MICROSTRIP VARACTOR-TUNED MILLIMETER WAVE IMPATT DIODE OSCILLATORS*

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Abstract

This paper describes varactor-tuned millimeter wave IMPATT diode oscillators in microstrip form using chip-mounted diodes. A combined tuning range of 26-39.2 GHz with 2-28 mW of rf power was achieved with two oscillators.

I. Introduction

This paper describes the development of electronically tunable mm-wave oscillators operating at Ka-band for use as local oscillators in wide band receivers. The approach was to build a varactor-tuned Impatt diode oscillator in microstrip form using chip mounted diodes to keep parasitics (that would restrict the attainable bandwidth) to an absolute minimum. The attractive features of this type of tunable source are the following:

1) A reasonably level output power over the tuning range.
2) Rapid tuning since only changes in varactor voltage are involved.
3) Low AM and FM noise using fixed bias p-type IMPATT diodes.
4) Small size and easy integration with other receiver components into a microwave integrated circuit package.

II. Technical Discussion

A. Diodes

The rf power source is a complementary N^+PP^+ IMPATT diode which had been proven to offer high efficiency, high power, and low noise operation at K- and Ka-band frequencies in a waveguide disc-cavity structure[1]. A power output of 500 mW at 10% efficiency was achieved. Furthermore, the diodes were able to be mechanically tuned over the full Ka-band range with a minimum power output of 360 mW and a minimum efficiency of 6.5%. The high efficiency of these diodes is partly attributed to their extremely low contact resistance obtained by having very thin, highly doped N^+ and P^+ layers with an integral copper heat sink.

For the tuning varactor the same type of diodes as described above were selected because of their low contact resistance and reasonably high capacitance ratio. A plot of the series resistance and capacitance versus voltage for a typical diode used as a varactor is shown in Figure 1. These values were obtained by using standard Q-measurement techniques with a UHF coax cavity.

B. Oscillator Configuration

The type of circuit chosen for the varactor-tuned oscillator was a series tuned circuit with the load impedance in shunt with the active device. A sketch showing how the Impatt and varactor diodes were arranged with respect to the fixed inductance (in the form of a bond wire) and the output circuit is given in Figure 2. As long as the load impedance is high ($\gtrsim$ 200 Ω), this shunt-loaded series tuned circuit will have a tunable bandwidth very close to that obtained with the series-loaded series tuned circuit.

A drawing of the complete oscillator circuit is shown in Figure 3. It employs wideband Chebyscheff band-reject filters for the bias circuits of the IMPATT and varactor diodes, a broadband tapered ridge waveguide-microstrip transition, and a two section $\lambda g/4$ impedance transformer in the output circuit. The filters were demonstrated to have 33-50 dB of rejection over the entire Ka-band range while the waveguide-microstrip transition had < 0.5 dB loss over the same range. The impedance transformer on the microstrip output line was designed to present a 300 Ω load impedance to the IMPATT diode. For the microstrip line, 10 mil thick Duroid enclosed in a channel of height .100" and width .130" was used as a substrate.

III. Experimental Results

Various tunable oscillators of the structure described above were tested and their bandwidth agreed within 10% of that predicted by theory for a series tuned circuit. To obtain this agreement the frequency dependence of IMPATT capacitance as shown by Ohtomo[2] had to be taken into account. The results with two oscillators having a combined tuning range of 26-39.2 GHz and a power output of 2-28 mW are shown in Figures 4 (a) and 4 (b). Note the nearly constant output power of 20 mW ± 1 dB over the 26.5-31.5 GHz range. For this test only 40 ma of bias current was applied to the diode and the overall conversion efficiency was 1.3%. The ability to obtain level output power was demonstrated by another test which gave 28 mW ± 1.5 dB over a 6 GHz tuning range. A tunable bandwidth as high as 8 GHz with 6-26 mW of output power was also achieved.

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IV. Conclusions

We have succeeded in designing and building broad tunable bandwidth mm-wave microstrip oscillators using p-type IMPATT diodes for both the power source and the tuning function. Their level output power and compatibility with other components in a microwave integrated circuit package make them ideal for use in wide-band mm-wave receivers. It is believed feasible that with the proper capacitance diodes, one microstrip oscillator can be electronically tuned over the entire Ka-band range.

References

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2. M. Ohtomo, "Broad-Band Small Signal Impedance Characterization of Silicon (Si) P^+-N-N^+ Impatt Diodes", IEEE Trans. Microwave Theory Tech., vol. MTT-22, pp. 709-717, July 1974.

