A MESFET-Controlled *X*-Band Active Bandpass Filter

Yukio Yamamoto, Ken-ichi Kawasaki, and Tatsuo Itoh

Abstract—**A new MESFET-controlled active band-pass filter has been developed in *X*-band. This filter loss is compensated for by the negative resistance generated by a MESFET. The series tank circuit of the filter includes another MESFET that is controlled either by a gate-to-source bias or by a semiconductor laser illumination. The center frequency of the passband can be shifted by 75 MHz with an accompanying bandwidth change from 6 MHz to 17 MHz when the gate-to-source voltage of the tuning MESFET is varied. Laser illumination of this MESFET shifts the center frequency of the filter by 57 MHz with a bandwidth change from 6.5 MHz to 10 MHz.**

I. Introduction

RECENTLY, many active devices suitable for use in microwave and millimeter wave regions have been reported. GaAs MESFET's that can be mounted in MMIC [1] are such devices, as several authors have reported [2]. One of the authors previously reported the microwave tunable high-*Q* active band-pass filters that used varactor diodes for tuning [3].

In this letter, we present a new MESFET-controlled active band-pass filter. Basically this is an end coupled microstrip bandpass filter. The half-wavelength resonator is composed of two quarter-wavelength microstrip lines and a connecting capacitor. The capacitor is actually a MESFET with its cover removed for illumination by a semiconductor laser. Therefore, the active bandpass filter is tuned not only by the gate-to-source voltage but also by the light intensity on the MESFET. The loss in the resonator of the filter is compensated for by the side coupled negative resistance generated by the MESFET amplifier [3]. Measured tuning ranges achieved in *X*-band are 75 MHz when the gate-to-source voltage is varied, and 57 MHz when illuminated by laser light.

II. Filter Structure and Experimental Procedure

Fig. 1 shows the structure of the one-pole MESFET-tuned active band-pass filters. This circuit was fabricated on a woven glass reinforced PTFE substrate with thickness of 0.737 mm and dielectric constant of 2.55. The drain of the tuning MESFET is open circuited. Both the tuning MESFET and the amplifying MESFET are NE72084Bs (NEC). The light source is a semiconductor laser LT022MS0 (Sharp) whose wavelength is 788 nm. Using a small lens, the light is focused on the gate-source gap area of the tuning MESFET. The output of the laser is changed from 0 to 5 mW when the laser current is changed from 36 mA to 52 mA [4]. S_{11} and S_{21} parameters of the filters were measured by a HP-8510 network analyzer.

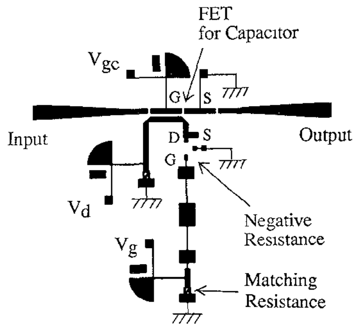

Fig. 1. Circuit pattern of the tunable active bandpass filter.

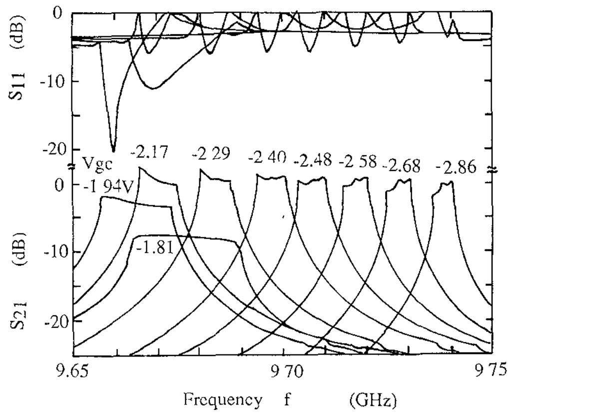

Fig. 2. Frequency shift of the passband as function of the gate-to-source voltage V_{gc}. $V_g = -0.461$ V, $V_d = 2.27$ V, $I_d = 70$ mA and $I_L = 0$.

