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L-Band SiGe HBT Active Differential Equalizers with Varactor-Tuned Bias Circuits for Variable, Positive or Negative Gain Slopes

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Abstract

L-band SiGe HBT active differential equalizers with variable, positive or negative gain slopes have been designed and fabricated for frequency and temperature compensation of microwave and optical systems. The active equalizer employs varactor-tuned base bias circuits for variable and positive gain slopes or varactor-tuned collector bias circuits for variable and negative gain slopes. The implemented active equalizers have achieved positive gain slopes of +88 to +121dB/GHz across 0.5 to 1GHz as well as negative gain slopes of -17 to -46dB/GHz over 0.1 to 0.8GHz. The active differential equalizers presented in this paper have an outstanding feature of showing abrupt gain slopes with the use of bandstop performances, which can be useful for frequency and temperature compensation with narrowband but abrupt gain slopes.

Keywords: microwaves, equalizer, differential amplifier, SiGe HBT, gain slope, dual resonators

1 Introduction

Wideband microwave transceivers have been long tackled with the pass-band negative gain slope due to the falling off of gain of transistors and the insertion loss of passive elements as frequency increases [1-2]. To address this issue, several types of passive equalizers/filters have been reported, having fixed positive or negative gain slope as a function of frequency [3]. To realize the adjustability for the required gain slopes, a variety of active equalizers using diodes or transistors have been reported, having variable positive or negative gain slopes [4-5]. The circuit configuration is based on a passive equalizer or a resistive filter where fixed capacitances are replaced by diodes or transistors in order to provide variable gain slopes. Although these active equalizers can provide broadband and moderate gain slopes, the insertion loss is large. To address this problem, the authors have presented an active differential equalizer with variable, positive and abrupt gain slopes as well as high gains [6]. The active equalizer has incorporated capacitance-selectable bridged-T attenuators [7] into the series feedback path to achieve variable positive gain slopes. The active equalizer, however, has provided only positive gain slopes. To overcome this problem, a novel active differential equalizer with variable, positive or negative gain slopes is presented in this paper. It employs varactor-tuned base bias circuits for variable and positive gain slopes or varactor-tuned collector bias circuits for variable and negative gain slopes. Since bandstop performances are utilized, narrowband but abrupt gain slopes can be easily obtained, which is useful for frequency and temperature compensation with narrowband but abrupt gain slopes.

2 Circuit Design

Two types of the active equalizer are graphically shown in Fig. 1. By keeping a peak frequency (A or B) constant and varying a bandstop frequency, variable, positive or negative gain slopes can be obtained.

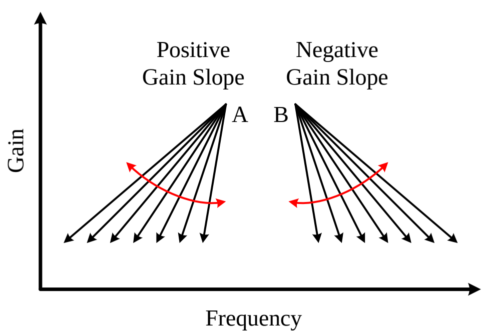


Fig.1 Two types of the active equalizer

Schematic diagrams of the active differential equalizer with varactor-tuned bias circuits are shown in Fig. 2 for variable and positive gain slopes and Fig. 3 for variable and negative gain slopes, respectively. In Fig. 2, a parallel LC circuit (L2 and C2) provides a constant peak gain. Varactor-tuned base bias circuits comprised of a series LC circuit (L1 and C1) are incorporated between base and ground so as to vary a bandstop frequency. A resonant frequency of a series LC circuit (L1 and C1) is designed to be lower than that of a parallel LC circuit (L2 and C2) to achieve positive gain slopes. That is, the peak frequency is designed to be higher than the bandstop frequency to achieve positive gain slopes. RL, RS and RE are a load, a feedback and a current source resistor, respectively. As a differential transistor pair, a cascade connection is used to achieve a variable gain. VB is a control voltage. The value of circuit elements is summarized in Table 1. In Fig. 3, a lossy match circuit (R1, L1 and C1) is employed in the input matching circuit to achieve a constant peak gain. Varactor-tuned collector bias circuits comprised of a series LC circuit (L2 and C2) is employed in the load to vary a bandstop frequency. In contrast to Fig. 2, the peak frequency is designed to be lower than the bandstop frequency to achieve negative gain slopes. RL, RS and RE are also a load, a feedback and a current source resistor. The value of circuit elements is summarized in Table 2.

