# K-BAND HIGH POWER SINGLE-TUNED IMPATT OSCILLATOR STABILIZED BY HYBRID-COUPLED CAVITIES

H. Komizo, T. Meguro, Y. Ito, and M. Shinoda
FUJITSU Laboratories Ltd., Kawasaki, Japan

## Abstract

Highly stable 0.7W CW K-band IMPATT power source with frequency stability of about $4\times10^{-5}$/0~50°C has been developed. This has been achieved by a combination of a single-tuned oscillator stabilized by hybrid-coupled cavities and one stage high power reflection type amplifier.

## Introduction

In this paper, a new cavity stabilizing technique applied to a K-band IMPATT oscillator is proposed which utilizes a compact magic T and $TE_{011}$ cavities. Also, are described the design of a high power IMPATT reflection type amplifier and over-all performance of the highly stable IMPATT power source, shown in Fig.1.

## Cavity Stabilized Oscillator

Reflection type cavity stabilizing method without a passivating circuit to obtain a highly stable and low noise Gunn or IMPATT diode oscillator was reported at X-band.[1] But, in the frequency region beyond K-band, the parasitic elements of the diode package greatly influence to the circuit impedance and it becomes rather difficult to get a reproducible and tunable stabilized oscillator by such a stabilizing method. Recently, K. Kohiyama[2] proposed a band rejection filter type method that enabled to get a single-tuned (i.e. free from mode-jumping) oscillation.

A hybrid-coupled cavities construction is known as a part of a microwave discriminating circuit that has a high $Q_{ex}$, high frequency sensitivity and also roughly single-tuned admittance locus.

The proposed solid-state oscillator stabilized by the hybrid-coupled cavities provided a single-mode oscillation without mode-jumping and a broadband mechanical tunability.

Figure 2 shows the cross sectional view of the IMPATT oscillator stabilized by hybrid coupled cavities. Two $TE_{011}$ mode high Q cavities with the resonant frequencies of $f_{01}$ and $f_{02}$, are connected to the both arms of H plane T-junction of a magic T through coupling apertures. The coaxial arm is terminated with a Epo-iron absorber 1.

A reduced height pill-type packaged Si IMPATT diode is mounted in the coaxial line which is extended from the RG-42 waveguide. At the other side of the coaxial line, is provided the stabilizing circuit[3] which consists of a radial filter and an Epo-iron absorber 2.

Figure 3(a) shows a simplified equivalent circuit of the oscillator. The difference $l_1 \sim l_2$ is chosen nearly $(2n-1)\cdot\lambda_{g0}/4$, where $\lambda_{g0}$ is the wavelength of the center frequency $f_0$, $f_0=(f_{01}+f_{02})/2$. The input admittance locus, looking from the reference point A, becomes like that of a staggered band rejection filter and at the out of band frequencies, the input impedance is pure resistive due to the absorber 1. The length $l_3$ (the distance from point A to the diode) is so chosen as to satisfy the oscillating condition.

Figure 3(b) shows the admittance loci looking from point B, in this case, $f_{01}>f_{02}$ and $l_1=\lambda_{g0}/8$, $l_2=\lambda_{g0}/8+\lambda_{g0}/4$, and $l_3=\lambda_{g0}/3+n\cdot\lambda_{g0}/2$.

The $Q_{ex}$ at the center frequency $f_0$ and the bandwidth of the band rejection filter is a function of the $Q_{ex}$ of each cavity and the frequency difference $\Delta f(=f_{01}\sim f_{02})$. Admittance locus varies from curve a to curve b in Fig.3(b), according to the increase of $\Delta f$. The $Q_{ex}$ at $f_0$ also gradually decreases and there exist a critical value in $\Delta f$ which gives a highest $Q_{ex}$ value at a given unloaded Q and $Q_{ex}$ values of the cavities. So, it is better to set the cavity frequencies to the critical point in $\Delta f$ to get a most stabilized oscillator.

The absorber 2 with the radial choke plays an important role to restrain spurious oscillation in the out-of-band. The coaxial post diameter $d^{\phi}$ mainly determined the coupling between the diode and the waveguide circuit.

Figure 4 shows the typical characteristics of the stabilized IMPATT oscillator. The Si IMPATT diode for the oscillator and the amplifier has about $10^{-4}$ cm$^2$ junction area, thermal resistance of bellow 16°C/W, a breakdown voltage of 38 V, and avalanche frequency of about 13 GHz at the operating current $I_{op}=200$ mA. The diode is soldered to a copper block for good heat-sinking of about 2.5°C/W thermal resistance.

