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TUNABLE ACTIVE BANDPASS FILTERS USING THREE-TERMINAL MESFET VARACTORS

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ABSTRACT

The concept of three-terminal MESFET varactors is presented. Based on this concept, two types of tunable active bandpass filter working at X-band are developed. The experimental result shows the possibility of using the MESFET in the active mode to generate both a negative resistance and a variable reactance.

INTRODUCTION

Recently, a MESFET controlled X-band active bandpass filter was developed by one of the authors[1]. By using the MESFET as a two-terminal varactor, the center frequency of the passband can be tuned by the optical-control method as well as the voltage-control method[2]. In this two-terminal MESFET varactor, only the gate-source capacitance contributes to the tuning procedure.

The MESFET, however, can also be used as a three-terminal varactor by employing all the three variable capacitances C_{gs}, C_{gd} and C_{ds}. In this paper, this concept is presented and is applied to the tunable active bandpass filters. Based on this concept, a tunable active bandpass filter using two MESFETs was developed. In this circuit, one MESFET is biased in the active mode to generate a negative resistance while the other is biased in the passive mode to be a three-terminal varactor.

The most significant advantage of using the three-terminal MESFET varactor is that the functions of the negative resistance MESFET and the three-terminal MESFET varactor can be combined together into one MESFET. Based on this concept, the two MESFETs used in the circuit described above can be replaced by one MESFET and a tunable active bandpass filter with only one MESFET was made. In this paper, the characteristics of these two circuits are studied and the experimental results are discussed.

THREE-TERMINAL MESFET VARACTOR

When the MESFET is used as a three-terminal varactor, three capacitances including gate-source capacitance(C_{gs}), gate-drain capacitance(C_{gd}), and drain-source capacitance (C_{ds}) are considered. For a negative gate-source voltage and a zero drain-source voltage, the capacitances C_{gs} and C_{gd} are about equal and the capacitance C_{ds} is smaller[3]. Since the drain-source current is zero, this MESFET is in the passive mode. When the gate voltage is changed, the capacitances C_{gs} and C_{gd} are changed while the capacitance C_{ds} is not changed. In this case, C_{gs} and C_{gd} are the dominant capacitances in the three-terminal MESFET varactor.

However, for a drain-source voltage larger than the saturation voltage, the charge accumulation occurs in the active channel and the active channel capacitance from this charge accumulation effect increases monotonically as V_{ds} increases. This phenomena was first reported by Engelmann and Liechti[4] and was elaborated by Willing *et al*[5]. The active channel capacitance contributes to the drain-source capacitance and makes C_{ds} increase as V_{ds} increases. The other two capacitances C_{gs} and C_{gd}, which decrease as V_{ds} increases, are less important in this case. Therefore, the dominant capacitance of the three-terminal MESFET varactor in the active mode is C_{ds}.

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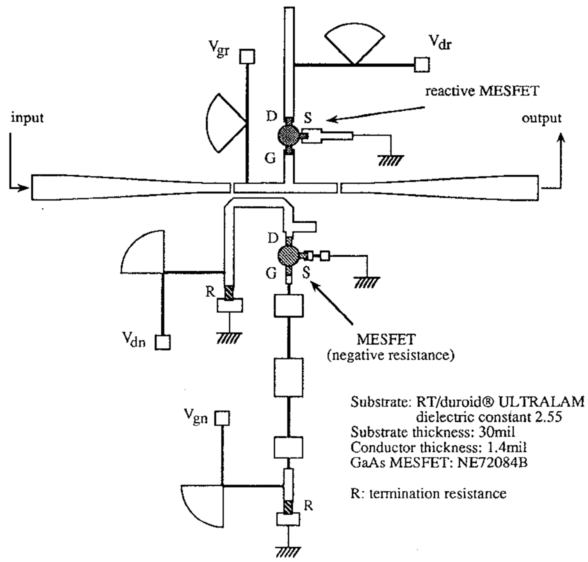

