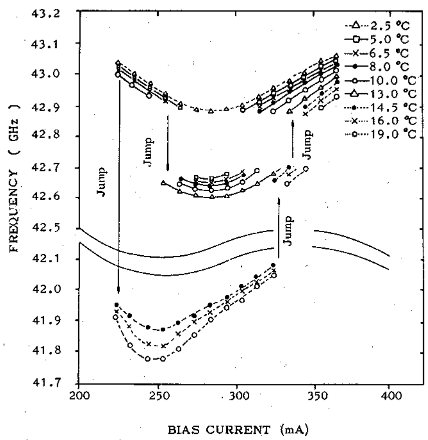

Fig. 14. Typical bias-tuning characteristics of an R-500 oscillator with a 11.2-V diode (parameter: oscillator temperature).

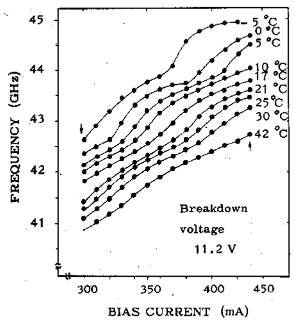

Fig. 15. Frequency as a function of bias current for an R-500 oscillator with a 11.2-V diode. ⬆ ⬇ Frequency jumps occur.

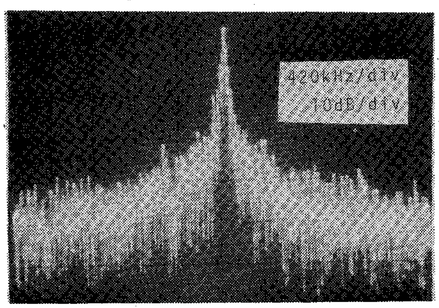

Fig. 16. Typical oscillation spectrum of a mechanically tunable oscillator. Frequency = 47 GHz.

V. CONCLUSION

The authors investigated experimentally the oscillation characteristics of IMPATT diodes mounted in low-impedance waveguide mounts for a frequency range of 19–92 GHz. Broad-band bias-current-tuned oscillators were obtained which cover almost the full waveguide bands; 20-, 24-, and 18-GHz tuning bandwidths were obtained with the R-500, R-620, and R-740 oscillators, respectively.

With respect to our broad-band bias-current-tuned IMPATT oscillators, the following points became evident from the experiments.

1) Oscillation frequency (f_o) and diode breakdown voltage (V_B), which are suitable for broad-band bias-current tuning, satisfy the following relation:

$$2.65 \leq \log_{10} f_o + 0.8 \log_{10} V_B \leq 2.74. \quad (2)$$

In this case, however, oscillator output power is reduced by more than 10 dB, compared to the oscillator operating in the frequency range in which the maximum power is obtainable. The oscillator which does not satisfy the relation in (2) had a fairly broad bandwidth by mechanical tuning, but had only a narrow bias-tuned bandwidth.

2) For the circuit limitation to the oscillation frequency range, the upper and lower limits of oscillation frequency are determined by the cutoff attenuation of the higher order mode (TE_{20}) in the rectangular waveguide and the ratio of the TE_{10} wavelength to the free-space wavelength, respectively. In the present case, the cutoff attenuation was about 20 dB/λ_0 and the ratio was approximately 2.

3) In these oscillators, the output power changes with the change in the impedance of the short plunger, while the change in the oscillation frequency is quite small. Therefore, the output power could be leveled by choosing a suitable value of the short-plunger impedance.

These results are useful for designing a bias-current-tuned broad-band IMPATT sweeper. The authors have built an experimental setup of a sweep oscillator.

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The authors wish to thank Dr. K. Miyauchi for his guidance and suggestions, and Mr. N. Kanmuri for his helpful discussions. The authors also wish to express their thanks to Dr. K. Suzuki, Dr. M. Ohmori, and T. Makimura for test diode preparation and helpful discussions.

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A Stabilized MIC Oscillator Using a Germanium Avalanche Diode

SHUTARO NANBU

***Abstract*—A stabilized *X*-band oscillator using a germanium avalanche diode in a microwave integrated circuit (MIC) is proposed. The stabilization is achieved by coupling a transmission cavity to the resonant cavity in which an avalanche diode is embedded. A mode-jumping problem inherent in a coupled-cavity oscillator was solved by coupling a third varactor-embedded low-*Q* cavity to the transmission cavity. As a result, single-mode oscillation in an MIC oscil-**

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lator was successfully obtained. Varactor tuning can also be realized with as small a change in output power as 7 percent for a tuning range of 30 MHz. The experimental results and the theoretical analysis of the new stabilized oscillator are given.

I. INTRODUCTION

Frequency stabilization is of practical importance in using such microwave oscillating diodes as an avalanche diode and a Gunn diode. By using coupled-cavity construction, high stabilization of oscillation frequency has been achieved for single-mode oscillation [1]–[3]. A difficulty, however, arises: mode jumping due to a bias or temperature change often causes a frequency flip. Too-critical tuning is required for suppression of the mode jumping especially in a microwave-integrated-circuit (MIC) oscillator for which circuit adjustment is not easy.