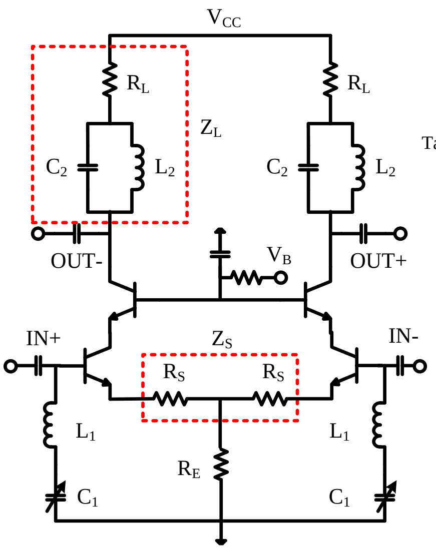


Table 1. Circuit Element Values

Element	Value
R_L [Ω]	56
R_S [Ω]	1
L_1 [nH]	10
C_1 [pF]	6 to 15
L_2 [nH]	4.7
C_2 [pF]	1

Fig.2. Schematic diagrams of the active differential equalizer with varactor-tuned base bias circuits for variable and positive gain slopes

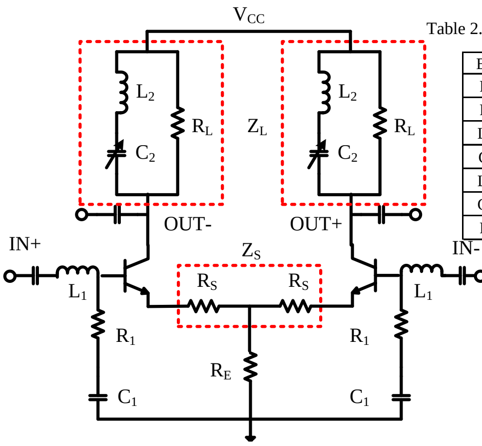


Table 2. Circuit Element Values

Element	Value
R_L [Ω]	56
R_S [Ω]	1
L_2 [nH]	1.5
C_2 [pF]	6 to 15
L_1 [nH]	10
C_1 [μF]	0.1
R_S [Ω]	1

Fig.3. Schematic diagrams of the active differential equalizer with varactor-tuned collector bias circuits for variable and negative gain slopes

3 Circuit Simulation

Based on the schematic diagrams of Figs. 2 and 3 as well as the circuit element value of Tables 1 and 2, the circuit simulation was accomplished by using ADS software. The value of RE was finally chosen as 100 ohms so as to achieve a total collector current of less than 8 mA in Figs. 2 and 3. The simulated results are displayed in Figs. 4 and 5, respectively. It is clearly shown that narrowband but abrupt gain slopes are successfully obtained.

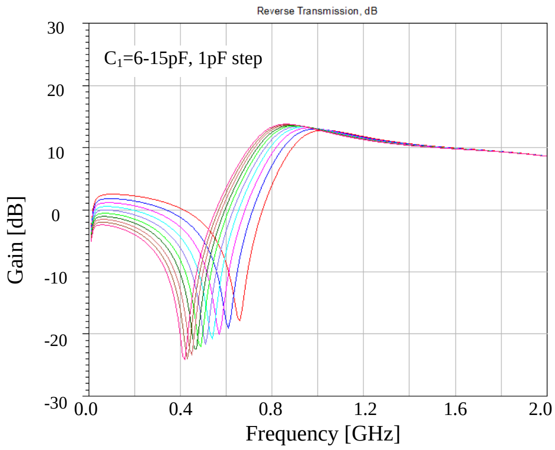


Fig.4. Simulated results of the active differential equalizer with varactor-tuned base bias circuits for variable and positive gain slopes

