MILLIMETER-WAVE, LUMPED-ELEMENT, GUNN VCO'S WITH ULTRAWIDEBAND (20 GHz) TUNING

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ABSTRACT

A new millimeter-wave Gunn VCO with ultrawideband tuning has been developed and modeled. The VCO is tuned at its reactively terminated fundamental frequency and output is obtained from the in-situ generated Gunn diode second harmonic. Measured state-of-the-art performance includes continuous tuning from 46 to 66 GHz, a 20-GHz tuning range, with a maximum power output of +6 dBm.

INTRODUCTION

Recently reported results have shown that the intrinsic advantages of a lumped-element circuit form can be realized in practice at millimeter wavelengths with oscillators, VCO's (1), and mixers (2). These advantages include broadband, continuous and spurious free performance, circuit loss comparable to that of a waveguide circuit, miniature circuit size, simple circuit topology and greater resolution and accuracy in circuit modeling and performance analysis as compared to commonly used distributed type circuits. The virtues of lumped-element circuit technology have been used as the basis for the development of an ultrabroadband Gunn VCO that is varactor tuned over the 46- to 66-GHz band, a tuning range of 20 GHz. This tuning capability exceeds that of currently available VCO's in this frequency band by a factor of five. These new ultrawideband VCO's can be used for full waveguide band fast-tuning drivers in EW applications, for wideband swept local oscillator receivers, and for instrumentation applications.

Technical Discussion

New VCO results and technology that will be presented in this paper are as follows:

- A new lumped-element circuit for an ultrabroadband, second harmonic, varactor-tuned, Gunn VCO
- A measured continuous tuning range of 20 GHz in a V band (50 to 75 GHz) VCO, which is five times the tuning capability of existing Gunn VCO's in this waveguide band
- A linear tuning range of 9 GHz, which is 45 percent of the total tuning range
- In-situ second harmonic generation in the Gunn diode, eliminating the need for a separate broadband doubler circuit
- Efficient and broadband Gunn diode second harmonic generation by reactively terminating the varactor-tuned fundamental oscillation close to the Gunn diode
- Modeling and analysis results of lumped-element second harmonic Gunn VCO's, including quantification of the model elements. Excellent agreement has been obtained between the measured and calculated tuning characteristics
- Increased immunity to load pulling as compared to a fundamental output VCO. This translates to the elimination of an output isolator in many applications

The second-harmonic Gunn VCO is designed to varactor tune the Gunn diode at fundamental frequency and to use the in-situ generated Gunn second harmonic as output. The fundamental oscillation is reactively terminated close to the Gunn diode. This has the favorable effect of enhancing the tuning capability of the VCO since the intrinsic diminishing effect on tuning range of resistive loading is eliminated.

A circuit diagram and layout of a second-harmonic, lumped-element, Gunn VCO for a V band (50 to 75 GHz) VCO is shown in Figure 1. The lumped-element concept is based on the use of circuit elements that are sufficiently small that they can be

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characterized as lumped components. The 0.074 in. x 0.074 in. notch into which the lumped-element circuit is assembled is sized to be cutoff to waveguide modes in the output frequency range of interest, thereby providing integrity to the lumped-element circuit form. The discrete circuit elements consist of a packaged Gunn diode, a hyperabrupt junction GaAs chip varactor, and three MIS chip capacitors. The inductive elements are the short lengths of line that provide the electrical connection between the discrete elements. The Gunn and varactor diode bias chokes are nominally a quarter wavelength long at the center of the output frequency band. The second harmonic output is capacitively coupled from the circuit and transmitted to a WR-15 section of output waveguide by means of the small diameter coax (0.034 in. OD) shown in Figure 1. The coax center conductor at the waveguide end of the coax is designed to provide a broadband transition from the nominal 50-ohm level of the VCO circuit to the nominal 400-ohm impedance level of waveguide. The output waveguide is cutoff to the fundamental frequency band which enables the Gunn diode to be reactively terminated in this frequency range.

