OPTICAL CONTROL OF MICROWAVE ACTIVE BAND-PASS FILTER USING MESFETs

*Yukio Yamamoto**, *Ken-ichi Kawasaki*+ *and Tatsuo Itoh*++

Department of Electrical and Computer Engineering,
The University of Texas at Austin, Texas 78712

ABSTRACT

A semiconductor laser tuned active band-pass filter is developed using a gate-to-source capacitance of an exposed MESFET for tuning. Another MESFET is used in the circuit to provide a negative resistance to increase the tank-circuit Q-value. Tuning range of 257 MHz was obtained for a two-pole filter in X-band.

INTRODUCTION

Direct optical control of microwave devices has been an area of growing interest [1]. Various kinds of optically controlled circuits, for example, amplifiers, mixers and phase shifters, have been reported already. Especially, fabrication of an optically tuned band-pass filter is an interesting area to date. Recently, the varactor tuned active band-pass filter was developed in X-band by one of the authors[2].

In this paper, we discuss the design potential of a MESFET-controlled band-pass filter which can be tuned optically for hundreds of MHz in X-band. Then, some preliminary experimental results are presented and discussed. In the filter design, MESFETs are used for a tunable tank circuit and a negative resistance circuit. The MESFET in the tank circuit is opened and controlled by a semiconductor laser. The tank circuit Q-value is increased by the negative resistance circuit. One-pole and two-pole MESFET-tuned active band-pass filters were fabricated, and their characteristics were studied.

* Present address; Department of Electrical Engineering and Electronics, Faculty of Engineering, Osaka Sangyo University, Daito, Osaka 574, JAPAN

+ Present address; DBS Business Department, Osaki Technology Center, Sony Co., Osaki, Shinagawa-ku, Tokyo 141, JAPAN

++ Present address; Electrical Engineering Department, University of California, Los Angeles, 405 Hilgard Av., Los Angeles, California 90024-1594

OF-II

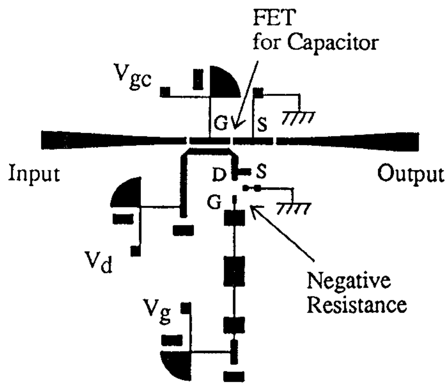
FILTER STRUCTURE AND EXPERIMENTAL PROCEDURE

The structures of the one-pole and two-pole active band-pass filters are shown in Fig.1. These are basically end coupled microstrip band-pass filters. The half-wavelength resonator is composed of two quarter-length microstrip lines (lengths X_1 and X_2) and a connecting capacitance C such as the gate-to-source capacitance of the MESFET. If it is assumed that the lines and capacitance are ideal, and $X_1 \approx X_2$, the resonant frequency f, is related to the capacitance C and the total length of the resonator ($X=X_1+X_2$) as

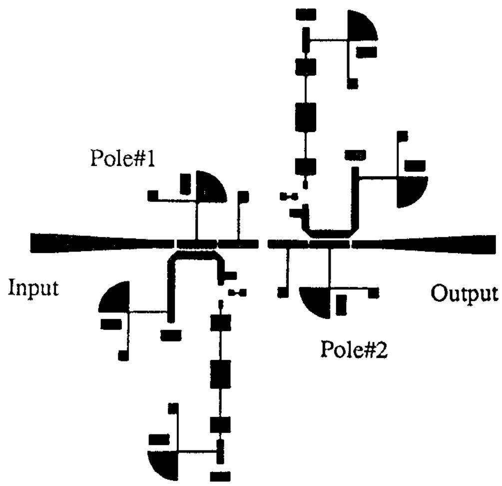
$$\cos(2\pi fX/v) \approx 1+4\pi fCZ_0\sin(2\pi fX/v) \qquad (1)$$

where Z_0 is the characteristic impedance of the line and v is the wave propagation speed in the line. The relations are shown in Fig.2. In the case of X=12 mm, for example, we can observe that the resonant frequency shifts about 200 MHz if the gate-to-source capacitance changes from 0.6 pF to 0.8 pF. In an actual device, the resonator has some loss, but the loss is compensated for by the MESFET amplifier[1].

CH2870-4/91/0000-0655$01.00 © 1991 IEEE



(a) One-pole filter



(b) Two-pole filter

Fig.1. (a) The microstrip circuit patterns of the one-pole tunable band-pass filter. (b) The microstrip circuit patterns of the two-pole tunable band-pass filter.