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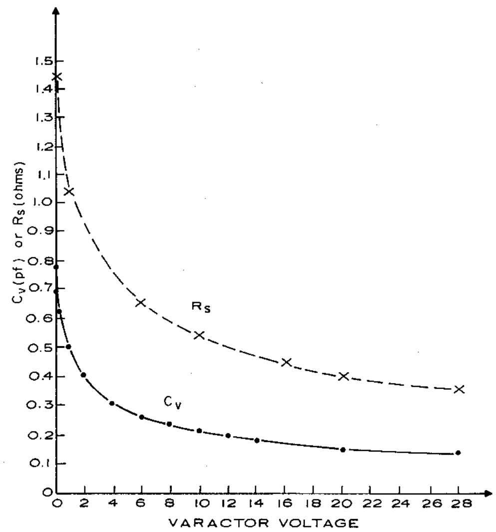


Figure 1. Varactor Series Resistance and Capacitance Versus Bias Voltage

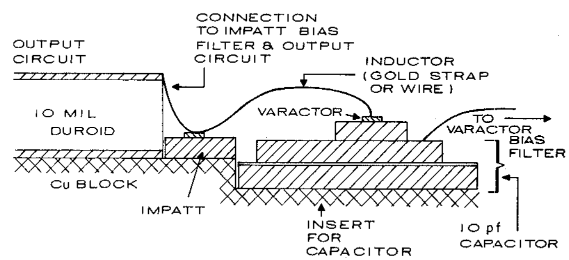


Figure 2. Shunt-loaded Series Resonant Circuit Configuration with Impatt and Varactor Diodes

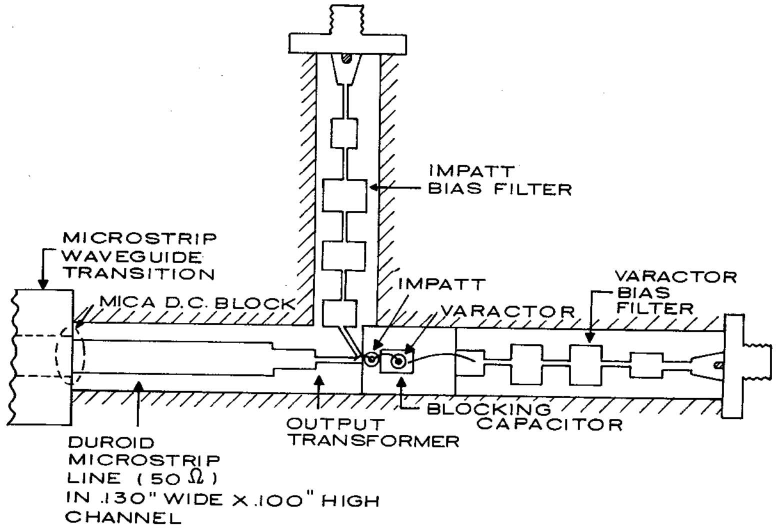
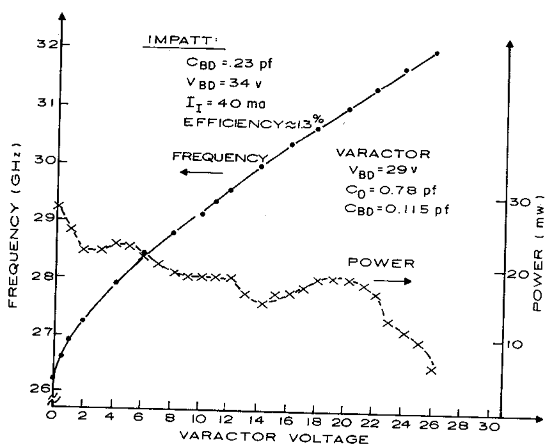
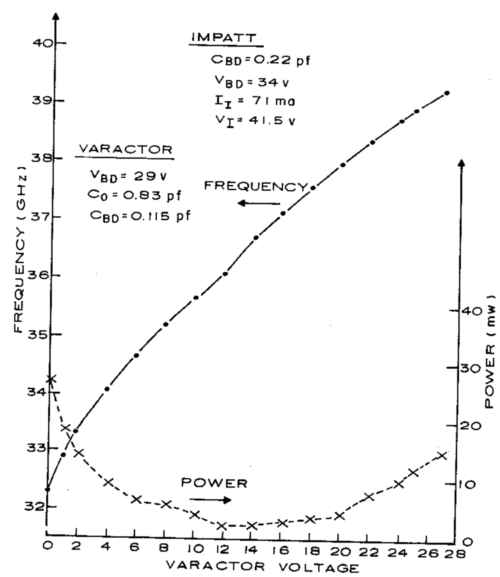


Figure 3. Drawing of Oscillator Circuit with Broad-band Bias Filters



(a) Low Frequency Unit



(b) High Frequency Unit

Figure 4. Oscillators with Combined Tuning Range of 26-39.2 GHz