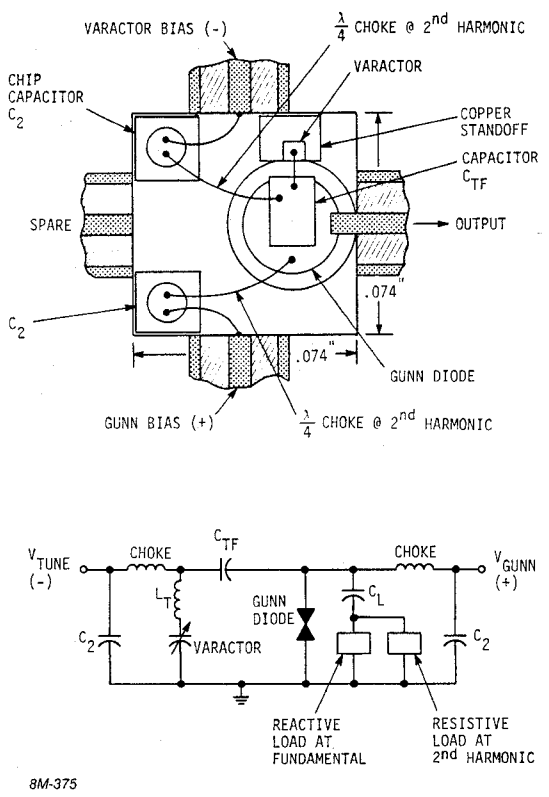

Figure 1. Layout of V-Band, Second-Harmonic, Lumped-Element, Gunn VCO

The circuit model of the second harmonic Gunn VCO is shown in Figure 2, including the coax line (Z_L, P_L, K_L) from the Gunn diode to the output waveguide section and the Gunn and varactor bias lines (Z_B, P_B, 1). Each bias choke is a thin wire above ground (K_B = 1). The circuit elements in the model were quantified in the manner described in our previous paper (1). The calculated tuning

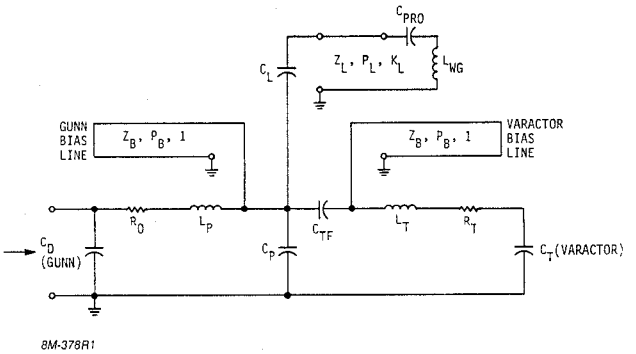

Figure 2. Equivalent Circuit Model of Second-Harmonic, Varactor-Tuned, Lumped-Element, Gunn Oscillator

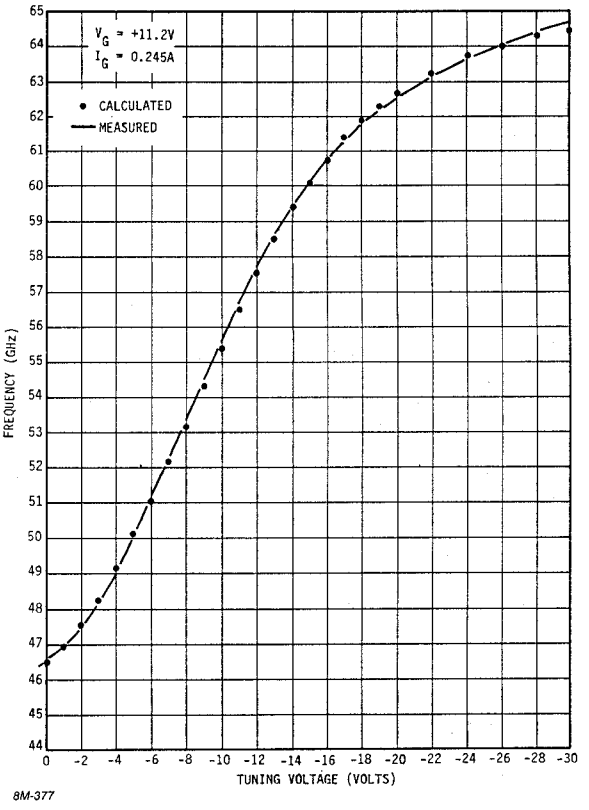

Figure 3. Calculated and Measured Tuning Characteristics of Second-Harmonic, Lumped-Element, Gunn VCO

characteristic of an InP Gunn VCO, based on the quantified model, is shown in Figure 3 and compared to the measured characteristic. The tuning characteristics are in close agreement, the maximum frequency difference being 0.6 percent.

A breadboard model of a second harmonic InP Gunn VCO is shown in Figure 4. The assembly has dual output ports. The tuning and output power characteristics of the VCO are shown in Figure 5. For these measurements, a fixed short was used at one of the output ports and was set for maximum VCO tuning range. The VCO tuned from 46.4 to 64.7 GHz, an 18.3-GHz tuning range, with a maximum tuning voltage of -30 volts. Linear tuning was exhibited over a 9-GHz tuning range, from 48.7 to 57.7 GHz, with a corresponding tuning voltage range of -4 to -12 volts. An additional 1.2 GHz of tuning was obtained with an increase of tuning voltage to -46 volts. Zero varactor current was observed over the full tuning range. Calculations indicate 2 GHz of additional tuning at the low end of the band with use of a dc blocking capacitor (C_{TF} in Figure 1) of higher value than the 1.5 pF capacitor used in the breadboard model. The 1.5 pF blocking capacitor was comparable to the 1.95 pF zero bias capacitance of the hyperabrupt junction tuning varactor.

