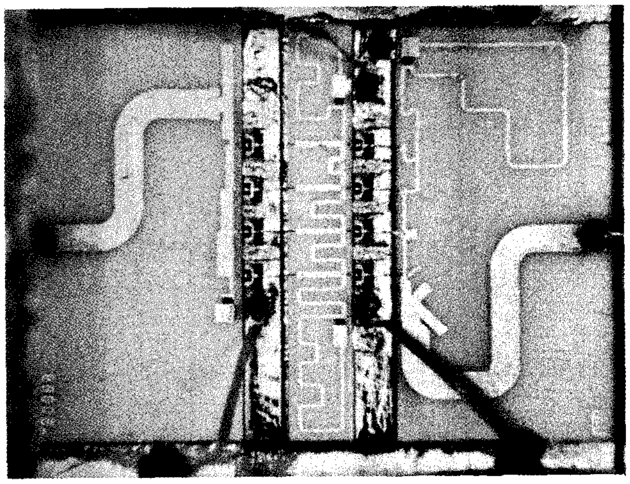

Fig. 7 Two-tier matrix amplifier on alumina.

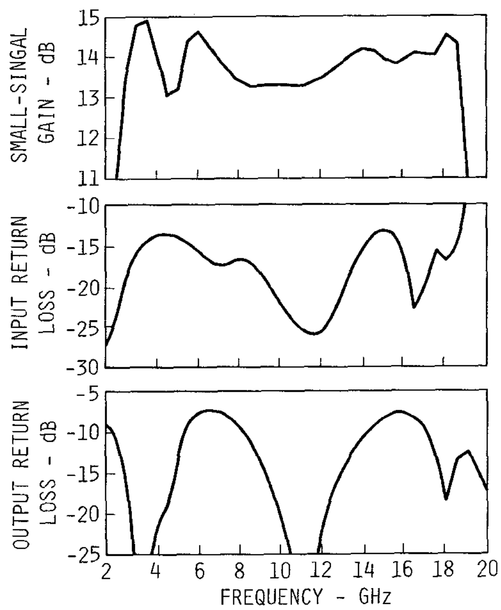

Fig. 8 Measured performance of the experimental amplifier module of Fig. 7.

small-signal gain and the input and output return loss are reflected in Fig. 8. The type of GaAs MESFET used in this module is the same as that employed in those of Figures 2 and 5. A comparison with those modules using quartz as substrate material reveals an appreciable loss in small-signal gain, partially due to the lower impedances of the transmission lines linking the active devices and the lower impedances of the biasing lines.

CONCLUSION

In summary, the paper has attempted to discuss the design and performance of a new amplifier concept and has demonstrated its feasibility on a number of practical models in form of a 2x4 array using eight identical GaAs MESFETs. It has been experimentally shown that, due to the combination of the multiplicative and the additive amplification process in one and the same module, gains in excess of 2.25 dB per active device can be achieved across a multi-octave frequency band simultaneously with low reflection losses and acceptable noise figures.

ACKNOWLEDGEMENT

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REFERENCES

[1] K.B. Niclas and R.R. Pereira, "The matrix amplifier: a high-gain module for multi-octave frequency bands," IEEE Trans. Microwave Theory Tech., vol. MTT-35, March 1987.