Fig. 1 Circuit structure of the tunable active bandpass filter with two MESFETs

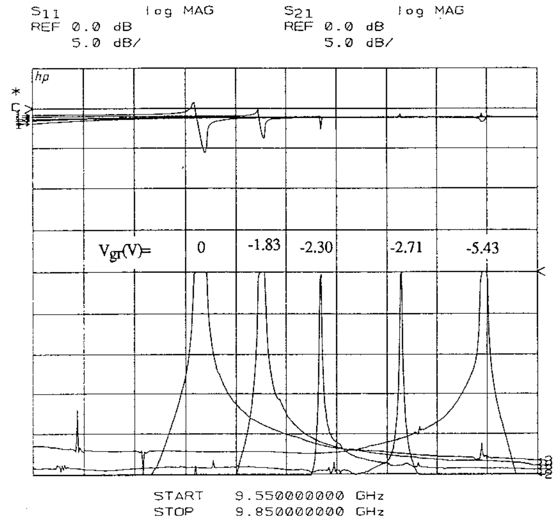

Fig. 2 Voltage-control tuning of the tunable active bandpass filter with two MESFETs

Bias condition: Vgn = -0.83V
Vdn = 1.4V
Vdr = 0V

TUNABLE ACTIVE BANDPASS FILTER WITH TWO MESFETS

The structure of the tunable active bandpass filter using two MESFETs is shown in Fig. 1. The reactive MESFET is biased in the passive mode and generates a variable reactance which is attached to the center portion of the half-wavelength resonator. When the reactance from the reactive MESFET is changed, the effective electrical length of the resonator is changed and thus the center frequency of the passband is changed. The other MESFET is biased in the active mode to generate a negative resistance[6].

The center frequency of the passband can be tuned by the *voltage-control* method and the *optical-control* method. The voltage-control tuning using the gate voltage of the reactive MESFET gives a tuning range of 170MHz, as shown in Fig. 2. The optical-control tuning, with a semiconductor laser diode as the light source, gives a tuning range of 50MHz(Fig. 3). Both of the tuning behaviors can be explained by the capacitances C_{gs} and C_{gd} which increase as the gate voltage or the illumination increases. As the capacitances increase, the effective electrical length of the resonator increases and the center frequency of the passband decreases.

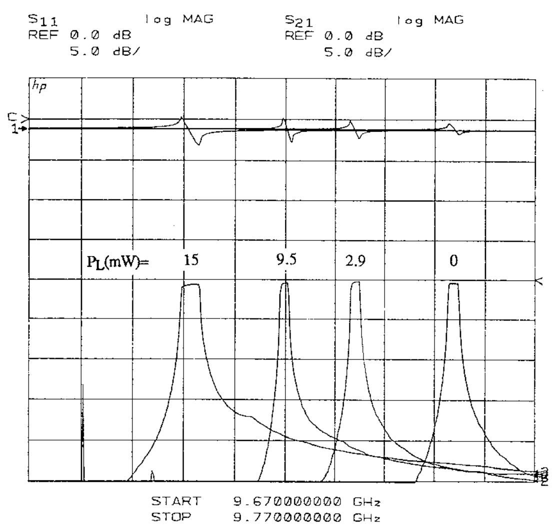

Fig. 3 Optical-control tuning of the tunable active bandpass filter with two MESFETs

