VARACTOR TUNED GUNN OSCILLATORS
WITH WIDE TUNING RANGE FOR THE
25 TO 75 GHz FREQUENCY BAND

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ABSTRACT

Wideband electronic tuning (to 13 GHz) has been achieved at millimeter wavelengths with varactor tuned Gunn oscillators (VCO's) by use of a simple, lumped element circuit. The VCO's operate as fundamental oscillators in the 25 to 40 GHz band and as second harmonic oscillators in the 50 to 75 GHz band.

Introduction

Wideband, varactor tuned Gunn oscillators (VCO's) at millimeter wavelengths occupy a prominent position in present and future receiver systems. This paper describes advances that have been made in the reported[1,2] tuning bandwidth of 1 to 3 GHz and frequency range of 35 to 38 GHz for millimeter-wave Gunn VCO's. By use of a simple, lumped element circuit, VCO tuning bandwidth of up to 13 GHz has been achieved in a series of miniature Gunn VCO's for the 25 to 75 GHz range. The VCO's operate as fundamental oscillators in the 25 to 40 GHz band and as second harmonic oscillators in the 50 to 75 GHz band. Previously reported[3,4] results with Gunn VCO's of a lumped element type have been in X- and Ku-bands (to 17 GHz) with fundamental oscillators.

This paper will also describe a new method that was used to measure the equivalent circuit parameters of the packaged Gunn diode. This characterization provided an accurate design model of the VCO from which performance could be reliably predicted.

Technical Discussion

Gunn diode oscillators built in distributed-type circuits such as waveguide, coax, or microstrip have been widely reported. The discrete element VCO circuit to be described closely approximates a lumped element circuit which has the advantage of being inherently more broadband than a distributed-type circuit. The validity of using a lumped element approximation for the VCO circuit has been verified by measurements, and follows from the use of circuit elements which are sufficiently small (electrically) that they can be functionally characterized as lumped components.

Figure 1 shows an assembled lumped element VCO circuit in Ka-band (26.5 to 40 GHz), its circuit diagram, and simplified equivalent circuit. This fundamental VCO has been reduced to an elemental form as evidenced by the minimal parts count and miniature circuit size (0.100 × 0.100 inch). The discrete circuit

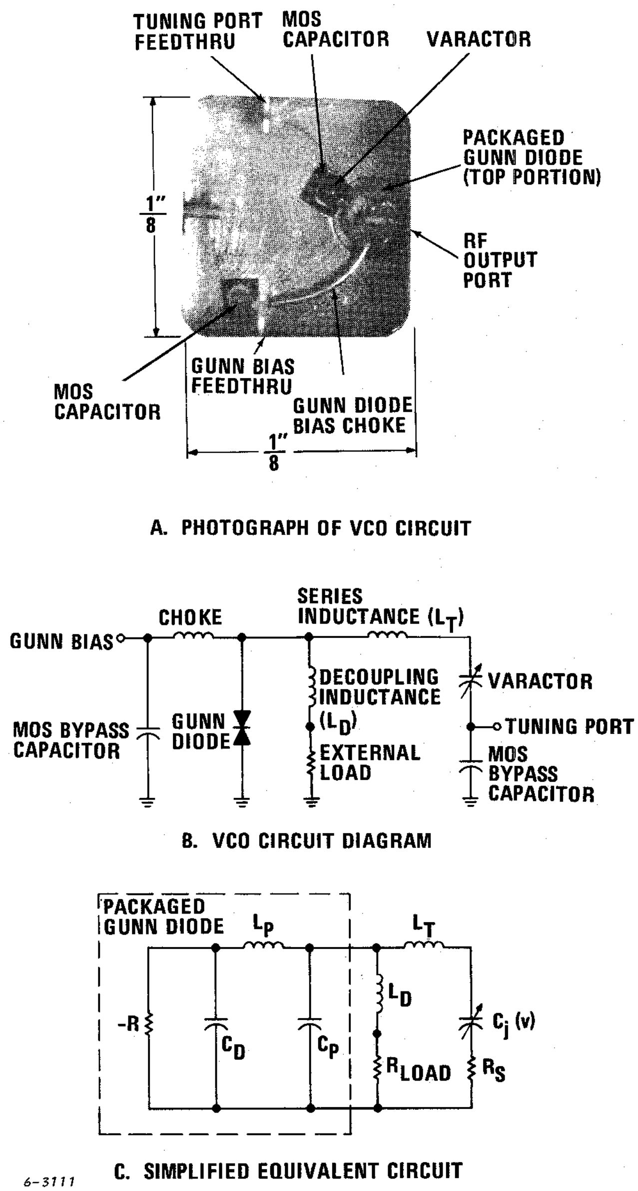

Figure 1. Lumped Element, Varactor Tuned, Gunn Diode Oscillator in Ka-Band (26.5 to 40 GHz)

elements consist of a packaged Gunn diode, a chip varactor, and two chip capacitors. The inductive elements, L_T and L_D, are short lengths of line which provide the electrical connection between the discrete elements. The lines are sufficiently short that they are, in effect, lumped inductive elements. Line lengths are not critical since line inductance is trimmed by a simple adjustment of the height of the arced line above ground. The Gunn diode bias choke is approximately a quarter-wavelength long. The basic simplicity of this VCO circuit, the small number of circuit elements, and the functional use of all element interconnections enabled wideband, continuous, and spurious-free tuning to be achieved at millimeter wavelengths.

