THE STACKFET: AN IMPROVED IMPLEMENTATION OF THE DUAL GATE FET

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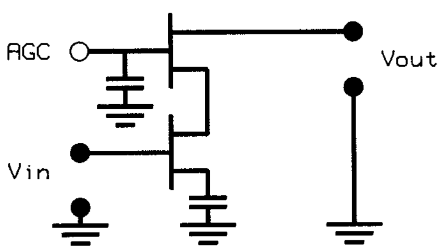
ABSTRACT

A new method of directly coupling two GaAs FET devices in series has been developed.* This structure, the STACK-FET, exhibits significantly improved gain performance over previous configurations and was used to design a balanced amplifier module giving 22.5 dB of gain over the 2-8 GHz band.

INTRODUCTION

This paper describes a novel GaAs FET structure which has been used to design very high gain, broadband amplifier modules. The structure is essentially an optimum implementation of a dual gate GaAs FET in which the gain of the two FET's is combined in a series biased, DC-coupled arrangement. Unlike a conventional dual gate FET, the RF interconnection of the STACKFET is such that each individual FET acts as if it is operating in RF common source mode, rather than a common source/common gate cascode combination. This results in much higher gain and stability, and very well-behaved matching and AGC characteristics (Figure 1).

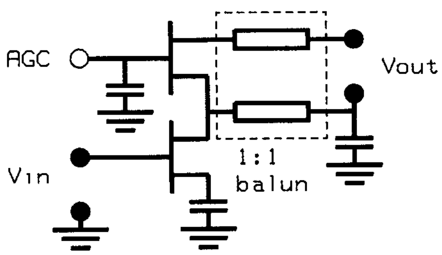


A.) Conventional dual gate configuration.

Freq	dB[s21]	dB[s11]	dB[s22]	K
2.0	17.22	-0.83	-0.45	0.48
6.0	14.61	-2.88	-0.19	0.05
10.0	11.44	-4.25	0.26	-0.62
14.0	11.65	-5.79	0.20	-0.34
18.0	12.32	-6.19	1.92	-3.13
20.0	11.95	-3.95	2.01	-2.50

A.) S-parameters of conventional dual gate device.

Figure 1a.



B.) STACKFET configuration.

Freq	dB[s21]	dB[s11]	dB[s22]	K
2.0	33.49	-2.96	-8.62	3.58
6.0	22.82	-5.70	-10.41	6.03
10.0	17.40	-7.55	-8.62	6.35
14.0	16.53	-12.14	-11.38	3.45
18.0	13.07	-9.66	-12.90	3.46
20.0	11.36	-7.72	-15.16	3.06

B.) S-parameters of the STACKFET.

Figure 1b.

*Patent pending.

THEORY OF OPERATION

Figure 1a shows a conventional dual gate FET as commonly used in amplifier and AGC applications. If the second gate is grounded to RF, the equivalent circuit can be represented as a common source device directly coupled to a common gate device. Such a device has the attraction of a fairly high magnitude of S21 over a wide frequency range (see Table 1a). Unfortunately, the output common gate device causes very unstable output characteristics which make practical broadband circuits difficult to design. The STACKFET structure is shown in Figure 1b. The difference is that the output voltage is taken between the drain and source of the second FET, rather than from drain to gate (ground). In order to provide an RF grounded output connection, a balun must be included as shown. The S-parameters of the new structure are shown in Table 1B, from which it is immediately evident that even higher S21 gain is obtained than from a conventional dual gate device. Importantly, input and output impedance levels are well behaved and easily matchable. Also, the K-factor shows very stable operation.

The STACKFET, therefore, has the advantages of a dual gate device without the drawbacks. In particular, AGC can be applied to the second gate and give good gain control even in broadband designs.

HIGH GAIN 2-8 GHz MODULE

Figure 2 shows the schematic layout of the balanced 2-8 GHz amplifier module incorporating the STACKFET device described above. The balun was realized in microstrip as two tightly coupled lines with a center frequency of 7 GHz. The even mode and odd mode impedances required for best circuit performance proved readily achievable in this configuration.