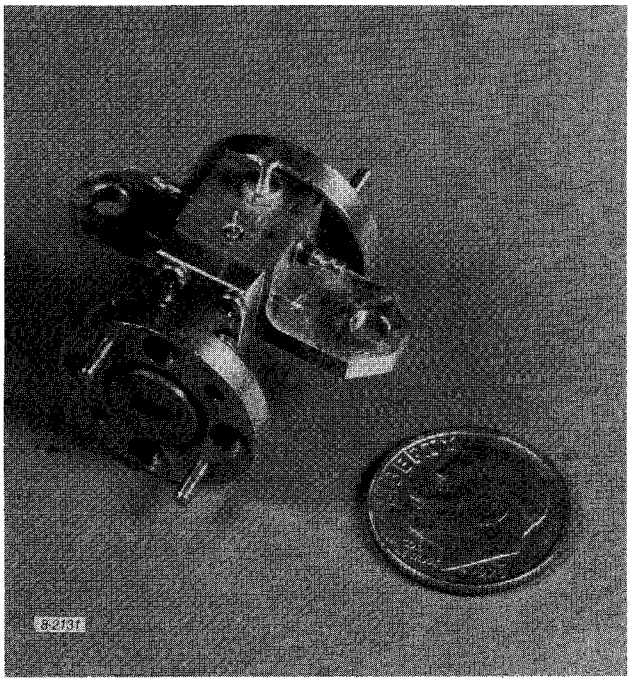

Figure 4. V-Band (WR-15), Lumped-Element, Second-Harmonic, Gunn VCO

Hence, the tuning range and linearity at the low end of the band in the data shown in Figure 5 was diminished by the padding of the varactor capacitance by capacitor C_{TF}. Both GaAs and InP Gunn diodes have been used and the best performance to date has been obtained with InP diodes.

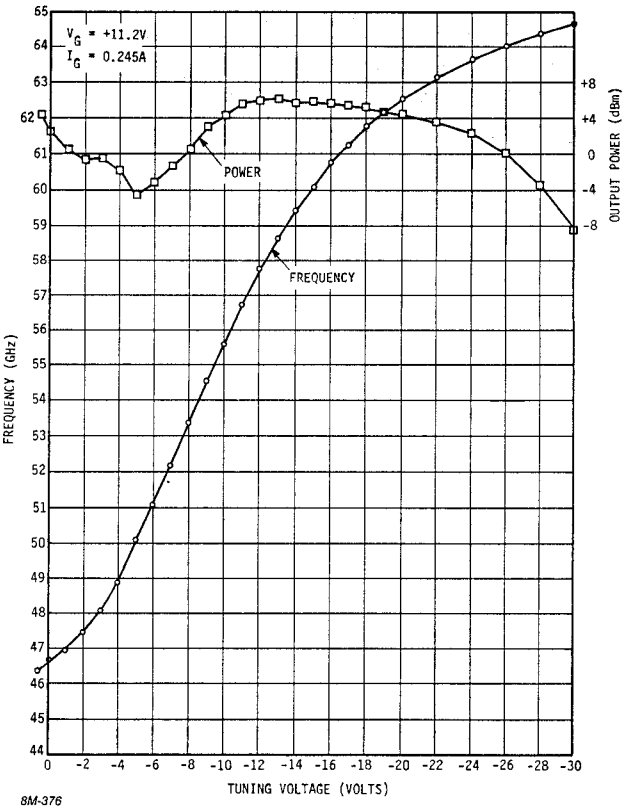

Figure 5. Measured Performance of Second-Harmonic, Lumped-Element, Gunn VCO

SUMMARY

The development and performance of a state-of-the-art millimeter-wave ultrabroadband VCO has been described. The VCO is varactor tuned at fundamental frequency and output is obtained from the in-situ generated Gunn diode second harmonic. Inherently broadband tuning capability is provided by the use of a lumped-element circuit form, reactively terminating the varactor-tuned fundamental oscillation band, and the use of the in-situ generated Gunn second harmonic as output. The measured VCO performance presented demonstrates the capability for full waveguide band tuning in U band (40 to 60 GHz). It is projected that the VCO technology can be extended to provide full waveguide band VCO's to at least V band (50 to 75 GHz).

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