Figure 2 shows an assembled VCO in a waveguide housing. The VCO circuit (Figure 1) was assembled in a recess under the screw attached cover. The probe, which extends from the top wall of the output waveguide, is a portion of a coax-to-waveguide adapter from the VCO circuit. Although oneport of the output waveguide is normally terminated in a short circuit, the VCO can be operated with dual-output ports for such applications as frequency locking or power dividing.

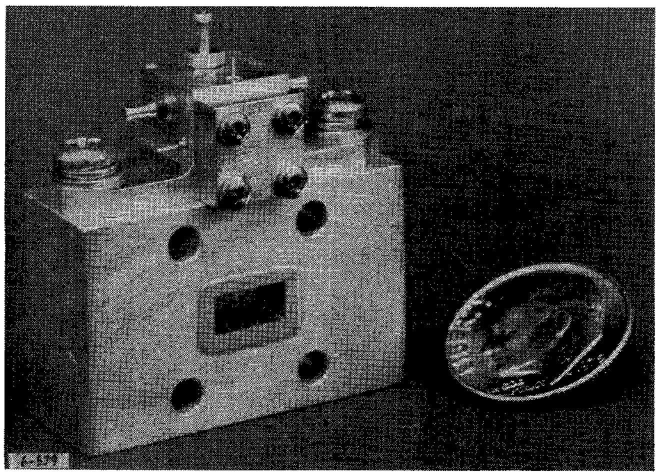

Figure 2. Lumped Element, Varactor Tuned, Gunn Diode Oscillator in Ka-Band

Both VCO's and fixed-frequency oscillators were built in the physical form shown. In the fixed-frequency models, the varactor was replaced with a chip capacitor. The measured performance of the VCO's and fixed frequency oscillators was in close agreement with the calculated performance. Figure 3 shows the measured tuning and output power characteristics of a Ka-band, fundamental VCO. This VCO tuned continuously from 29 to 36 GHz with maximum output power of +12 dBm at 36 GHz. The 7-GHz tuning range was obtained with only a 3.2 to 1 varactor capacitance variation. The Gunn diode was vendor rated at 35 GHz. Figure 4 shows measured results with fixed frequency oscillators. The data was obtained with a broadband

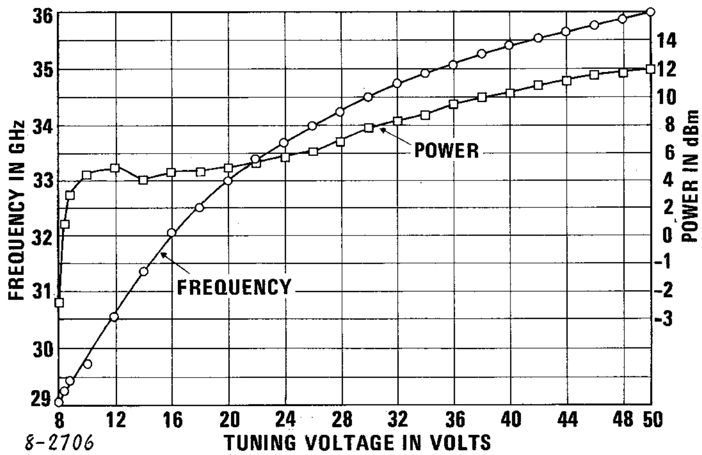

Figure 3. Varactor Tuned, Fundamental Gunn Oscillator

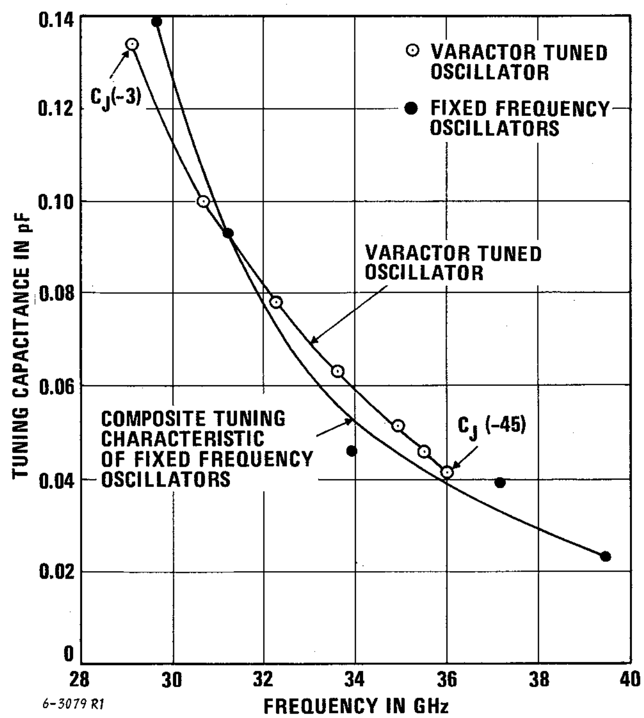

Figure 4. Measured Composite Tuning Characteristic of a Series of Lumped Element Fixed Frequency Gunn Diode Oscillators and a Varactor Tuned Gunn Oscillator