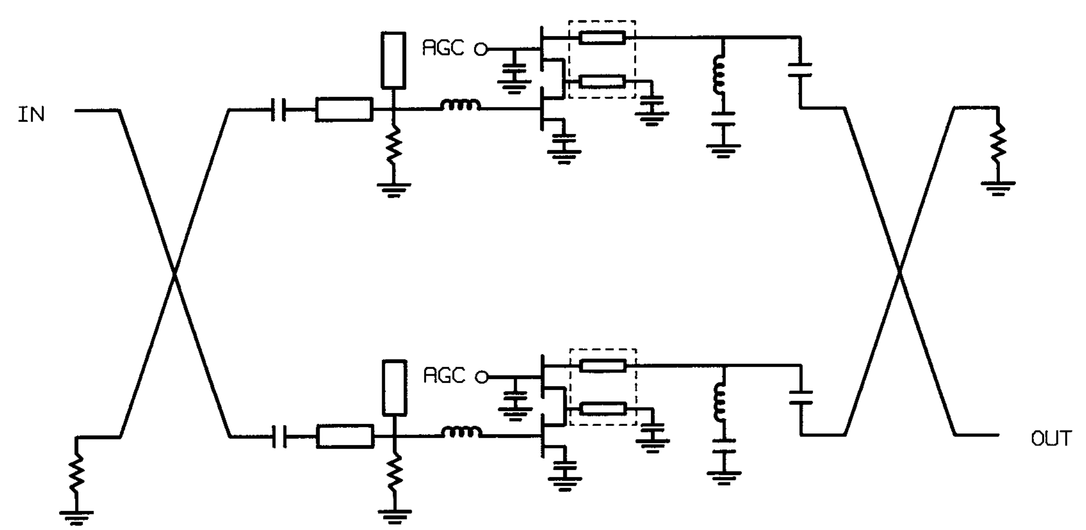


Figure 2.

2-8 GHz balanced gain module using the STACKFET.

MEASURED MODULE DATA

The gain block produced 22.5 dB of gain over the full 2-8 GHz bandwidth which is to our knowledge the highest reported gain performance to date for a balanced module over this frequency range. Noise figure and 1 dB compression power for this module was comparable to a conventional single gate 300 micron MESFET used in balanced configuration. Data for the module is shown in Figure 3 and Figure 4. Using better power devices, a module was built that gave 20 dBm 1 dB compression power with 18 dB of gain.

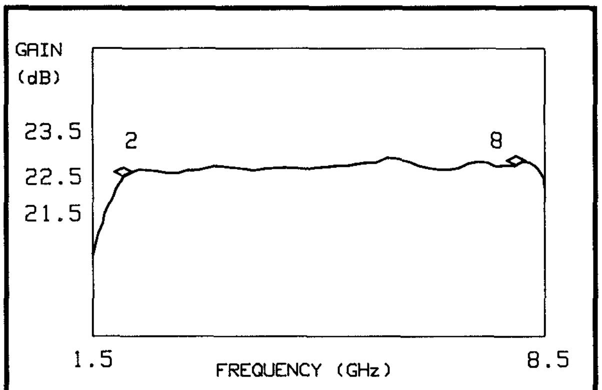


FIGURE 3. GAIN PERFORMANCE

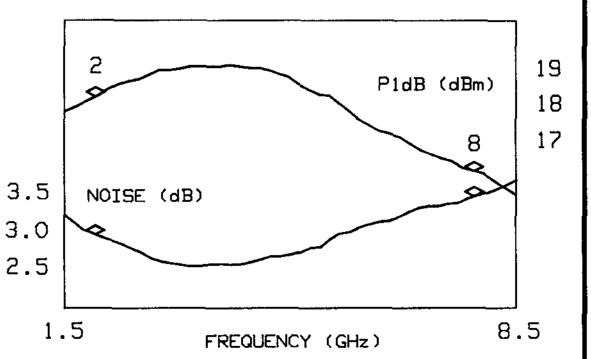


FIGURE 4. NOISE AND POWER PERFORMANCE

GAIN CONTROL CHARACTERISTICS

As in conventional dual gate circuits, varying the voltage applied to the second gate provides a method for achieving gain control. The 2-8 GHz module showed 30 dB of gain control range while maintaining good flatness. The AGC was relatively linear making it useful in many applications where simple drive circuitry is preferable. This AGC response is shown in Figure 5.

