MECHANICALLY TUNEABLE, CAVITY-STABILIZED, MILLIMETER-WAVE IMPATT OSCILLATORS

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Abstract

The paper describes prototype results on mechanically-tuneable, cavity-stabilized, V-band and W-band impatt oscillators. The oscillators are easily tuned over a wide range of frequencies. The V-band oscillator has a 20% tuneable bandwidth (54 GHz to 66 GHz) with 200 mW minimum output power. The W-band oscillator has a 14% tuneable bandwidth (95 GHz to 110 GHz) with 50 mW minimum output power.

Introduction

Impatt oscillators for use as transmit oscillators in a wideband PCM communication system must provide adequate power with high stability and low noise. To reduce costs, the oscillators must contain few piece-parts and be easily tuned over a wide range of frequencies. This paper describes cavity-stabilized, mechanically-tuneable designs that meet these requirements at 60 GHz and 105 GHz.

The oscillators are for use in a system with the following requirements:

Power Output	300 mW at 40 GHz 50 mW at 110 GHz
FM noise	< 375 Hz/$\sqrt{\text{KHz}}$
Temperature stability	< ±330 KHz/°F
Junction temperature	≤ 230°C

Design Considerations

The oscillators are similar in nature and are based on the single-tuned design first proposed by Harkless[1] in 1967. An equivalent circuit of the Harkless design is shown in Figure 1. The impatt diode is connected to a match-terminated transmission line. The line is series-loaded at some point with a cavity resonator (ω_o) coupled to a load. At all frequencies except ω_o, the impedance Z_o presented to the diode is too high for the diode to oscillate. At ω_o, the cavity introduces a large mismatch ($Z_R >> Z_o$) on the line. With a suitable spacing, ℓ, between the diode and cavity, the impedance presented to the diode is sufficiently low for the diode to oscillate.

The circuit is single-tuned, and the frequency of oscillation is determined by the cavity. The frequency is varied by adjusting both the cavity tuning and the cavity-diode spacing ℓ. The cavity improves the stability, and reduces the FM noise of the oscillator by the factor[2]

$$S = 1 + \frac{Q_L}{Q_{OSC}}$$

where Q_L is the loaded Q of the cavity, and Q_{OSC} is the Q of the impatt diode.

Kenyon[3], Magalhaes[4] and Magalhaes and Kurokawa[5] developed the coaxial-waveguide model of this oscillator circuit in 1970. Since then several other versions have been described in the literature[6,7]. Only recently have results been published on the tuneable range of the oscillator design. Huish et al[8] used metallic spacers to adjust the cavity-diode spacing. They indicated that the 30-50 GHz band may be covered with four oscillator codes.

This paper describes a stripline-waveguide model similar to the Harkless circuit. It differs in that the diode is contained in a channel in the end wall of the cavity. Tuning is accomplished by changing the position of the diode with respect to the center of the cavity end wall, and by adjusting the resonant frequency of the cavity with a quartz tuner. As discussed in the following section, the use of stripline permits a simple mechanical arrangement for continuous tuning of the oscillator.

Description

A cross-section of the oscillator is shown in Figure 2. The impatt diode is located near one end of the channel in the diode housing. In the channel is a 0.002 ins. thick strip air-line. The strip air-line is short enough to be supported by the diode at one end, and by the termination and bias stand-off at the other end. Directly in front of the diode on the strip air-line is a low impedance section as shown in Figure 3. This insures that the impedance presented to the diode is sufficiently low for the diode to oscillate.

The diode and cavity are contained in different housings. Figure 3 shows the approximate position of the diode with respect to the cavity under operating conditions. A separate line length between the diode and cavity does not exist since the diode is contained within the area formed by the cavity. The impedance presented to the diode is adjusted by varying the diode position on the cavity end wall. This is done by sliding the diode housing with respect to the cavity housing.

Referring again to Figure 2, the termination, as described earlier, insures the diode cannot oscillate at other spurious frequencies. The termination is made from a microwave absorber which is an insulator for direct currents. Bias is applied to the diode through the bias standoff beyond the termination.

A separate input iris for the cavity is not required. The cavity diameter and strip air-line configuration provide the desired coupling. The cavity length is adjusted for the TE_{111} mode to resonate at the high end of the band. The quartz rod tunes the cavity to different frequencies within the band. A single output iris diameter is selected to optimize the power from the oscillator over the tuning band.