This short paper describes a new MIC oscillator circuit, in which single-mode oscillation without mode jumping was obtained. The circuit is composed of three cavities: a cavity comprising an oscillating diode, which is called a diode cavity hereafter, a transmission cavity, and a low-Q cavity. The diode cavity and the transmission cavity form a conventional coupled cavity, to which the third low-Q cavity with a varactor diode is newly attached. The last cavity introduces a conductance loss only in the vicinity of the unwanted mode to suppress the mode jumping effectively.

II. OSCILLATOR CONFIGURATION

The construction of the present oscillator is shown in Fig. 1, where (a) and (b) show the circuit layout and cross-sectional view of an oscillator, respectively. A suspended stripline is employed for its high-Q characteristic, for which an air layer 0.80 mm thick is constructed under the substrate made of alumina ceramic 0.65 mm thick. The conductive strip is formed by vacuum evaporation of chromium and gold, by electroplating of gold, and by photoengraving.

A germanium avalanche diode is embedded in diode cavity A to which a transmission stabilizing cavity B is capacitively coupled. To cavity B is also coupled the low-Q cavity C with a varactor diode. A metal screw, a, for mechanical tuning and a titanium dioxide (TiO_2) disk, b, for compensation of temperature variation of oscillation frequency are placed in the air layer under the cavity B. A protrusion c on the cavity B serves to remove parasitic oscillation, which is inherent in a perfectly circular structure due to mode degeneracy. An output stripline is tapered to secure impedance matching between the microstrip and the suspended stripline.

III. OPERATING PRINCIPLES

The new oscillator can be represented by an equivalent circuit shown in Fig. 2 as three coupled resonators; f_A, f_B, and f_C are resonant frequency, Q_A and Q_C are internal Q's, Q_B represents the loaded

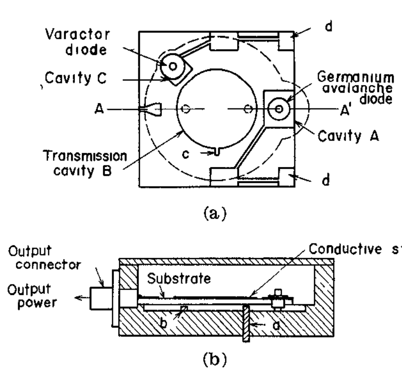

Fig. 1. Construction of an MIC germanium avalanche diode oscillator: a, tuning screw; b, TiO_2 disk; c, protrusion; d, low-pass filter. (a) The circuit layout. (b) Cross section AA'.

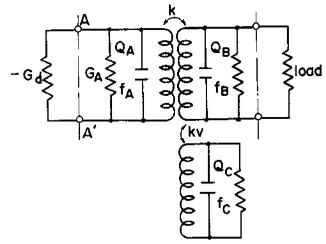

Fig. 2. Equivalent circuit of the oscillator.

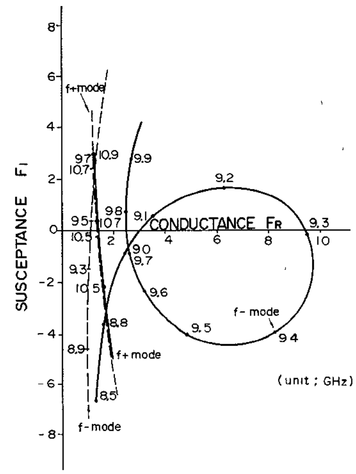

Fig. 3. Admittance loci at the frequencies close to the two resonances; f_+ mode and f_- mode. f_A = 9.8 GHz; f_B = 10.1 GHz; f_C = 9.3 GHz; K = 0.1; Q_A = 30; Q_B = 150; Q_C = 30. The dotted line is for K_v = 0, the solid line is for K_v = 0.08.

TABLE I
THE VALUES OF CIRCUIT PARAMETERS USED IN THE EXPERIMENTS

Parameter	Values	Parameter	Values
f_A	9.7~10.4 GHz	Q_A	27~32
f_B	10.1 GHz	Q_B	150 (loaded Q) 800 (unloaded Q)
f_C	9.4 GHz	Q_C	30

Q's, K and K_v are coupling factors, and G_A is the conductance loss.

It is well known that in the conventional coupled cavity consisting of cavity A and cavity B, two stable-mode oscillations of frequencies f_- and f_+ ($f_- < f_+$) are possible [2], [4]. The conductances for those modes are nearly equal under the frequency stabilization condition ($f_A \approx f_B$) so that the mode jumping between the two modes occurs easily. This problem can be overcome by coupling a low-Q cavity C to the conventional coupled cavity.

