A DC-18GHZ GaAs MESFET MONOLITHIC VARIABLE SLOPE GAIN-EQUALIZER IC

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ABSTRACT

A broadband GaAs MESFET gain-equalizer with variable linear slope control has been developed, to be reported of the first time for this type of circuit. The IC uses a modified bridged-T configuration. It provides an attenuation slope of -0.67dB/GHz at the maximum linear slope state with a minimum insertion loss of 2.7dB at 18 GHz, and a deviation of linearity less than 0.25dB from DC to 18GHz. The slope is electrically variable from -0.67dB/GHz to 0.0dB/GHz and, upward to +0.22dB/GHz. The input and output VSWRs are less than 2:1 over the entire frequency and control range.

INTRODUCTION

In recent years, broadband monolithic microwave IC(MMIC) amplifiers covering DC to beyond 18GHz are becoming very prevalent[1, 2], using the distributed-amplification approach[3]. Associated with this development come a number of new broadband MMIC control circuits such as: broadband mixers, switches, phase shifters, and attenuators [4, 5, 6, 7]. The attenuators have been used very commonly for compensating a microwave system's gain variation over temperature. But the response of a system over temperature, aside from gain variation, will generally have a gain slope variation which also needs to be compensated. In this paper, we present the development results of a DC-18GHz GaAs MESFET monolithic variable slope gain-equalizer IC which can be used for compensating the gain slope variation over temperature of a broadband amplifier system. This is believed to be the first report of this type of control circuit.

DESIGN AND FABRICATION

The circuit was designed to have attenuations of 14dB at DC and 2dB at 18GHz respectively, resulting in an attenuation slope of about -0.67dB/GHz at the maximum slope state. The attenuation slope is adjustable continuously from the maximum state down to 0, and also upward toward the positive slope direction to maximize the slope control range. The input and output VSWRs were also designed to be low ($\leq$ 2:1) for all control states for the IC to be directly cascadable with other microwave components.

The IC design being reported uses a modified bridged-T configuration employing two GaAs MESFETs. Figure 1 shows the schematic diagram of the monolithic variable slope gain-equalizer IC.

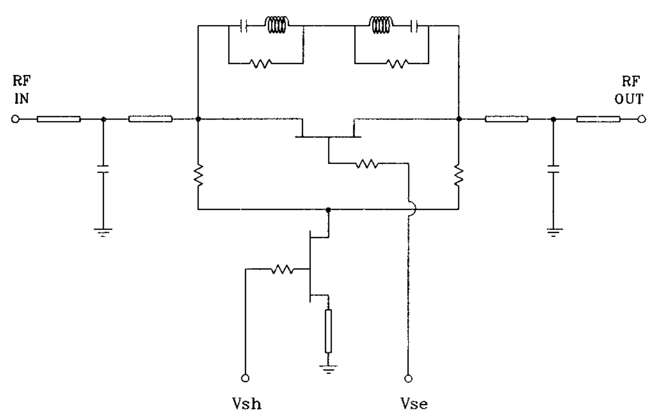

FIGURE 1 SCHEMATIC DIAGRAM OF THE DC-18 GHZ MONOLITHIC VARIABLE SLOPE GAIN-EQUALIZER IC

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The bridged-T topology was chosen to provide minimum insertion loss at 18GHz and also to maintain good input/output return losses. The use of GaAs MESFETs, instead of diodes, makes the DC bias and control of the IC easier and extends the operating frequency down to DC. Two new features were incorporated in the design: 1) Three single resonators were added to the basic bridged-T circuit. The two series arm resonators also included shunt resistors. 2) The gain-equalizer was designed such that the control voltages were in a linear complementary relationship to each other, i.e., Vse + Vsh = Vp, where Vse and Vsh being the control voltages, and Vp being the FET pinch-off voltage. This will greatly simplify the IC operation and the control circuit design.