The ribs on the sides of the cavity in Figure 3 are used to move the resonant frequency of the orthogonally polarized TE_{111} mode outside the tuning range of the oscillator. The orthogonal mode can be excited if the strip air-line is not symmetrically located with respect to the cavity.

The strip air-line format is selected since the line length required is short. It avoids thin and delicate dielectric substrates that are required in conventional striplines at these frequencies. It also eliminates dielectric losses and permits the strip air-line to be thermal compression bonded directly to the diode and bias standoff avoiding plated through holes and pressure-type contacts.

The cavity and output iris are coined into the copper cavity housing. Coining is an inexpensive and reproducible method of manufacture. Features such as the ribs are easily included in the coining die. The die is polished for a high quality cavity finish. The front face of the housing is machined for the required output iris thickness.

The oscillator is temperature compensated by clamping the quartz tuner at a suitable point in the cavity housing[3], as shown in Figure 2. When the temperature increases, the differential expansion relative to the clamp point causes the quartz rod to withdraw from the cavity offsetting the frequency decrease due to cavity expansion.

The oscillator is designed to bolt directly onto a modulator housing or an oversize waveguide flange. Only two adjustments are required to tune the oscillator. The cavity is adjusted to resonate at the desired frequency, and the cavity center-diode center spacing is adjusted to provide the correct impedance for the diode.

The tuning adjustments are made in the fixture shown in Figure 4. The fixture permits accurate and controlled adjustments of the cavity-diode spacing while maintaining an intimate contact between the diode and cavity housings. Once the adjustment is complete, the housings are securely locked and the fixturing removed.

Results

Figure 5 shows the typical tuneable range for a V-band impatt oscillator. The diode current is 130 mA, and the junction temperature < 200°C. The tuneable bandwidth is 20% (54 GHz to 66 GHz) at the 200 mW output level. The dotted lines show the power variation with frequency (tuner adjustment) for a given cavity center-diode center spacing, x. A 0.070 ins. diode position adjustment is required to tune the oscillator across the band. The measured oscillator Q is in the range 170 to 250, the efficiency in the range 5% to 8% and the FM noise is < 170 Hz/$\sqrt{\text{KHz}}$ across the band.

Figure 6 shows the results on four W-band oscillators assembled to check reproducibility. The capacitance of the four diodes used in the oscillators vary from 0.070 pF to 0.088 pF. The diode current in each case is 100 mA, and the junction temperature is < 230°C. The tuneable bandwidth is 14% (95 GHz to 110 GHz) at the 50 mW output power level. The measured oscillator Q is in the range 150 to 350, the efficiency in the range 3% to 4.5%, and the F.M. noise is typically < 210 Hz/$\sqrt{\text{KHz}}$. A 0.035 ins. spacing adjustment is required to tune each oscillator across the band.

Figure 7 shows typical curves of frequency and power versus diode current for one of the W-band oscillators. The oscillator is tuned for maximum output power at 100 mA. The results are obtained by varying the diode current only. At 100 mA the pushing figure for the oscillator is approximately 210 KHz/mA.

Figure 8 shows the temperature stability of one of the W-band oscillators with the quartz tuner locked at different positions, L, with respect to the cavity center. The oscillator is tuned to 106.5 GHz. At this frequency the ± 330 KHz/°F temperature stability requirement for the system is achieved with L = 0.170 ins. ± 0.040 ins.

Conclusions

Low noise, cavity-stabilized, mechanically-tuneable, impatt oscillators have been designed at 60 GHz and 105 GHz. The oscillators meet the system power, noise, and stability requirements. They are tuneable over relatively wide (14% to 20%) bands, and have efficiencies from 3% to 8% depending on the frequency. They contain a small number of piece parts, are easily tuned, and, therefore, should be inexpensive to manufacture.

Acknowledgments

The author wishes to thank Larry Smith, John Rupp and Basil Lewis at Bell Laboratories, Reading, Pa. for providing the impatt diodes; Dave Gunderson at Bell Laboratories, Holmdel, N.J. for making noise measurements; Jim Hare, George Palmer and Ken Steinmetz at Bell Laboratories, Allentown, Pa. for mechanical contributions. The advice guidance and contributions of Clare Barnes are also greatly appreciated.