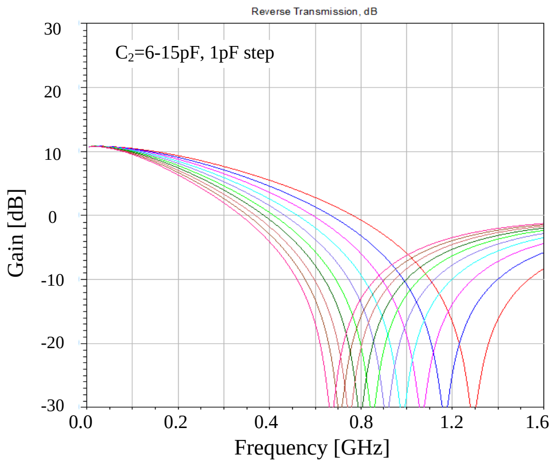
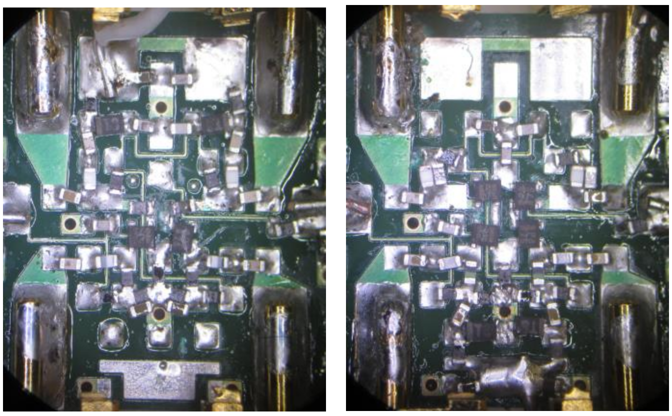


Fig.5. Simulated results of the active differential equalizer with varactor-tuned collector bias circuits for variable and negative gain slopes

4 Circuit Fabrication

Photographs of the active differential equalizer with varactor-tuned bias circuits are displayed in Fig. 6(a) for variable and positive gain slopes and Fig. 6(b) for variable and negative gain slopes, respectively. The active differential equalizers were fabricated on the FR-4 substrate with a dielectric constant of 4.5. 0.35μm SiGe HBTs with an ft of 25GHz (Toshiba MT4S102T), 1005-type resistors, inductors and capacitors are mounted on the substrate by soldering. A surface mount type of the varactor diode with a capacitance ratio of 2.5 (Toshiba 1SV279) was used. The circuit size is 14 x 16 x 1.2 mm3.



(a) Positive Slope (b) Negative Slope

14 x 16 x 1.2 mm^3

Fig.6. Photographs of the active differential equalizer with varactor-tuned bias circuits

5 Circuit Performance

Measured gains of the active differential equalizers are plotted in Fig. 7 for variable and positive gain slopes and Fig. 8 for variable and negative gain slopes. The active differential equalizers have accomplished positive gain slopes of +88 to +121dB/GHz across 0.5 to 1GHz and negative gain slopes of -17 to -46dB/GHz over 0.1 to 0.8GHz. The measured gains are in good agreement with the calculated gains in Figs. 4 and 5. Bias conditions are also shown in Figs. 7 and 8.

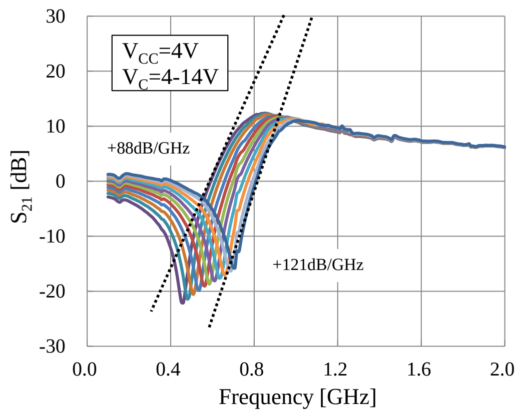


Fig.7. Measured gains of the active differential equalizer with varactor-tuned base bias circuits for variable and positive gain slopes

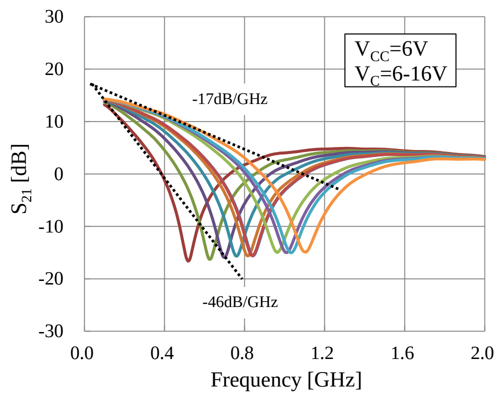


Fig.8. Measured gains of the active differential equalizer with varactor-tuned collector bias circuits for variable and negative gain slopes

6 Conclusion

Design, fabrication and performance of L-band SiGe HBT active differential equalizers with variable, positive or negative gain slopes have been presented.

Since the active differential equalizers have varied a bandstop frequency while keeping a peak frequency constant, narrowband but abrupt gain slopes have been successfully demonstrated. The implemented active equalizers have shown narrowband but abrupt gain slopes as simulated, which can be one of the candidates for frequency and temperature compensation with narrowband but abrupt gain slopes of microwave and optical systems.

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