A MILLIMETER-WAVE, THIRD-HARMONIC, GUNN VCO WITH ULTRA-WIDEBAND TUNING

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ABSTRACT

State-of-the-art ultra-wideband tuning (69 to 91 GHz) has been demonstrated with a third-harmonic, varactor-tuned, GaAs Gunn oscillator. The 22-GHz wide tuning band was obtained by tuning the voltage controlled oscillator (VCO) at fundamental frequency and using the in-situ generated Gunn-diode third harmonic for output. This is the first reported operation of a third-harmonic Gunn VCO.

INTRODUCTION

A VCO technique will be described that has enabled state-of-the-art ultra-wideband tuning (69 to 91 GHz) to be demonstrated with a varactor-tuned Gunn oscillator. Ultra-wideband VCO's offer creative opportunities to designers of Electronic Warfare (EW) systems, swept local oscillator receivers, and instrumentation equipment since they provide a means to realize simpler system architectures, smaller size, lower power consumption, and lower cost in addressing new and retrofit system needs.

Millimeter-wave, varactor-tuned Gunn oscillators are conventionally built as fundamental or second harmonic VCO's in various distributed circuit forms (waveguide, microstrip, etc.) and have been widely reported. Our recently published results (1, 2, and 3) have reported a significant increase in VCO tuning range by use of a lumped element rather than a distributed type circuit since a lumped-element circuit is inherently more broadband. In the work reported herein, an advance in the state of the art of widely tunable millimeter-wave VCO's has been achieved with a third-harmonic, varactor-tuned, Gunn oscillator built in lumped-element circuit form. The VCO is tuned at a fundamental frequency from 23 to 30.33 GHz which is tripled to 69 to 91 GHz, a 22-GHz tuning band, by the in-situ generated third harmonic of the Gunn diode. The in-situ harmonic generation in the Gunn diode is inherently broadband and eliminates the need for an external tripler.

The work to be reported in this short paper is an extension and enhancement of the lumped-element VCO technology previously reported by AIL Systems Inc. (1, 2, and 3) with fundamental and second harmonic Gunn VCO's. The new results to be reported include the following:

- First reported description and performance of a VCO that uses Gunn-diode third harmonic for output. Previously reported VCO's have been of the fundamental and second harmonic type.
- Measured ultra-wideband tuning bandwidth of 22 GHz (69 to 91 GHz) with a varactor-tuned Gunn oscillator. This state-of-the-art tuning capability (27.5% of center frequency) is 1.7 times the largest continuous tuning bandwidth previously reported in this frequency region with a Gunn VCO (4).
- Lumped-element VCO circuit refinements that have resulted in the frequency extension of the use of lumped-element VCO circuit technology to 91 GHz in W-band (WR-10) from the previously reported maximum frequency of 66 GHz in V-band (WR-15) (1).

TECHNICAL DISCUSSION

The layout and equivalent circuit model of a W-band third-harmonic, lumped-element, Gunn VCO are shown in Figures 1 and 2, respectively. The circuit model of the third-harmonic VCO is a modification of that for a second-harmonic VCO previously described by us (1). The lumped-element concept is based on the use of circuit elements that are sufficiently small that they can be characterized as lumped components (2). The discrete circuit components are a packaged Gunn diode, a chip varactor, and four chip capacitors. The Gunn and varactor bias chokes are quarter wavelength lines. The miniature size of the VCO circuit elements enables the VCO circuit to be assembled in an area nominally 5/64 x 5/64 in. The multiplicity of short lines attached to by-pass capacitor C_3 presents an equivalent lumped inductance (L'_p in Figure 2) in parallel with the Gunn-diode package capacitance (C_p). These lines are trimmed in number to tune out the Gunn diode package capacitance. The RF output line is a short length of 0.034-in. diameter coax and is inductively coupled (L_L) to the Gunn diode. The center conductor at the output end of the coax is sized to provide a broadband coax to waveguide transition to a short section of VCO output waveguide (Figure 3) that is cutoff to fundamental and second harmonic frequencies.

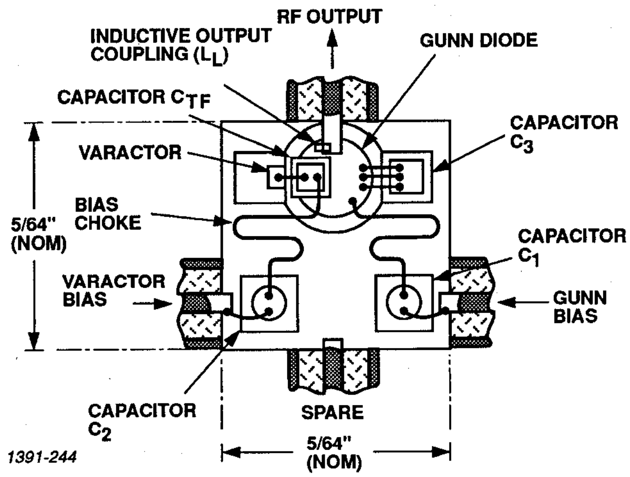

Figure 1. Circuit Layout of a Wideband, Third-Harmonic Lumped-Element, Gunn VCO

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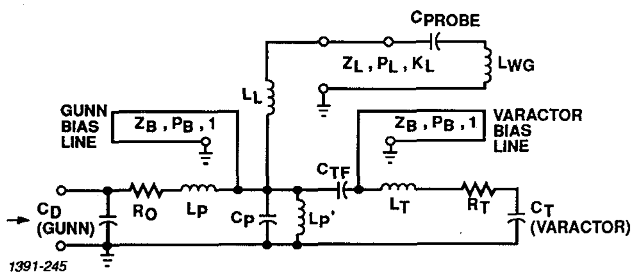

