

# A band-pass filter based on the optically controllable $S_{22}$ parameter of a MESFET

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**Abstract:** It is noticed that drain reactance of a MESFET is significantly changed by laser irradiation, and a novel optically tunable filter is proposed. One MESFET works not only as a negative resistance, but as a tuning element. Tuning range of 104 MHz is obtained in X-band by optical tuning.

**Keywords:** Microwave filter, Active filter, Tunable filter, Metal semiconductor field effect transistor, Optically controllable filter

**Classification:** Microwave and millimeter wave devices, circuits, and systems

## References

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## 1 Introduction

Recently, techniques for a Microwave Integrated Circuit have been progressing through communication systems and microwave circuits have been becoming much more complex and miniaturized. In order to simplify complex microwave circuits, various techniques for optical control of microwave devices have been proposed. One of the authors reported an optically controlled band-pass filter using an amplifying MESFET and a tuning MESFET which worked as a two terminal varactor [1, 2, 3]. The imaginary part of the  $S_{22}$  parameter for the MESFET is significantly changed by varied drain current under the constant drain voltage condition. On the other hand, many authors investigated optically generated currents in a MESFET, and showed that light irradiation caused an increase of the drain current [4, 5, 6]. The negative resistance circuit in the filter is an injection-locking type MESFET oscillator, therefore, the input reactance of the circuit depends on the  $S_{22}$  parameter of the MESFET [7]. It can be expected that the increase in the drain current due to the laser irradiation causes a significant change in the imaginary part of the  $S_{22}$  parameter for the MESFET.

Using this principle, the authors proposed an optically controllable double tuned filter called a “three-terminal MESFET filter with an open stub [7].” In that report, the tuning principle and the equivalent circuit of the filter were shown. The double tuned system in the filter, however, was slightly complicated to tune. If the negative resistance circuit is directly attached to the half-wavelength resonator, the filter is easier to tune compared with the double tuned filter. In this paper, a novel band-pass filter using the negative resistance circuit, which is directly attached to the half-wavelength resonator, is proposed. The input reactance of the negative resistance circuit is simulated using the measured S parameters of the MESFET. Experimental results are also given.

## 2 Optical control of the negative resistance circuit

S parameters of an NE72084B type MESFET (NEC Co.) with its cover removed were measured by a 360-type network analyzer (Wiltron Co.) with and without laser irradiation. The drain voltage ( $V_d$ ) is 3.0 V and its current ( $I_d$ ) is 30 mA without laser irradiation. When the MESFET is illuminated by an SDL-5311-G1 type semiconductor laser (SDL Co.),  $V_d$  and  $I_d$  are shifted to 1.87 V and 56.7 mA, respectively. The wavelength and the output power of the laser are 827 nm and 47 mW, respectively.

Using these S parameters, with and without laser irradiation, the input impedance of an injection locking type negative resistance circuit was calculated by a Touchstone microwave circuit simulator (EEsof Co.). The structure of the negative resistance circuit is shown in Fig. 1. The input reactances of the negative resistance circuit are shown in Fig. 2. The maximum change of the input reactance due to the laser irradiation is observed at 10 GHz and is about 10 ohms. In the real circuit, the negative resistance circuit also works as an inductor, therefore the input inductance is shifted

about 0.16 nH at 10 GHz by laser irradiation. Based on this concept, an optically tunable active band-pass filter has been developed and is introduced in the following section.

