WIDEBAND TUNABLE AND HIGHLY STABILIZED MILLIMETERWAVE IMPATT DIODE OSCILLATORS

T. Miyakawa, N. Tokoyo, T. Nakagami and H. Hayashi
Fujitsu Laboratories Ltd.
Nakahara, Kawasaki, 211 Japan

Abstract

Millimeterwave IMPATT diode oscillators which can be tuned from 35 to 75 GGz and from 70 to 100 GHz are developed. By connecting a high Q cavity, a highly stabilized oscillator is also constructed.

Introduction

One of the characteristic features of the guided millimeterwave communication is that a wide frequency band is used. The frequency band 43 to 87 GHz includes more than 50 channels in the W-40G system developed in Japan.[1]

Recently IMPATT diodes have become the most feasible solid state power source in millimeterwave frequencies. In applying them for the millimeterwave communication systems, it is important to develop a wideband tunable oscillator which can be used as a signal generator in the measurement of equipments and circuit components. It is also important to develop a local oscillator whose frequency can be easily adjusted and stabilized at the specific frequency band.

This paper describes the millimeterwave IMPATT diode oscillators which are constructed as the wideband tunable oscillator and the highly stabilized oscillator by using basically the same circuit configuration. The difference is that a waveguide short is used in the former and a cavity resonator in the latter.

General Description of the Oscillator

The cross-section of the developed oscillator is shown in Figure 1, which is a waveguide-coaxial circuit with the diode raised to the center of waveguide.[2] Curves in Figure 1 show the variation of oscillation frequency and output power. This performance is characterized by two peaks in the output power. At peak I, both the frequency and the power change with the movement of the waveguide short, while at peak II only the power changes.

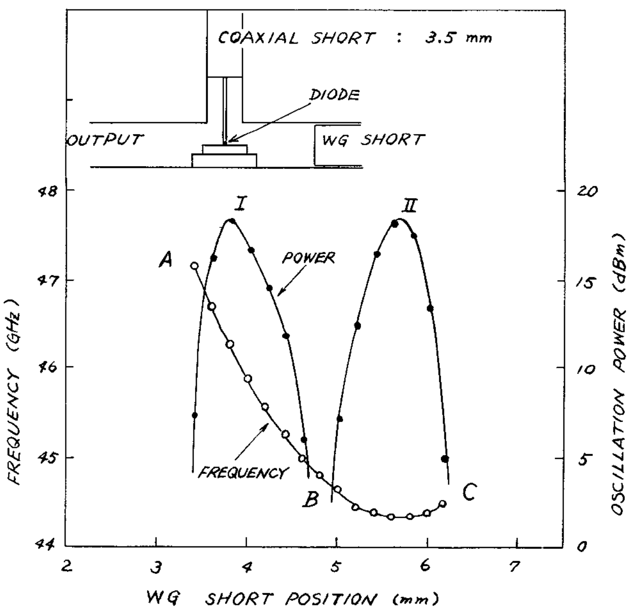

Figure 1. Oscillation Characteristics

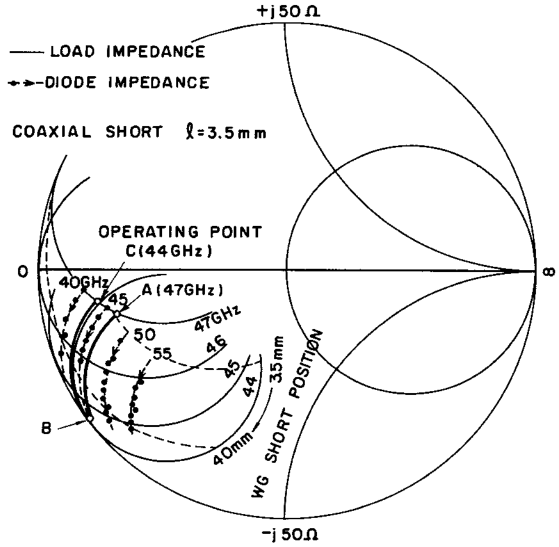

Figure 2. Explanation of the Oscillator Performance

This performance is explained as follows by using Figure 2. Broken lines represent the measured device lines, i.e., loci of the negative of diode impedances as functions of current amplitude at the respective frequencies, in which arrows indicate the increase of amplitude. The load impedance have been measured at X-band frequencies with a 5-time scaled up circuit. The operating point of the oscillation is given by the intersection of the device line and the load impedance locus at the same frequency.