III. Experimental Results

A. Gate Voltage Tuning

Fig. 2 shows that the frequency shift of the pass-band depends on the gate voltage (V_{gc}) of the tuning MESFET. The parameters of the MESFET amplifier are: the gate voltage (V_g) = -0.461 V, the drain voltage (V_d) = 2.27 V, the drain current (I_d) = 70 mA. The laser current (I_L) is 0. In the region with a gate voltage lower than -1.94 V, the pass-band characteristic is observed. The center frequency is shifted by 75 MHz with the change of V_{gc} under the condition that the transmission loss is no more than 3 dB.

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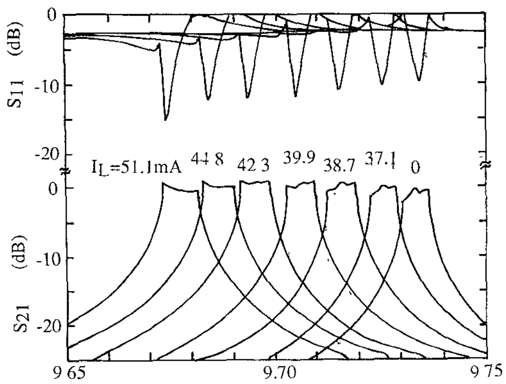

Fig. 3. Frequency shift of passband as function of the current I_L of the laser. $V_{gc} = -2.54$ V, $V_g = -0.456$ V, $V_d = 2.17$ V and $I_d = 67$ mA.

Also, the bandwidth of the passband is changed from 16 MHz to 6 MHz with the change of V_{gc}.

B. Laser Irradiance Tuning

Fig. 3 shows the dependence of the passband frequency on the laser current (I_L). The gate-to-source voltage V_{gc} is -2.54 V. The MESFET amplifier is in the following conditions: $V_g = -0.456$ V, $V_d = 2.17$ V, and $I_d = 67$ mA. The center frequency in the nonirradiated case is 9.734 GHz. As the laser current is increased from 0 to 51.1 mA, the change of the center frequency is 57 MHz. The bandwidth increases from 6.6 MHz to 10 MHz corresponding to the change of 51.1 mA in the laser current I_L. In this figure, it is observed that the transmission losses ($-S_{21}$) in the pass band are less than about 1 dB when the laser power is changed from 0 through 5 mW.

IV. Discussion

It is observed in Fig. 2 that the plateau part becomes flatter and longer when V_{gc} increases from -2.86 V to -1.81 V. Fig. 3 shows that the similar change occurs when the laser current increases. The cause of these changes is being investigated.

When V_{gc} is decreased (< -1.94 V), the depletion layer is built up which decreases the gate-to-source capacitance. On the other hand, the laser irradiation creates many charge pairs which decrease the depletion layer. Phenomenologically, the frequency response curve at $I_L = 51.1$ mA in Fig. 3 corresponds to the response at a voltage V_{gc} between -2.17 V and -2.29 V in Fig. 2. Therefore, it is possible to obtain a wider frequency shift of the pass-band than 57 MHz, if a more powerful laser is used.

V. Conclusion

A laser-controlled active bandpass filter in *X*-band is presented. A MESFET provides a negative resistance to compensate for the filter losses. Another MESFET is used for frequency tuning. The center frequency of the passband is changed by 75 MHz when the gate-to-source voltage of the tuning MESFET is varied. A noticeable shift of the passband center frequency (57 MHz) is observed by the irradiation of the tuning MESFET by a laser (788 nm, 5 mW). The results indicates a possibility of frequency shift wider than 57 MHz using the laser with a higher power. It is observed that the bandwidths of the passbands change from 6 to 16 MHz due to the change of the gate-to-source voltage and the laser irradiation.

Although the results presented here are preliminary, they indicate a possibility to fabricate an optically controlled microwave active bandpass filter.

References

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