The resonators (including the shunt resistors) provide the desired attenuation slope over the operating frequencies while maintaining a minimum insertion loss at 18GHz. The FETs, combined with the resonators, allow electrically variable slope adjustment through FET gate voltage controls. In addition, a two-section low pass matching circuit was added to the input as well as the output of the bridged-T section to improve the input/output return losses of the IC.

To meet the design goals, the MESFETs were selected to use a device size of 0.5umX150um each, and the resonators were optimized to give a linear attenuation slope from DC to 18GHz. The two series arm resonators were realized using semi-lumped L-C elements having a series resonance frequency at around 18GHz. The shunt arm resonator was realized using a 92 ohm short-stub transmission line having a shunt resonance frequency at around 18GHz. A distributed MESFET model, including signal transmissions through the drain and source manifolds, was employed in the design to account for parasitic and dispersive effects. The circuit was then optimized over the operating frequencies of DC-18GHz and over the control voltage range.

The IC was fabricated using epitaxial GaAs material. The IC processing included MIM capacitors, GaAs and metal resistors, and via-holes. A photo of the fabricated MMIC chip is shown in Fig.2. The circuit measures 1.1mmx1.8mm.

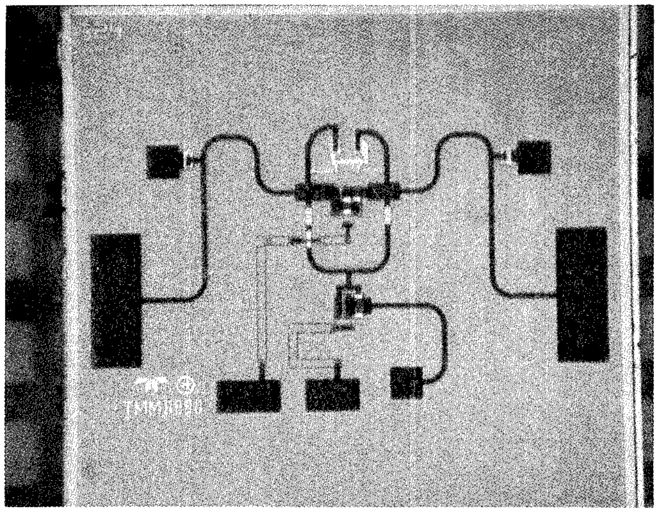

FIGURE 2 PHOTOGRAPH OF THE MMIC CHIP

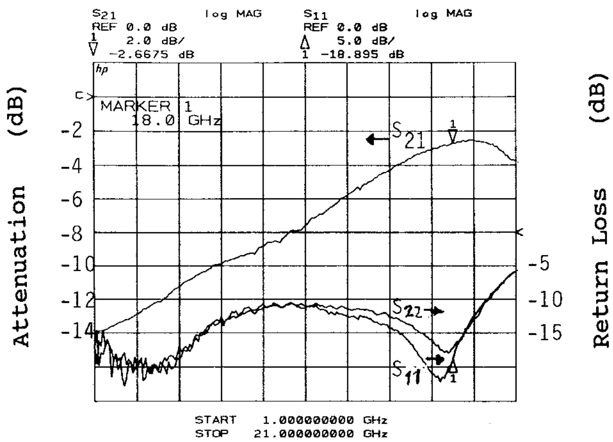

FIGURE 3 MEASURED ATTENUATION SLOPE AND RETURN LOSS vs. FREQUENCY at maximum linear slope state, Vse=-2.6V, and Vsh=-0.4V

MEASURED PERFORMANCE

The IC FETs from the fabricated IC wafer were measured. They had an Idss of about 300mA/mm and a pinch-off voltage of about -3.0V. The measured results of the ICs are presented in Figs.3-5. Fig.3 shows the attenuation slope and return loss vs. frequency at the maximum linear slope state. The control voltages are -2.6V and

-0.4V at the series and shunt fets respectively. The slope is -0.67dB/GHz with a deviation of linearity less than 0.25dB over the entire bandwidth. The input and output VSWRs are less than 2:1. The attenuation slope and return loss at the maximum reverse slope state are shown in Fig.4. The control voltages are -0.4V and -2.6V respectively. The slope is +0.22dB/GHz. The input and output VSWRs are also less than 2:1. Fig.5 shows the variable slope feature of the IC with the attenuation slope vs. frequency as a function of gate control voltages. Fig.5 covers the control voltage range from 0V to -3.0V (Vp). At -3.0V the attenuation slope at low frequency increases further, but the linearity degrades.