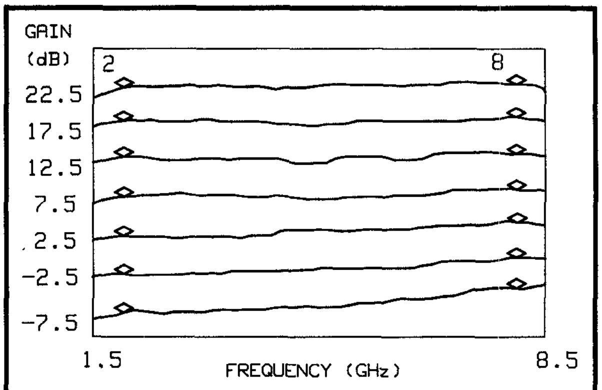


FIGURE 5. GAIN CONTROL RESPONSE

ON-BOARD TEMPERATURE COMPENSATION CIRCUITRY

One use for the gain control capability of the module is temperature compensation. Typical gain variation versus temperature was .02 dB per degree C. Temperature sensing and scaling circuitry was designed onto the circuit to provide a voltage that changed linearly with temperature. This voltage, when used to drive the second gate of the STACKFET, served to compensate the module's inherent gain change over temperature. The self compensated module gave 19.5 dB +/-.5 dB of gain over the +84 degrees C to -55 degrees C temperature range. This is shown in Figure 6.

In addition to providing temperature compensation for itself, the module has also been shown to compensate for another module. The result was a two stage balanced amplifier giving 34 dB +/-.5 dB of gain over 2-8 GHz. This represents a very DC efficient (.3 dB/mA), high gain per unit length amplifier.

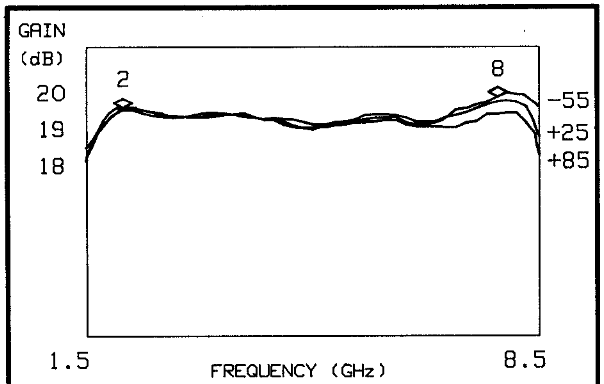


FIGURE 6. TEMPERATURE PERFORMANCE

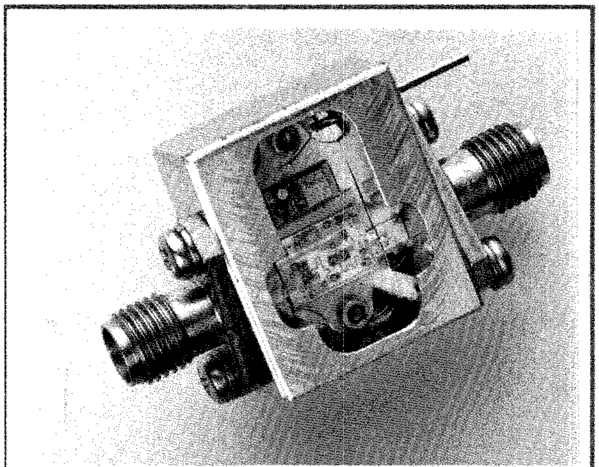


FIGURE 7. SINGLE STAGE AMPLIFIER

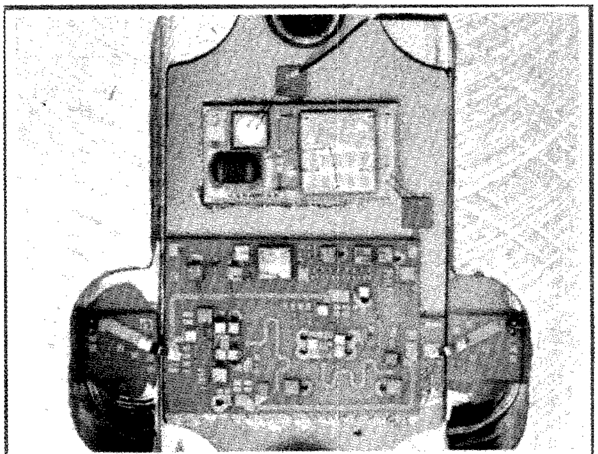


FIGURE 8. STACKFET MODULE

CONCLUSIONS

It has been shown that a new method of coupling two GaAs FET devices (the STACKFET) was used to design a balanced 2-8 GHz gain module. The module produced 22.5 dB of gain over the full bandwidth as well as exhibiting very good AGC characteristics.

ACKNOWLEDGEMENTS

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