The admittance looking to the right from AA' in Fig. 2 is calculated from the circuit parameters shown in Table I. The results are shown in Fig. 3. A prominent conductance peak is observed in the vicinity of f_C. The increased conductance at frequencies close to f_C will suppress additional oscillation due to the f_- mode resonance when f_C is designed to be close to f_-. On the other hand, the conductance of the circuit for the f_+ mode hardly increases so that the power loss due to the cavity C is very small for an oscillation in the f_+ mode.

The mode suppression is effective as long as the negative conductance of the avalanche diode is smaller in magnitude than the conductance of the f_- mode shown in Fig. 3. From the large-signal admittance of germanium avalanche diodes [5], an available output power as a function of load conductance can be calculated at the two frequencies of f_+ and f_-. The results show that if the conductance looking to the right from AA' in Fig. 2 is designed to be from 1.3 to 1.5 times larger for the f_- mode than for the f_+ mode, the unwanted oscillations in the f_- mode can be suppressed efficiently by the use of the cavity C within the limit of the bias current of about 60 mA. An output power of at least 50 mW is expected for the f_+ mode.

In the present oscillator, electronic tuning is also available by means of the varactor diode in the cavity C. Only slight variation in output power was caused by the varactor tuning, because in f_+ mode operation the variation of the conductance looking to the right from AA' in Fig. 2 is small when the bias voltage applied to the varactor diode is increased.

IV. EXPERIMENTAL RESULTS

The values of the circuit parameters used in the experimental MIC oscillator as shown in Fig. 1 are given in Table I. In this oscillator, single-mode oscillation in the f_+ mode was obtained for output power below 50 mW, as expected from the analysis in Section III. The varactor tuning range of, at most, 50 MHz was also attained with a sensitivity of 2 MHz/V, and the output power change was less than 7 percent for a tuning range of 30 MHz in the typical oscillator (f_A = 9.8 GHz). The mechanical tuning range of 450 MHz was achieved with the tuning screw. The oscillation frequency was tuned to 10.525 ± 5 MHz. The oscillation built up at as low an input power as 0.8 W. The input power giving an output power of 30 mW was as low as 1.5 W. A high frequency stability of 10 ppm/°C was obtained over the temperature range from −20° to 60°C because the variation of the resonant frequency of the cavity B is compensated through TiO_2. The rms frequency deviation in a bandwidth of 1 Hz and the single-sideband AM noise-to-carrier ratio in a bandwidth of 1 Hz were as low as 2 Hz and −148 dB, respectively, at the modulation frequency of 1.4 kHz.

In order to investigate the degree of stabilization due to the cavity B, many germanium avalanche diodes having different admittance values were embedded by turns in two kinds of oscillators: 1) an oscillator with cavities A, B, and C, and 2) an oscillator with a cavity A only. In both oscillators, the dimension of the cavity A is the same and the tuning screw is not inserted. The admittances of both oscillators embedded with the same avalanche diode are adjusted so as to build up oscillation at the same bias current. The oscillation frequencies were measured in both oscillators. The result is shown in Fig. 4. The stabilization factor due to the cavity B is characterized by the quantity S defined as

$$S = 1 \bigg/ \frac{\partial f}{\partial f_A}$$

where the variation of f_B is ignored [1], [2]. It is seen from Fig. 4 that S is about 5 at about 9.8 GHz of f_A in the present MIC oscillators.

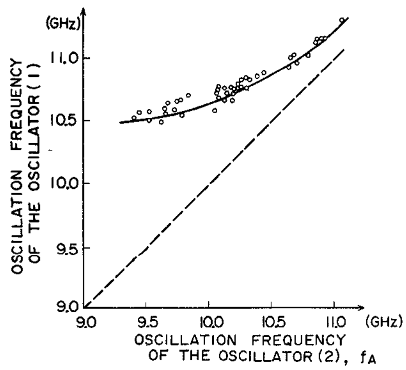

Fig. 4. The degree of stabilization due to cavity B. (1) The present oscillator. (2) The oscillator with cavity A only.

V. CONCLUSION

A single-mode oscillation with high stability in an MIC oscillator has been obtained by coupling a third varactor-embedded low-Q cavity to a conventional coupled-cavity oscillator. It has been confirmed theoretically and experimentally that the third cavity can serve not only for suppressing an unwanted mode but also for varactor tuning with little variation of the output power.

The advantage of using a germanium avalanche diode in the present MIC oscillator is fully exhibited in low-noise [6] and low-input-power operation.

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Avalanche Diode Noise Sources at Short Centimeter and Millimeter Wavelengths

NIGEL J. KEEN

***Abstract*—Semiconductor noise sources for microwave frequencies have been constructed using commercial avalanche diodes in waveguide mounts. For the diodes and waveguide configurations reported here the upper usable frequency is approximately 40 GHz.**

The measurements are in limited agreement with previous predictions. It is possible that a reduction in package and diode parasitics would improve this agreement, and raise appreciably the upper usable frequency of such noise sources.

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