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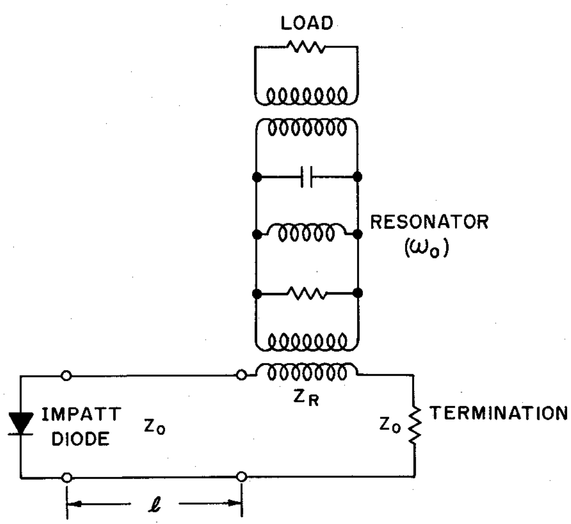

Figure 1 - Equivalent circuit of the Harkless design

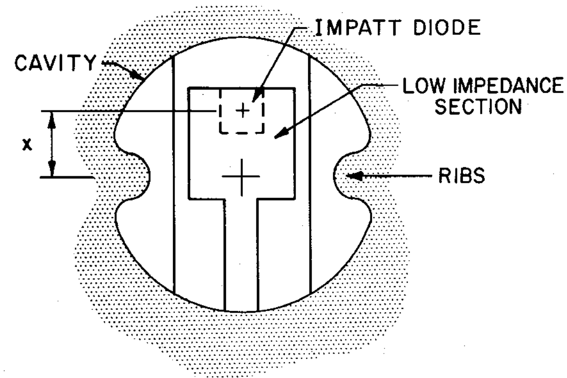

Figure 3 - Impatt diode position in the oscillator relative to the cavity center

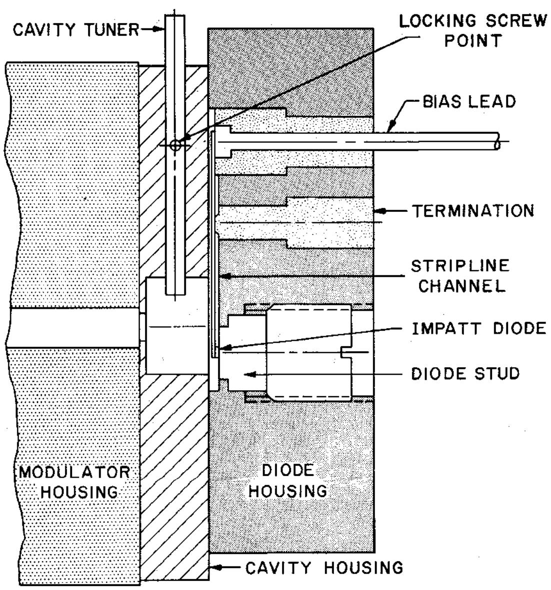

Figure 2 - Cross-section of the impatt oscillator

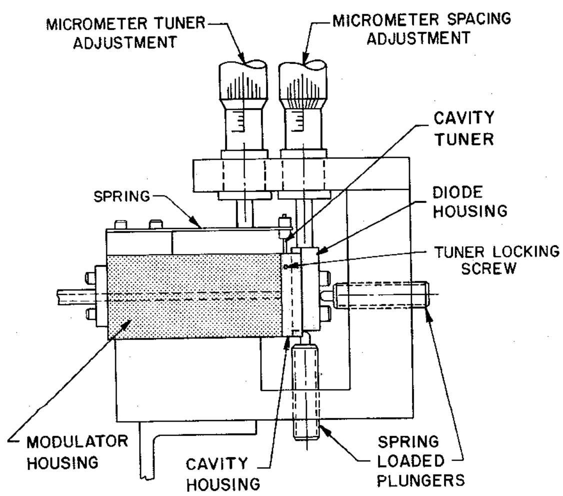

Figure 4 - Oscillator tuning fixture

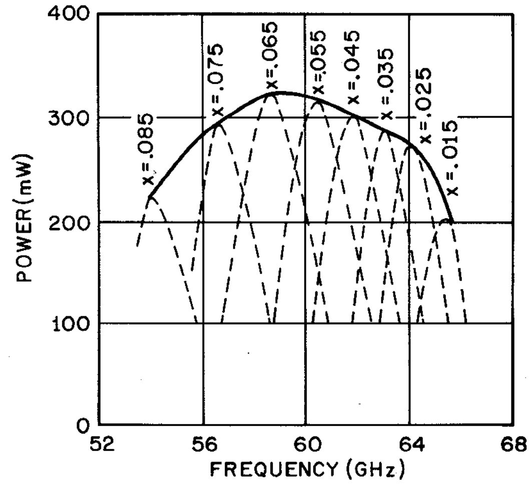

Figure 5 - Tuneable range for a V-band oscillator. x is the cavity center-diode center spacing (ins.)