When the waveguide short is moved from the diode, the operating point moves as A → B → C in Figure 2, accompanying the change in the output power and frequency as A → B → C in Figure 1. At points A and C the current amplitude is small and at B the real part of the impedance is small. This causes the decrease in the output power at these points. The operating points corresponding to peaks I and II lie between A and B and between B and C, respectively, where the amplitude and the impedance become optimum.

Small frequency variation at peak II is due to the fact that the device line and the impedance locus between B and C coincide at nearly 44 GHz and the operating point moves along this line with the movement of waveguide short. When the coaxial short is made longer, circles of load impedance move clockwise in Figure 2 and the frequency of the operating point on the line A — B — C becomes lower. This means that the output power and the frequency at peak II can be varied by the waveguide short and the coaxial short , respectively.

Wideband Tunable Oscillator

Wideband tunable oscillators have been constructed on the principle of operation which gives peak II, using waveguides R-500 for the 35 to 60 GHz range and R-740 for the 60 to 100 GHz range. The diode is a Si—p^+nn^+ IMPATT diode fabricated with a beam lead structure and a quartz stand-off.

Figure 3 shows the wideband oscillation characteristics. The solid lines are obtained by replacing fixed length coaxial shorts. The dotted lines are the continuous tuning characteristics obtained with the oscillator which provides a mechanically movable coaxial short, whose photograph is shown in Figure 4 (a). These characteristics have been obtained by maximizing the output power with the waveguide short at each frequency. Lower output power and narrower tuning range for the case of continuous tuning are caused by the loss of movable short which has a gap to insure the smooth slide tuning. It is found that the output power of 15 ~ 21 dBm can be obtained within the wide tunable range.

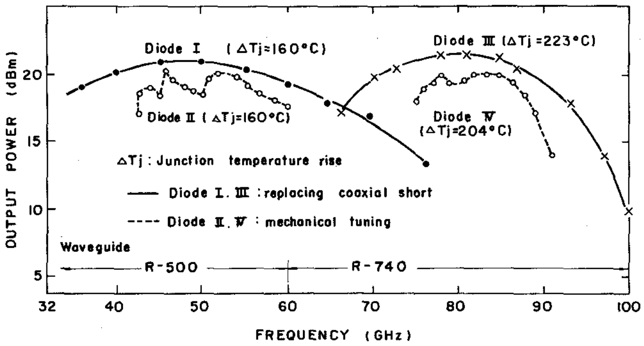

Figure 3. Wideband Oscillation Characteristics of Millimeterwave IMPATT Diode Oscillators

Highly Stablized Oscillator

At peak I, the frequency is controlled by the waveguide short. If a cavity is connected in place of the waveguide short, the load impedance varies along a circle similar to one of solid circles in Figure 2 in the vicinity of the resonant frequency. This is because the variation of the load impedance due to the movement of the waveguide short is substituted by that of cavity impedance due to the frequency variation. Since the load impedance is made highly dependent on the frequency by connecting the cavity, the high stability of oscillation frequency is achieved.