Bias condition: Vgn = -0.83V
Vdn = 1.4V
Vgr = -2.53V
Vdr = 0V

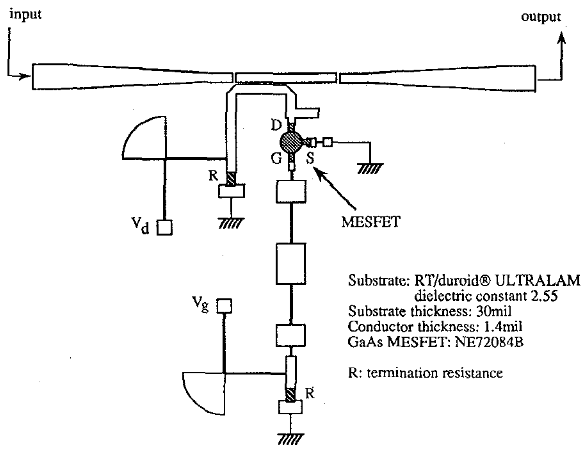

Fig. 4 Circuit structure of the tunable active bandpass filter with one MESFET

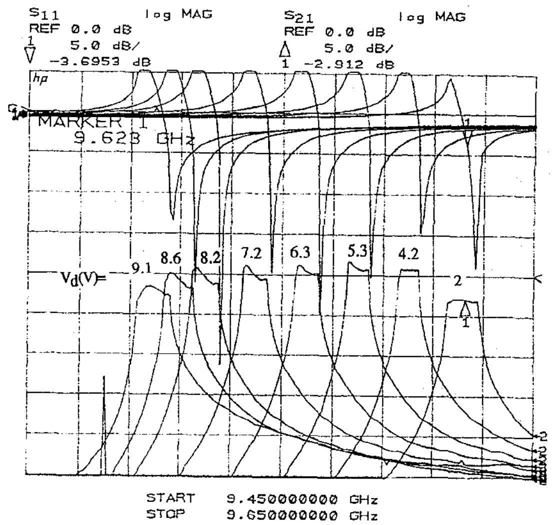

Fig. 5 Vd-tuning of the tunable active bandpass filter with one MESFET

Bias condition: Vg = -1.6V

TUNABLE ACTIVE BANDPASS FILTER WITH ONE MESFET

This filter is designed from the filter with two MESFETs described above by removing the reactance-tuning circuit away and reduced the gap width between coupled lines from 18mil to 8mil[4]. The MESFET is biased in the active mode to generate a negative resistance. However, the MESFET can also be a three-terminal varactor in the active mode. Therefore, under suitable bias condition the center frequency of the passband can be tuned without disturbing the negative resistance. The tuning range obtained by changing the drain voltage is 120MHz(Fig. 5) and the tuning range obtained by changing both V_d and V_g is 150MHz(Fig. 6).

The optical-control tuning is not practical for this filter because the tuning range is less than 10MHz. The reason is that the gate of the MESFET needs to be biased at a much higher voltage than the optimum voltage for the optical-control tuning to generate a negative resistance which compensates the loss of the circuit. Although the optical-control tuning is not practical for the filter with one MESFET, the achievement of using one MESFET to replace two MESFETs in the tunable active bandpass filter is still believed significant.

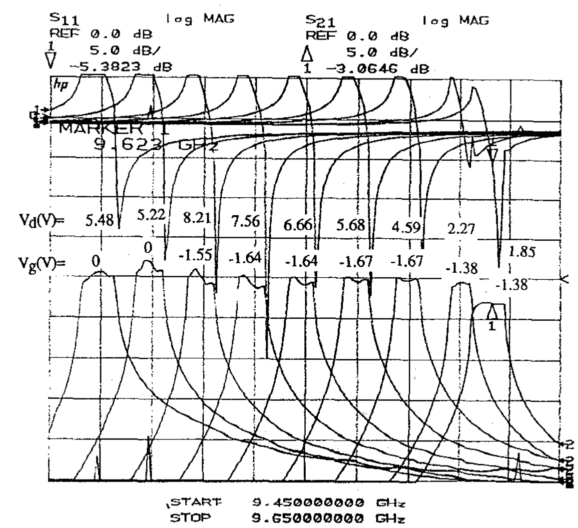

Fig. 6 Voltage-control tuning of the tunable active bandpass filter with one MESFET using Vd and Vg

CONCLUSION

Based on the concept of three-terminal MESFET varactor, two types of tunable active bandpass filter are made. The first circuit uses two MESFETs of which one is used as a MESFET varactor and the other is used to generate a negative resistance. The second circuit uses only one MESFET which has both functions of the two MESFETs in the first circuit. The advantage of using the MESFET as a three-terminal varactor is to let the MESFET plays both roles at the same time, thus simplifying the circuit configuration and fabrication. This finding demonstrates the potential of using both real and imaginary parts of the equivalent impedance of the active device.

ACKNOWLEDGMENT

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