WIDEBAND ELECTRONICALLY TUNED
MILLIMETER-WAVE IMPATT OSCILLATORS*

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Abstract

Development and characterization of wideband, low-noise electronically tuned IMPATT diode oscillators in millimeter-wave frequencies are described.

Introduction

Recently the need for reliable, low-cost and wideband millimeter-wave sources and receivers has been growing rapidly. Because of their broadband negative-resistance characteristics and high output power capabilities at both microwave and millimeter-wave frequencies, IMPATT diode oscillators have become increasingly important. The dependence of its operating frequency on the dc bias current provides a convenient way to vary the frequency of oscillation electronically. This bias-tuned IMPATT diode oscillator exhibits broad swept frequency range which is not yet achievable with either varactor- or YIG-tuned oscillators using IMPATT, Gunn or BARITT devices. We have developed wideband electronically tuned IMPATT diode oscillators with low noise characteristics as scanning local oscillators. Two bias-tuned IMPATT oscillators which cover the entire Ka-band (26-40 GHz) have been developed. The noise characteristics of these oscillators have been extensively evaluated. Noise figure ranging from 7 to 14 dB DSB has been achieved for a receiver using these scanning L. O. units demonstrating the feasibility of using these bias-tuned IMPATT oscillators as the swept frequency L. O. for scanning receiver applications.

Design Considerations

The waveguide circuit for the scanning oscillator was designed with the goal of achieving a broad frequency tuning both mechanically and electronically while maintaining a reasonable output power level and good noise characteristics over the tuning range. A multiple-step quarter wave-length impedance transformer is used to reduce the waveguide impedance near the diode. An inductive post contact is used to provide the required dc bias current to the diode.

The IMPATT diodes used for this work are single-drift p^+nn^+ silicon diffused junction diodes with breakdown in the range of 26 to 28 volts and zero-bias capacitance in the range of 2.0 to 3.3 pf. They are sealed in quartz package with extremely low package parasitics which are essential for achieving broadband and low noise.

In order to achieve low noise over the entire sweeping range of frequency, it is essential that the circuit impedance has no loops and no acute angle intersection with the locus of the device impedance. When circuit impedance has loops in the frequency range of interest, jumps in power and frequency occur as the bias current is varied. High noise are usually observed before the jump. This is because the angle which the loci of the device and circuit impedances intersect approach zero and the AM noise is inversely proportional to the sine of this angle. On the other hand, broadband noise may occur simply because this angle is small and not necessarily due to the existence of loops. High noise conditions may also arise due to a high content of second harmonic. It is well known that the device impedance at the fundamental frequency is also a function of both the amplitude and phase of the second harmonic. The device impedance at the fundamental frequency may be perturbed significantly when the content of second harmonic is high. High noise conditions again may occur when the angle between the device and circuit impedance loci is small. Therefore, in order to achieve low noise characteristics for the IMPAT L. O. over a wide range of frequency, elimination of loops in circuit impedance and suppression of second harmonic and bias circuit oscillation are the primary goal for achieving good noise characteristics.

Performance

Two bias-tuned IMPATT oscillators which cover the entire Ka-band have been developed. Figures 1, 2, and 3 show respectively the dc bias current, output power and AM noise of both units as a function of frequency. For each unit, continuous frequency tuning with output power ranging from 1 mW to 40 mW over a frequency range of 9 GHz was obtained. This power level is sufficient for typical millimeter-wave mixer applications. A double sideband AM noise-to-carrier ratio ranging from -113 to -125 dB (measured with B = 100 Hz and f_m = 50 KHz) has been achieved.

Noise figure of a receiver using these scanning local oscillators and a balanced mixer was also measured over a frequency range of 30 to 38 GHz (see Figure 4). DSB noise figure ranging from 7 to 14 dB has been achieved. For frequencies other than this range in Ka-band the VSWR at L. O. port of the mixer was too high to obtain meaningful noise figure measurement. However, since the AM noise characteristics of the scanning L.O. units do not vary significantly in the frequency ranges below 30 GHz and above 38 GHz it is expected that relatively low noise figure can also be obtained in these frequency ranges with the scanning L.O. and a properly designed mixer. The effect of AM noise of scanning L.O. on the receiver noise figure can be minimized by improving the balance of mixer diodes. This is illustrated in Figure 5 in which the total receiver noise figure vs. AM noise of L.O. are calculated for five values of L.O. noise suppression factor α. It can be seen that the balanced mixer used in the experiment has an α of 25 dB and that a lower receiver noise figure can readily be achieved with a balanced mixer having a higher value of α.

Conclusions

We have demonstrated the feasibility of low noise, wideband solid-state scanning local oscillators with the effective use of the electronic tuning characteristics of IMPATT diodes at millimeter-wave frequencies.