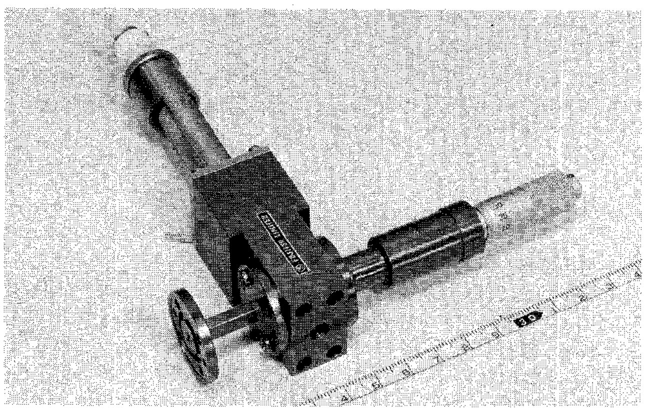

Figure 4 (a). Continuously Tunable Oscillator

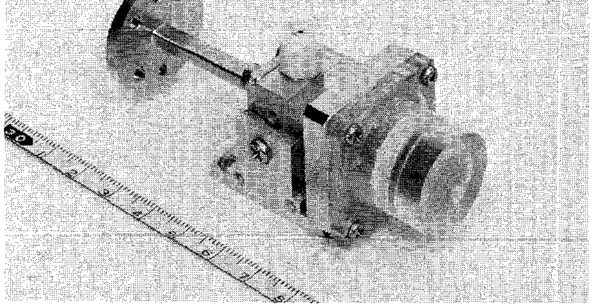

Figure 4 (b). 80 GHz Highly Stabilized Oscillator

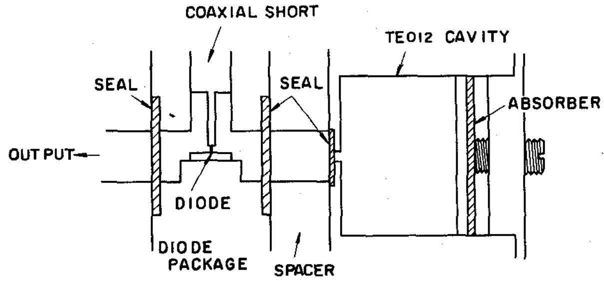

Figure 5. Cross-section of Stablized Oscillator

Based on this concept, the stabilized oscillators have been constructed in 40 and 80 GHz bands. Figure 4 (b) and Figure 5 show a photograph and a cross-section of these oscillators, respectively. The cavity is made of superinvar and has a air-tight structure with a silica-gel container, so that the resonant frequency is protected from the influences of ambient temperature and humidity. To minimize the loss in the cavity, cylindrical TE_{012} mode is adopted because of its high unloaded Q. In order to achieve the high reliability required for the practical application, the diode is mounted in a waveguide package sealed with quartz windows.

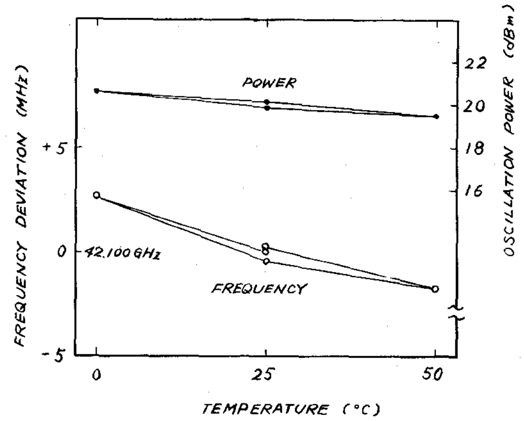

Figure 6. Temperature Characteristics of the Stabilized Oscillator in 40 GHz Band

Figure 6 shows the temperature characteristics of the stabilized oscillator in 40 GHz band. The stabilization factor on the order of 2 x 10^{-6}/°C has been obtained. Typical data in 40 GHz and 80 GHz bands are summarized below.

	40 GHz band	80 GHz band
Center frequency	42.100 GHz	81.000 GHz
Output power	20 dBm(ΔT_j=150°C)	15 dBm(ΔT_j=200°C)
Frequency deviation (0 ~ 50°C)	± 2.5 MHz or less	± 4 MHz or less
Output power deviation (0 ~ 50°C)	0.5 dB or less	1 dB or less

Conclusion

The operation and the electrical performance of the wideband tunable oscillators and the highly stabilized oscillators using IMPATT diodes are described. Wideband tunable oscillators are applicable as signal generators for the measurement in millimeterwave frequencies. The output power and the frequency stability obtained with the highly stabilized oscillators show the feasibility of these oscillators as local power source in the practical system.

References

(1) K. Miyauchi, this symposium.
(2) H. Hayashi et al., "80GHz IMPATT Amplifier," ISSCC Digest of Technical Papers, pp. 102—103 (Feb. 1974).