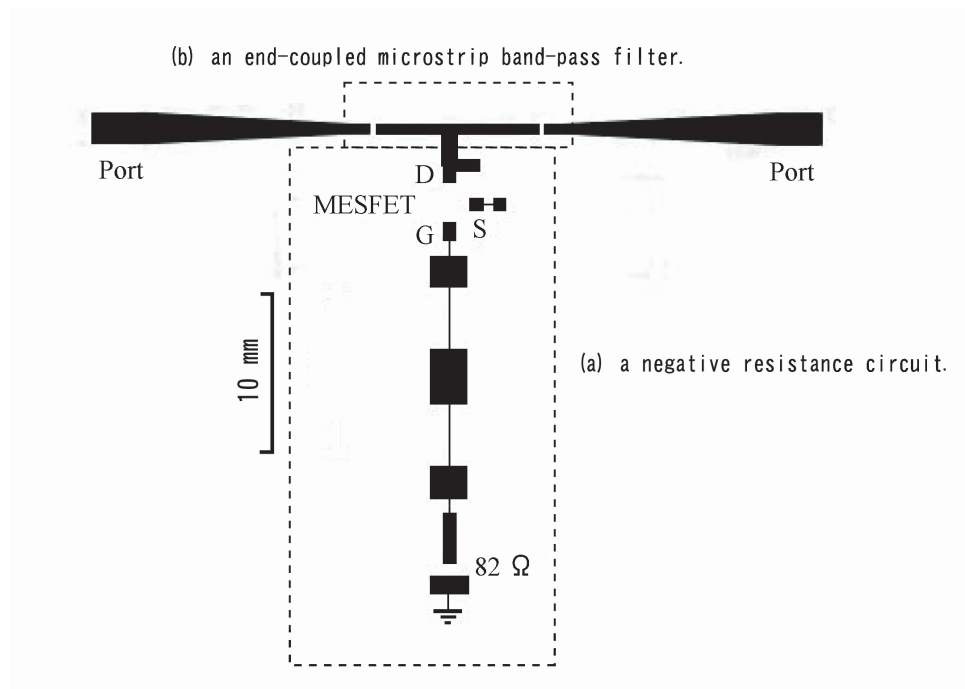


**Fig. 1.** Top view of the layout of the active band-pass filter.

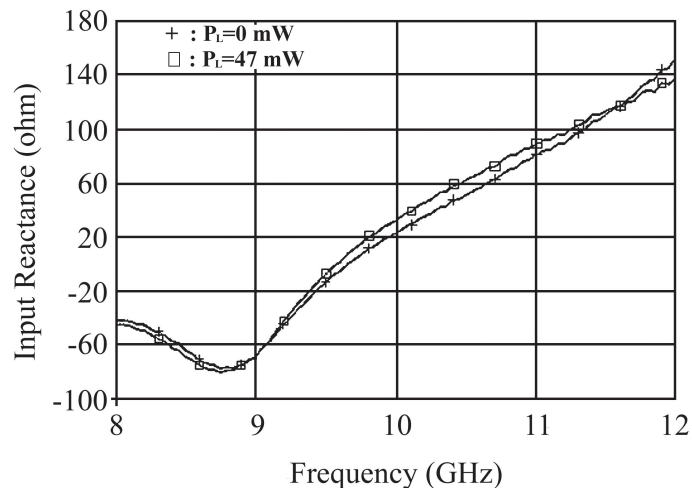


**Fig. 2.** The calculated input reactances using the measured MESFET scattering parameter. The drain voltage and the drain current are 3.0 V and 30 mA, respectively. The laser irradiation power is 47 mW.

### 3 Filter structure

The basic structure of the active band-pass filter is shown in Fig. 1. This is basically an end-coupled microstrip band-pass filter. The negative resistance circuit shown in the preceding section is attached to the center portion of the end-coupled half-wavelength resonator. This filter uses only one MESFET which works as a common device for tuning and amplifying. A coupling circuit and a matching resistance [1, 2] are replaced by a circuit that is directly connected the resonator and the negative resistance circuit. Therefore, the electrical length of the resonator is directly changed by the circuit input reactance and thus the center frequency of the pass-band can be shifted easily. The circuit was fabricated on a woven-glass-reinforced Teflon substrate with thickness of 0.76 mm and a dielectric constant of 2.55.

### 4 Experimental results

Figure 3 shows the dependence of the pass-band frequency on the laser irradiation power ( $P_L$ ). The parameters of the MESFET are:  $V_d$  is 3.50 V and  $V_g$  is  $-1.021$  V. When the laser power is changed from 0 to 40 mW,  $I_d$  is changed 24.8 mA to 33.7 mA, and the center frequency is shifted by 104 MHz, from 8.845 GHz to 8.949 GHz. This optically tunable range exceeds 1% of the center frequency. This wide tuning range is fulfilled by the direct use of the input reactance of the negative resistance circuit. Of particular note, the center frequency shift of 73 MHz is obtained with only 1 mW of laser irradiation. In this laser power range, the frequency shift rate due to the irradiated laser power is 73 MHz/mW. On the other hand, the frequency shift rate due to the gate voltage is about 185 MHz/V. Therefore, the effective gate voltage rate of the laser power is 0.4 V/mW. On the other hand, the rate is only 5 mV/mW in the laser power range from 1 mW to 40 mW.

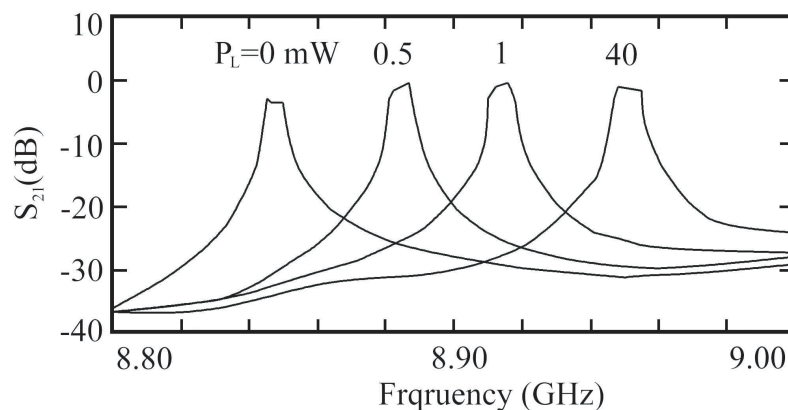


**Fig. 3.** Frequency shift of the pass-band as a function of the laser irradiation power ( $P_L$ ).  $V_g = -1.021$  V and  $V_d = 3.50$  V.

## 5 Conclusions

The input reactance of the injection locking type negative resistance circuit was derived from the drain reactance of a MESFET. When the depletion layer of the MESFET is illuminated by a semiconductor laser, the input reactance is significantly changed. A novel active band-pass filter in X-band was proposed using this tuning principle. The negative resistance circuit is attached to the center portion of the end-coupled half-wavelength resonator in the filter. The maximum tuning range of 104 MHz is observed by optical tuning. The optically tunable range of the filter exceeds 1% of the center frequency. The results demonstrate the potential for using the drain reactance of a MESFET in various optically controllable microwave circuits.