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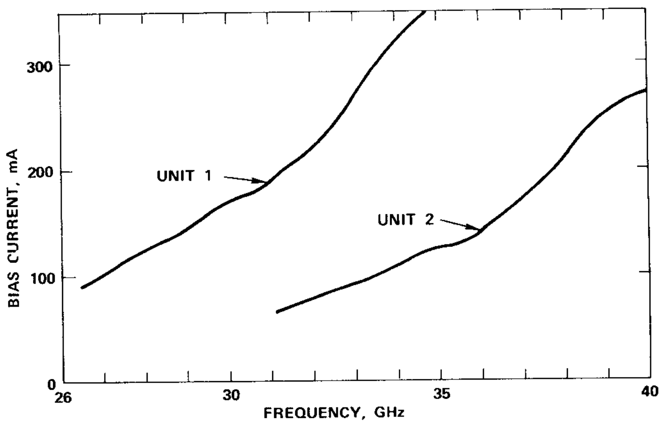

Figure 1 Bias current vs. scanning frequency.

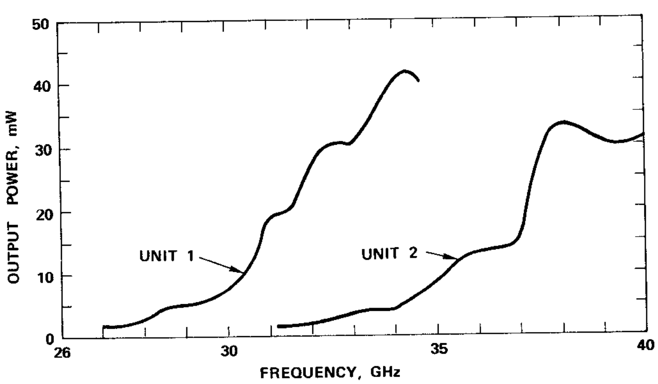

Figure 2 Output power vs. scanning frequency.

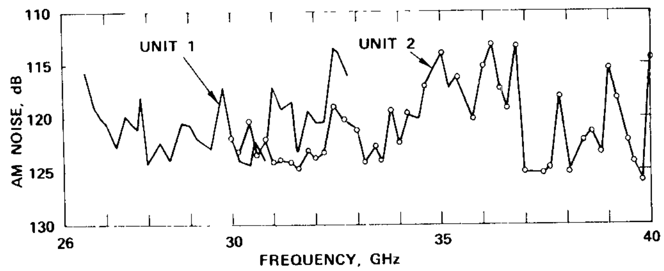

Figure 3 Double sideband AM carrier-to-noise ratio in a bandwidth of 100 Hz and at a frequency 50 KHz away from carrier.

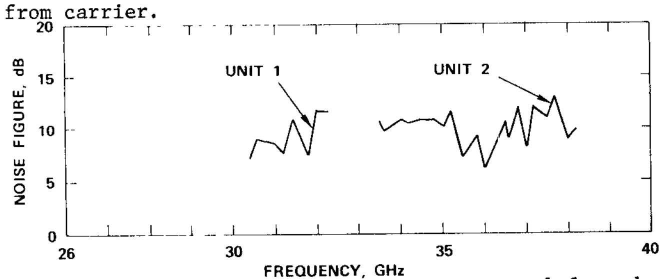

Figure 4 Noise figure of a receiver using a balanced mixer and the scanning L.O. units characterized in Figures 1-3.

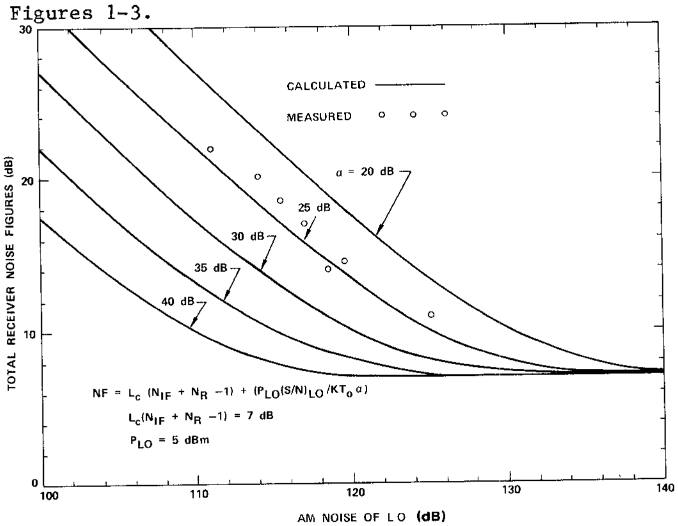

Figure 5 Effect of L.O. noise on receiver noise figure. (AM noise of L.O. is measured in a bandwidth of 100 Hz at 50 KHz from the carrier.)