The stabilized output power of more than 350 mW with a pushing figure of 15 KHz/mA and efficiency of 3.2%, were obtained at an operating junction temperature of 230°C. In this experiment, the parameters of the hybrid-coupled cavities are as follow; the cavity $Q_0$ and $Q_{ex}$ are about 15000 and 5000, respectively, and $f_0 = 25.353$ GHz, $\Delta f \approx 3$ MHz.

The frequency stability of about $4\times10^{-5}$/0~50°C has been obtained using the temperature compensated INVAR cavities and simple protection from humidity.

## Reflection Type Amplifier

Almost same mount construction as the oscillator is used for the amplifier, except for the hybrid-coupled cavities replaced by a short-plunger. The $l_4$ was changed to get an optimum coupling to a circulator.

To obtain the maximum output power $P_{om}$ of the amplifier, the optimum load conductance $G_{lm}$ can be decided from the relation between the electronic conductance $G_d$ and RF device voltage $V_{ac}$, $G_d=G_0-kV_{ac}^2$[4] at a given input power level, where $G_0$ and k denote the small signal negative conductance and $-\partial G_d/\partial V_{ac}$, respectively. Go and k can be derived from the several measured $G_d$ values corresponding to the input power $P_i$ and the gain.

Output power[5] $P_o$ of an amplifier is the sum of the $P_i$ and the generated power $P_d$ from the device. $G_{lm}$ for the $P_{om}$ can be determined by calculation under a given $P_i$.

Furthermore instability phenomena observed under large signal condition were eliminated by the above mentioned stabilized circuit with absorber 2.

Figure 5 shows the linearity characteristics of the amplifier which is designed to provide a maximum output power at input level of 25.5 dBm with operating current 230 mA.

The amplifier provided the small signal gain of 5 dB, maximum output power of more than 1 W with 1.5 dB gain and maximum generated power about 25.6 dBm. At $P_i$ of 25.5 dBm, the 1 dB bandwidth is about 2.5 GHz with a gain of 3 dB, and the gain variation due to the ambient temperature variation from 0°C to 50°C is about 0.2 dB.

Figure 6 shows the overall performance and block diagram of the 25 GHz band power source using the stabilized IMPATT oscillator and one stage amplifier. The output power of more than 0.5 W (typical 0.7 W at room temperature) is available with the frequency stability of about $4 \times 10^{-5}$/0~50°C.

## Conclusion

A new cavity stabilizing method is proposed which utilizes the hybrid-coupled cavities, well-known construction as a part of a microwave discriminator.

The K-band IMPATT power source using the stabilizing method is suitable for a stable and reliable local oscillator for mm wave PCM system, followed by a frequency multiplier, and also for a pumping source of a parametric amplifier.

## Reference


(1) Y.Ito, H.Komizo and S.Sasagawa, "Cavity Stabilized X-band Gunn oscillator", IEEE Trans. Microwave Theory Tech. vol. MTT-18, pp. 890-897, November 1970.

(2) K.Kohiyama and K.Monma, "A New Type of Frequency-Stabilized Gunn Oscillator", Proc. of the IEEE, pp. 1532-1533, October 1971.

(3) H.Komizo, Y.Ito, H.Ashida and M.Shinoda, "0.5 W CW IMPATT Diode Amplifier For High Capacity 11 GHz FM Radio Relay Equipment", 1972 ISSCC Dig. Tech. Papers, pp. 36-37 February 1972.

(4) W.J.Gewartowski, "The Effect of Series Resistance on Avalanche (IMPATT) Oscillator Efficiency", Proc. IEEE, vol. 56, No.6, pp. 1139-1141, June 1968.

(5) Chang W.Lee and Wei C. Tsai, "High Power GaAs Avalanche Diode Amplifiers", IEEE International Convention, Digest Tech. Papers, pp.368-369, March 1971.