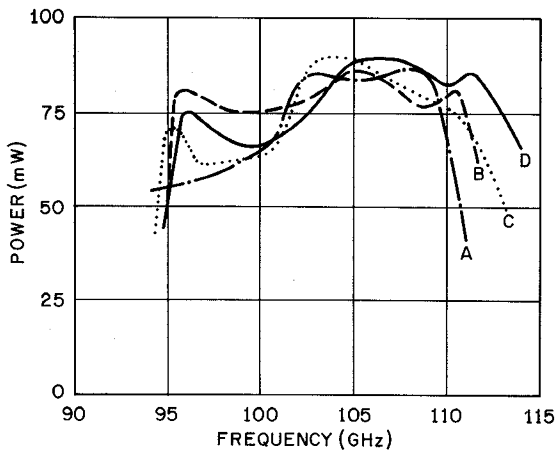

Figure 6 - Tuneable range for four W-band oscillators
Capacitance Diode A = 0.086pF
Capacitance Diode B = 0.077pF
Capacitance Diode C = 0.077pF
Capacitance Diode D = 0.070pF

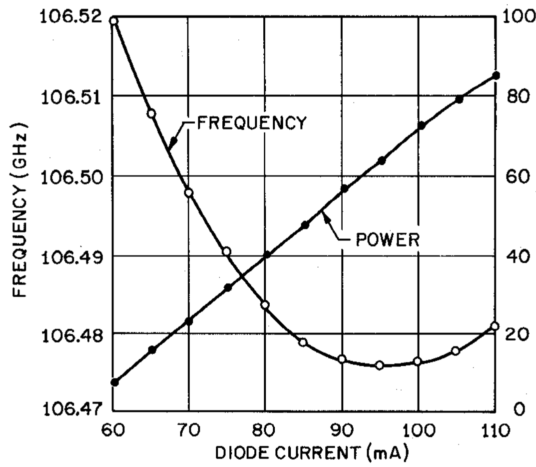

Figure 7 - Frequency and power variation with diode current for a W-band oscillator

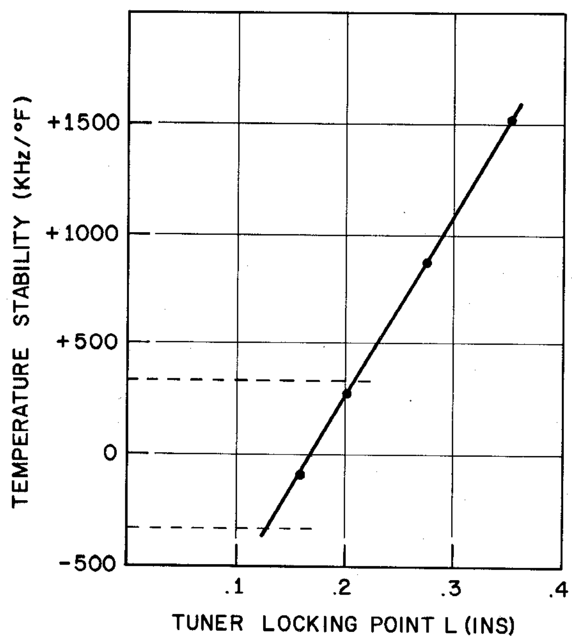

Figure 8 - Temperature stability of a W-band oscillator versus tuner locking point. L is measured from the cavity center