Gunn diode that was tuned by a series of fixed chip capacitors. Tuning capacitance is plotted versus frequency for this series of oscillators. The output power of these oscillators ranged from 80 mW at the low frequency end to 30 mW at the high end of the range. A composite tuning characteristic for the series of oscillators is shown. The tuning characteristic of the VCO whose performance was shown in Figure 3 is also plotted in Figure 4. These tuning data are in close agreement over the 7-GHz VCO tuning range achieved to date. The comparative results indicate that a 10-GHz VCO tuning capability can be expected with a broadband Gunn diode and a varactor with a 6 to 1 capacitance ratio.

In the frequency range above 50 GHz, tuning ranges greater than 10 GHz were achieved by using the second harmonic generated by the Gunn diode. The physical form of the VCO is similar to that shown in Figure 2, but with the addition of a filter to reject the fundamental from the output. Figure 5 shows the performance of a VCO which tuned continuously from 50 to 60 GHz. The average power across the 10-GHz tuning range is 0.65 mW. Output power is a function of VCO circuit loading at both fundamental and second harmonic. Figure 6 shows the tuning characteristic of a VCO that tuned from 58 to 71 GHz, a tuning range of 13 GHz.

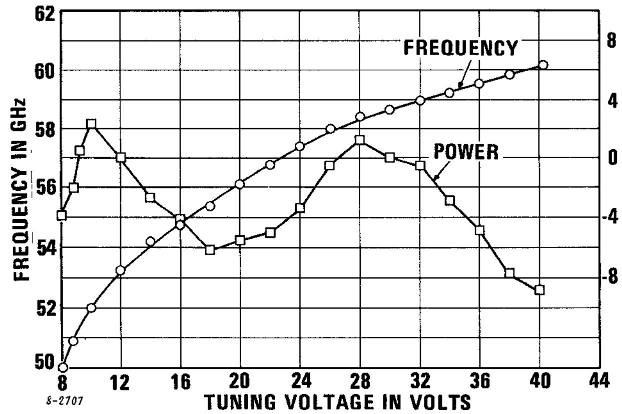

Figure 5. Varactor Tuned, Second Harmonic, Gunn Oscillator

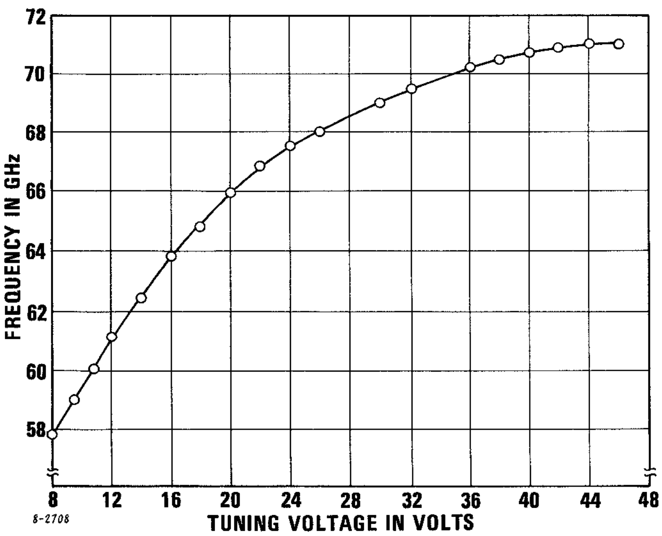

Figure 6. Varactor Tuned, Second Harmonic, Gunn Oscillator

A characterization of the Gunn diode and its package was essential for an accurate analytical design model of the VCO. The equivalent circuit parameters of the packaged Gunn diode (Figure 1C) were measured using a modified form of the VCO shown in Figure 1A. By lightly coupling the test VCO to a sensitive detector, the unknown elements in the VCO circuit were reduced to the Gunn diode capacitance C_D, packaged inductance L_p, and package capacitance C_p. The values of these three elements followed from a solution of the circuit equations at resonance for measured values of oscillation frequency corresponding to three known perturbations of varactor capacitance. Characterizing the Gunn diode in the frequency range of use provided an accurate design model which resulted in close agreement between calculated and measured VCO performance.

Conclusions

Recent work with millimeter-wave, wideband, varactor tuned Gunn oscillators in a lumped element circuit configuration has been described. Fundamental and second harmonic type millimeter-wave VCO's were developed which demonstrate advances in terms of tuning bandwidth and frequency range. Further improvements in VCO output power and tuning are expected with work in progress with broadband Gunn diodes and hyperabrupt junction varactors.

Acknowledgements

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