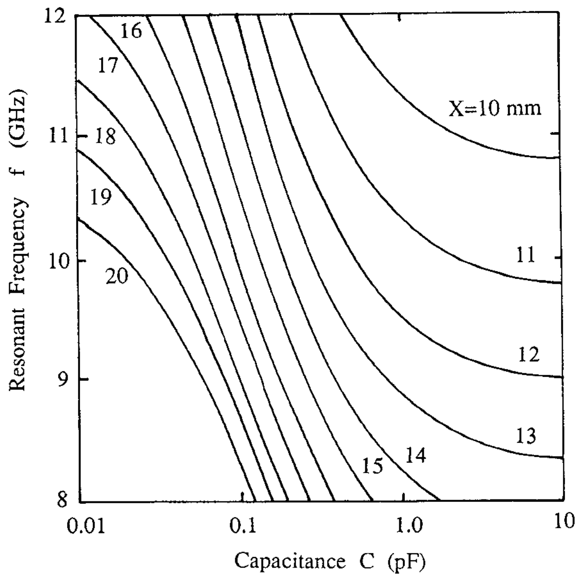


Fig.2. The relations between the capacitance and the resonant frequency. (the dielectric constant: 2.55, the thickness of the substrate: 0.737 mm, the characteristic impedance: 82 Ω, the width of the microstrip resonator: 0.85 mm.)

These microstrip circuits were fabricated on the PTFE substrate with thickness of 0.737 mm and the dielectric constant of 2.55. The MESFETs are NE72084B (NEC). The gate-to-source capacitances C of the MESFETs are controlled by the gate-to-source voltage and by the irradiated light intensity. The light sources are semiconductor lasers LT022MS0 and LT021MC0 (Sharp) whose wavelengths are 788 nm. The light is focused on the gate-source gap area of the opened MESFET whose drain is open circuited. The output of the laser was changed from 0 to 15 mW, when the laser current was changed from 36 mA to 82 mA[3]. The S_{11} and S_{21} parameters of the filters were measured by a HP-8510 vector network analyzer. The gate-to-source capacitances were measured by a HP-4275A LCR-meter.

EXPERIMENTAL RESULTS AND DISCUSSIONS

To predict the possible tuning range, the gate-to-source capacitances of the NE72084B were measured at 400kHz. The results are shown in Fig.3. The capacitance changed from 1.1 pF to 0.57 pF when the gate-to-source voltage V_{gc} of the capacitor MESFET changed from -0.21 V to -2.71 V. From the results, we predict that it is possible to obtain considerable tuning range if the MESFET is properly operated in the V_{gc} region between -2.7 V and 0 V.

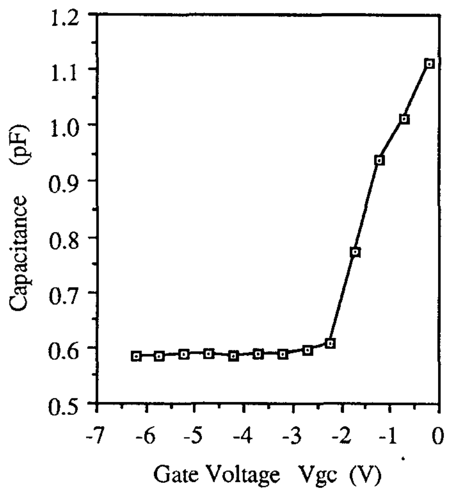


Fig.3. The measured gate-to-source capacitances of the opened NE72084B with the variation of the gate-to-source voltage.

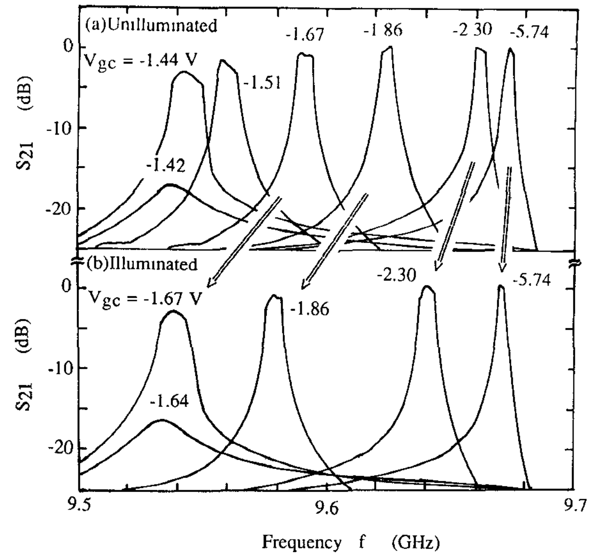


Fig.4 The frequency shift of the pass-band of one-pole filter with the variation of the gate-to-source voltage Vgc. The experimental conditions for the negative-resistance MESFET: $V_g = 0$ V, $V_d = 2.01$ V and $I_d = 100$ mA.
(a) Without laser irradiance. (b) Laser current $I_L = 80$ mA.