The measurement results show that the adjustments of the control voltages are very simple, being in a linear complementary relationship (Vse + Vsh = -3.0V) as designed. This will allow the control of the IC through a single control voltage with the addition of a single operational-amplifier inverter. Furthermore, the measured data indicate that the upper operating frequency actually extends to approximately 19.5GHz. This will provide enough margin for the IC bandwidth tolerance to process variation, hence increasing the IC yield in production.

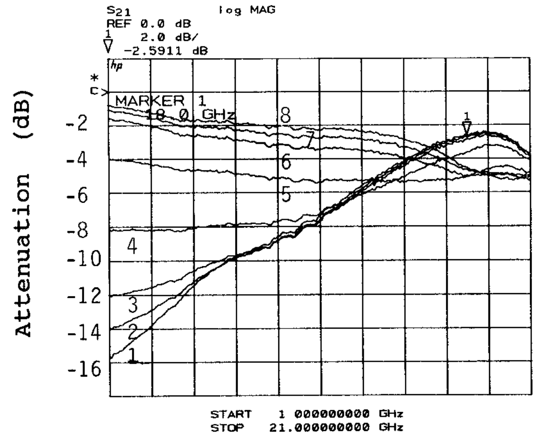

FIGURE 5 MEASURED ATTENUATION SLOPE vs. FREQUENCY AS A FUNCTION OF GATE CONTROL VOLTAGES (Vse,Vsh)
1.(-3.0,0.0) 2.(-2.6,-0.4) 3.(-2.2,-0.8) 4.(-1.8,-1.2) 5.(-1.4,-1.6) 6.(-1.0,-2.0) 7.(-0.4,-2.6) 8.(0.0,-3.0)

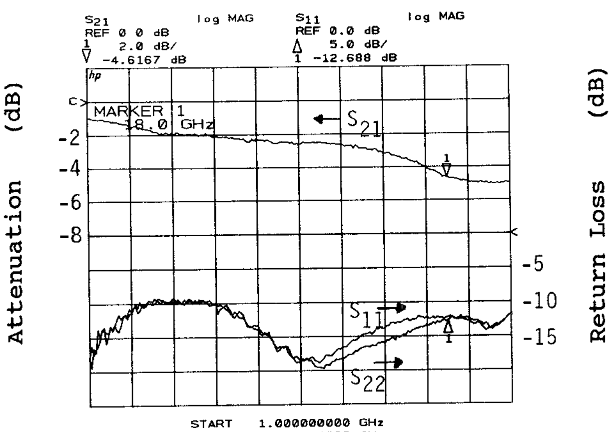

FIGURE 4 MEASURED ATTENUATION SLOPE AND RETURN LOSS vs. FREQUENCY at minimum slope state, Vse=-0.4V, and Vsh=-2.6V

CONCLUSION

A GaAs MESFET monolithic variable slope gain-equalizer IC has been developed covering DC-18GHz bandwidth. The IC has demonstrated an attenuation slope variable from -0.67dB/GHz to 0.0dB/GHz, and upward to +0.22dB/GHz. The input/output return losses were found to be less than 2:1 at all control states. The good performance, simplicity of the IC control, and the variable slope control feature, should make this IC* useful in applications requiring compensation of gain-slope variation over temperature of broadband amplifiers/systems over a wide dynamic range.

ACKNOWLEDGMENTS

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* A patent application is being filed.

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