Figure 2. Equivalent Circuit Model of a Third-Harmonic, Varactor-Tuned, Lumped-Element, Gunn Oscillator

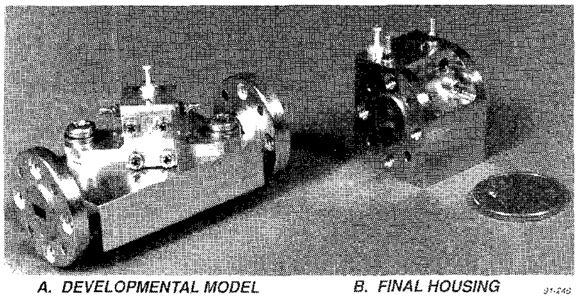

Figure 3. Millimeter-Wave, Third-Harmonic, Gunn VCO

Since the output waveguide is cut off to energy propagation at fundamental frequency, the tuning circuit is isolated from the load and reactively terminated, thereby enhancing its tuning capability and Q-factor and eliminating the need for an output isolator. The active element used in the developmental VCO was a Varian high efficiency (5.2%), Ka-band, GaAs Gunn diode. The fundamental frequency range of 23 to 30.33 GHz was tuned with a Microwave Associates hyperabrupt junction GaAs varactor with a junction capacitance of 0.4 pF at –4 V and a gamma factor of 1.25. The developmental model and the final housing for the VCO are shown in Figure 3. The VCO circuit is assembled in a small cutout under the screw attached cover. Both models have dual waveguide output ports.

The measured tuning and output power characteristics of the developmental VCO are shown in Figure 4. This data was obtained with a fixed short at one of the two output ports of the VCO. The VCO tuned continuously and smoothly from 69 to 91 GHz, a tuning bandwidth of 22 GHz, corresponding to 27.5% of center frequency. The smooth and continuous nature of the tuning characteristic over this ultra-wideband frequency range is notable and credited to the use of a lumped-element VCO circuit and in-situ third-harmonic generation by the Gunn diode. Third-harmonic operation was verified by measurement of the varactor-tuned fundamental frequency which was one-third of output frequency. The output spectrum of the VCO was examined with an HP 8566B Spectrum Analyzer and shows an insignificant level of second harmonic. Suppression of the second harmonic is an intrinsic feature of the VCO circuit. It has also been verified that the third-harmonic output was generated by the Gunn diode and not by the tuning varactor. The phase noise of the VCO has not been measured. Based on measurements previously made with a second-harmonic Gunn VCO at 61 GHz (1), the phase noise of the third-harmonic VCO is extrapolated to be –90 dBc/Hz at a 100 kHz offset frequency.

There is an intrinsic trade-off of output power with tuning range with use of third-harmonic output from a Gunn diode. As shown in Figure 4, the measured output power of the VCO ranged from –1 dBm to –13 dBm. This output is a sufficient local oscillator power level to drive a biased mixer or a low barrier height mixer. Higher output power is possible by complementing the VCO with a W-band wideband HEMT amplifier (5 and 6).

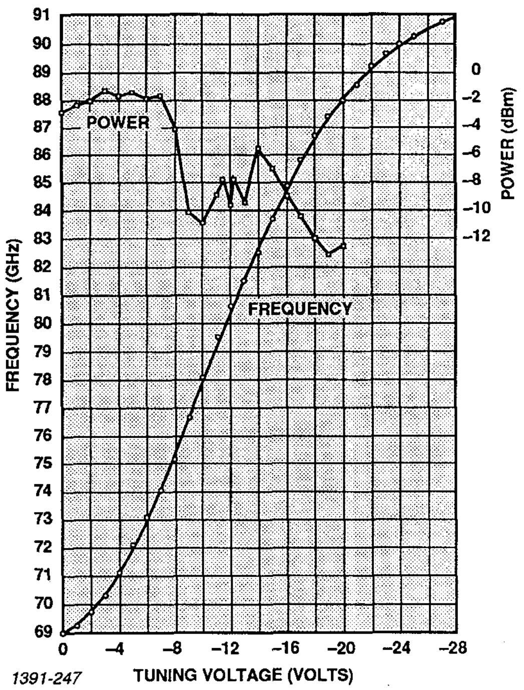

Figure 4. Third-Harmonic, GaAs Gunn VCO Tuning and Output Power Characteristics

SUMMARY

State-of-the-art ultra-wideband tuning (69 to 91 GHz) has been demonstrated with a third-harmonic, varactor-tuned, Gunn oscillator. These are the first reported results with a third-harmonic Gunn VCO and the 22-GHz tuning bandwidth is 1.7 times larger than that previously reported in this frequency range with a VCO. The VCO is tuned at fundamental frequency and output is obtained from the in-situ generated third-harmonic of the Gunn diode. The use of VCO's with ultra-wideband tuning presents new design opportunities to system engineers in their approach to meet the requirements of new and retrofit EW systems, wideband receivers, and instrumentation equipment. This technique will allow for simpler system architectures, smaller size, lower power consumption, and lower cost.

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