Actually, Fig. 4 (a) shows the dependence of the pass-band on the gate-to-source voltage V_{gc} in the one-pole filter. For the MESFET of a negative resistance, the operating parameters are: the gate-to-source voltage (V_g) = 0 V, the drain voltage (V_d)= 2.01 V, and the drain current (I_d) = 100 mA. The center frequency of the pass-band changes considerably as the gate-to-source voltage (V_{gc}) changes from -1.51 V to -2.30 V. The results correspond to the tendency of the capacitance change in Fig.3. When the gate-to-sourrce voltage (V_{gc}) changes from -1.44 V to -1.42 V, however, the transmission loss ($-S_{21}$) increases remarkably and a noticeable frequency shift is not observed. Fig.4 (b) shows the dependence of the pass-band on the gate-to-source voltage V_{gc} under laser irradiance. The laser current (I_L) is 80 mA. The center frequency of the pass-band changes remarkably by the laser irradiance for the corresponding Vgc in (a) when the gate-to-source voltage V_{gc} is between -2.3 V and -1.67 V. When V_{gc} changes to -1.64 V, however, the transmission loss increases considerably. The gate-to-source voltage in the loss-increased condition (-1.64 V) is less than the value without laser irradiance (-1.42 V). Light illumination creates a significant amount of charge pairs in the depletion area, and they change not only the capacitance but also other parameters: for example, the gate-to-source resistance. The changes of these parameters cause the tank circuit Q to decrease, but the well-matched negative resistance circuit will compensate for the change of the Q-value. To obtain the proper design condition of the matching circuit, we tried to adjust the MESFET bias voltages to compensate for those changed parameters. Actually, it was possible to increase the tuning range by compensation for element parameter change. The results are shown in Figs.5 and 6. The tuning ranges of 225 MHz for the one-pole filter and 253 MHz for the two-pole filter were observed. If the matching circuit is designed properly, it is possible to realize a band-pass filter with an optically tunable range exceeding 200 MHz .

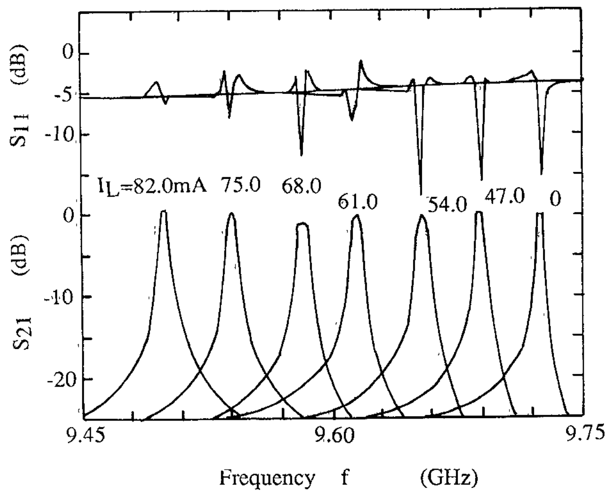


Fig.5. The pass-band frequency shift of the one-pole filter in the compensated case.

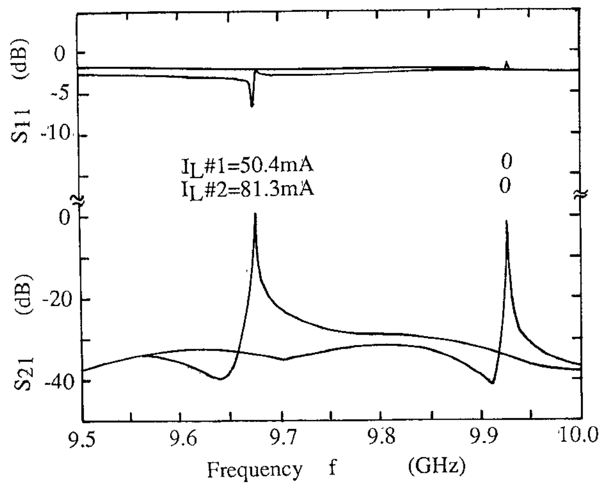


Fig.6. The pass-band frequency shift of the two-pole filter in the compensated case.

CONCLUSIONS

Semiconductor laser controlled active band-pass filters have been designed in X-band. As the gate-to-source voltage V_{gc} of the capacitor MESFET is higher than -1.67 V, laser irradiance of about 15 mW causes the decease of the tank circuit Q-value because of charge pair creation. The compensation for the change of element parameter was very effective, and the tuning ranges of 225 and 253 MHz have been obtained for the one-pole and the two-pole filters, respectively. The results show the design potential of an optically tunable band-pass filter, which consists of MESFETs, with a possible tuning range of 200 MHz.

ACKNOWLEDGMENT

This work was supported by US Army Research Office under contract DAAL-03-88-K-0005.

REFERENCES

[1] A.J.Seeds and A.A.A.de Salles,"Optical control of microwave semiconductor devices," *IEEE Trans. Microwave Theory Tech.*, vol.MTT-38, pp.577-585,May 1990.

[2] C.Y. Chang and T. Itoh, "A varactor-tuned, active microwave band-pass filter," *1990 IEEE MTT-S Int. Microwave Symp. Dig.*, pp.499-502, May 1990.

[3] Data sheet of the LT022MS0 and LT021MC0 laser diodes (Sharp Co.) 1988.