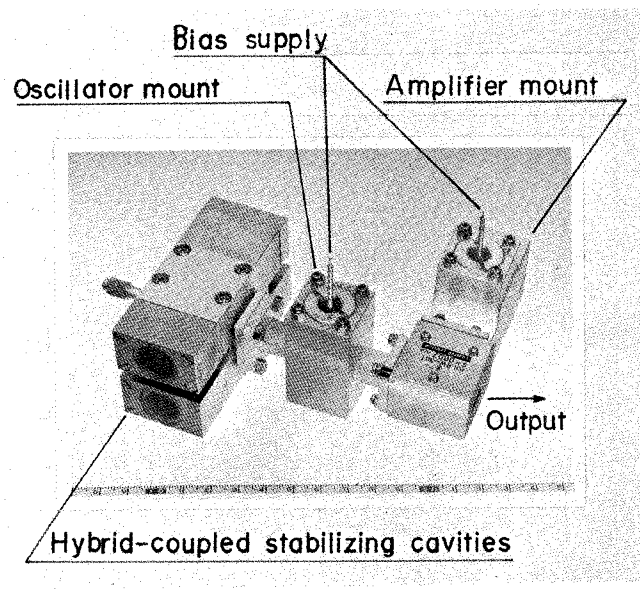


FIG. 1 K-BAND HIGH POWER AND HIGHLY STABLE IMPATT DIODE POWER SOURCE

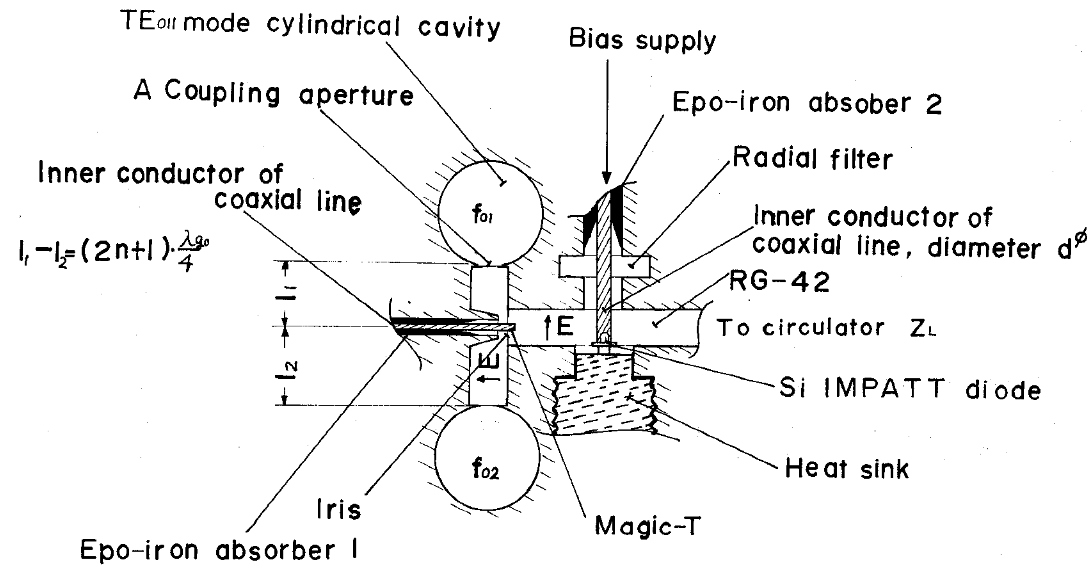


FIG. 2 CROSS SECTIONAL VIEW OF THE CAVITY STABILIZED IMPATT OSCILLATOR STABILIZED BY THE HYBRID-COUPLED CAVITIES

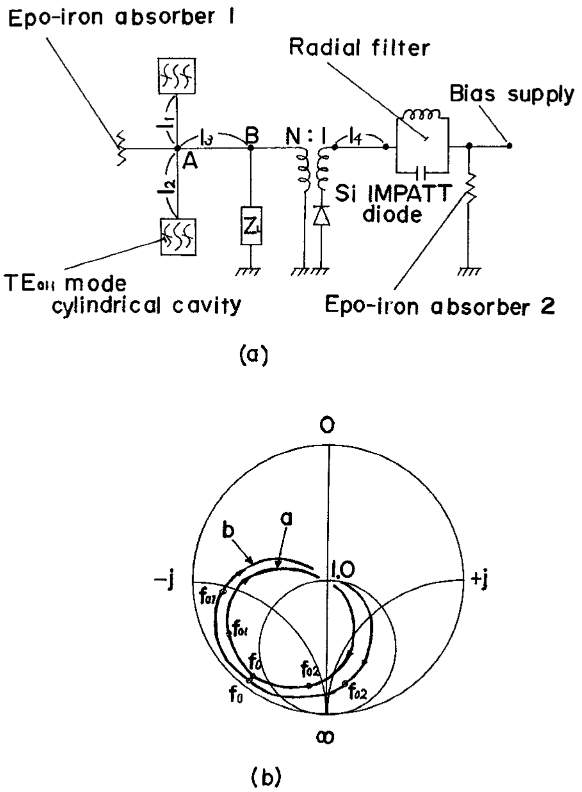


FIG. 3 (a) SIMPLIFIED EQUIVALENT CIRCUIT OF THE STABILIZED OSCILLATOR
(b) INPUT ADMITTANCE LOCI OF THE HYBRID-COUPLED CAVITIES LOOKING FROM POINT B IN FIG. 3 (a)

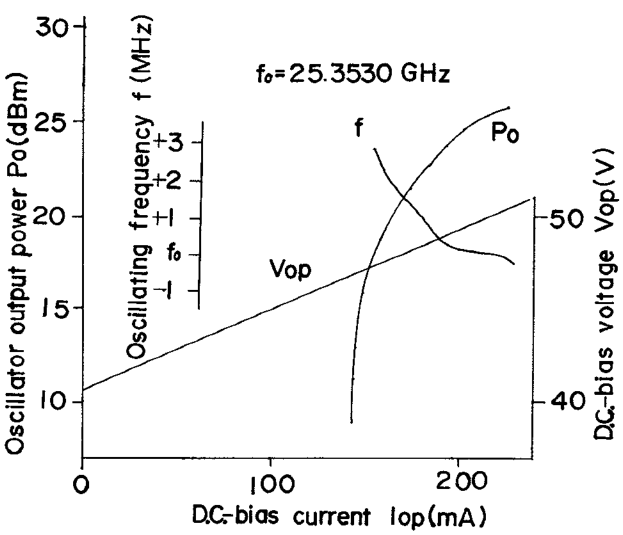


FIG. 4 CHARACTERISTICS OF THE IMPATT OSCILLATOR STABILIZED BY HYBRID-COUPLED CAVITIES

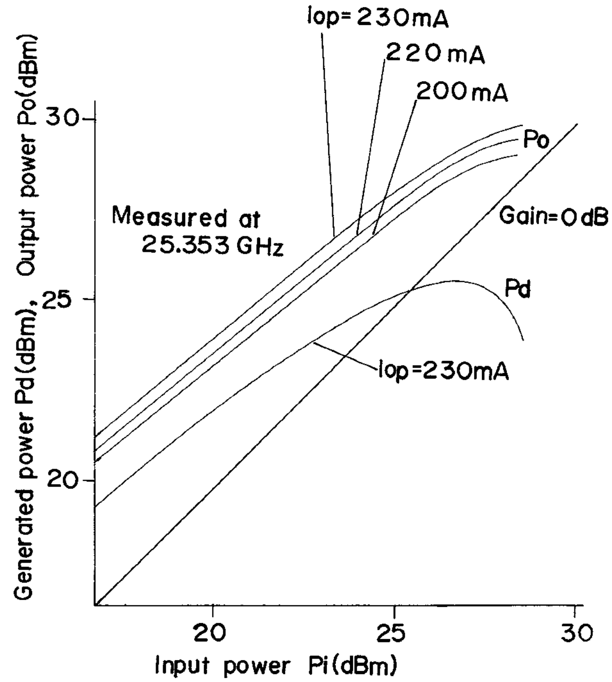


FIG. 5 CHARACTERISTICS OF THE IMPATT REFLECTION TYPE AMPLIFIER

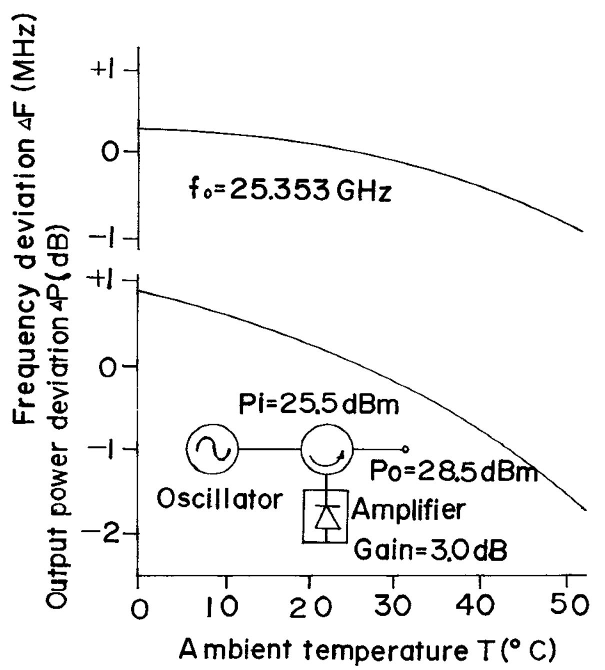


FIG. 6 OVERALL PERFORMANCE AND BLOCK-DIAGRAM OF THE K-BAND IMPATT DIODE POWER SOURCE