Discussion and Conclusions

This paper has shown how to construct general TE_{011}-mode circular-waveguide filters by demonstrating (theoretically and practically) the realization of both positive and negative coupling elements in a canonical form. The experimental filter responses indicate excellent agreement with theory. It has been shown that the degenerate TM_{111} mode can be effectively suppressed, and a suppression method has been analyzed and successfully implemented in the experimental filters. Finally, a method for temperature compensation of TE_{011}-mode cavities will be described in an accompanying paper [10]. This technique enables lightweight thermally stable bandpass filters to be constructed from aluminum instead of Invar and/or graphite-reinforced fibers. Significant savings in weight and cost of fabrication are therefore achieved.

Acknowledgment

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Short Papers

A Discriminator-Stabilized Microstrip Oscillator

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***Abstract*—A 5.2-GHz microstrip Gunn oscillator has been frequency stabilized by means of a novel microstrip discriminator and integrated feedback loop. A stabilization factor of 1000 was measured for the oscillator with an external *Q* of 50. The self-capture bandwidth of the discriminator circuit is large enough to eliminate the need for a search voltage to obtain initial frequency locking.**

I. Introduction

Solid-state oscillators have a relatively low-frequency stability and require frequency stabilization in order to be used as signal sources in radio communication systems. The purpose of this short paper is to describe a stabilization technique which is suited to microstrip oscillators. Stabilization can be achieved by several techniques, such as, frequency or phase locking to a stable reference signal, locking to a high-Q cavity, or by use of a discriminator circuit. Among these techniques, the discriminator scheme offers the possibility of a simpler and less costly stabilization circuit by using microstrip technology. A new thin-film discriminator is proposed in this short paper which can be readily integrated with a microstrip oscillator to provide high-frequency stability.

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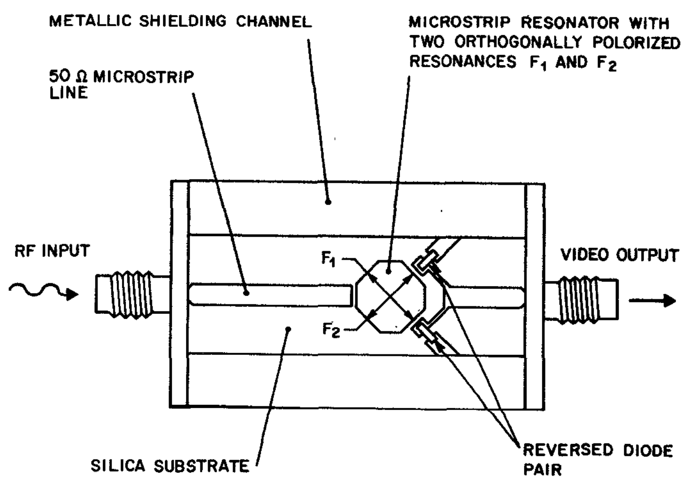

Fig. 1. Circuit configuration of the microstrip discriminator showing how each diode is capacitively coupled to one of the two orthogonal modes of the microstrip resonator.

II. Microstrip Discriminator

The thin-film discriminator is shown in Fig. 1. It consists of a double-mode microstrip resonator with a pair of detector diodes. The resonator has the geometrical shape of a rectangle with truncated corners and its electrical properties are similar to the resonator used in a recently developed thin-film millimeter-wave downconverter [1], [2]. The RF input signal excites two ortho-

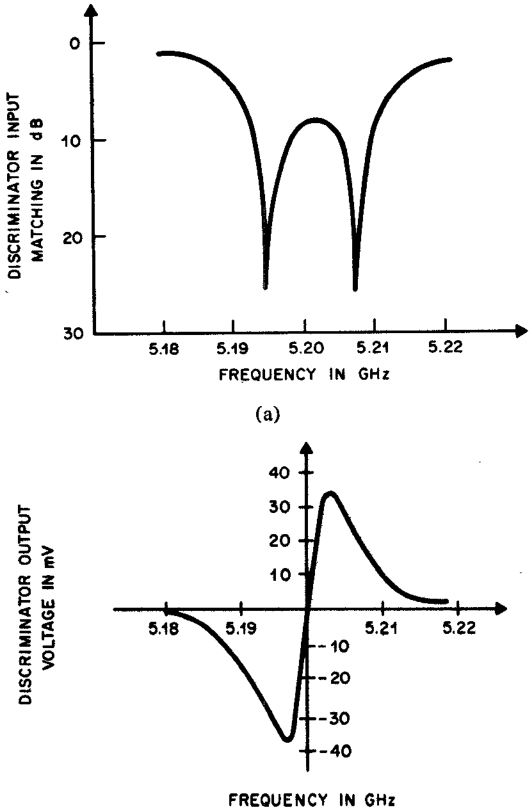

Fig. 2. (a) Return loss of the input signal injected into the discriminator. (b) Detected output signal of the discriminator.

gonal resonances, as shown in Fig. 2(a), which are determined by the electrical dimensions of the rectangular resonator. The transmitted signal is detected by a reversed diode pair giving the output signal shown in Fig. 2(b). Frequency tuning of the discriminator is achieved by either adjusting the resonator lengths or by dielectrically loading the resonator along the resonance axes.

III. Microstrip Oscillator

A microstrip Gunn oscillator was used to measure the stabilization performance of the discriminator. It employs a Microwave Associates Gunn-diode Model 49138 which can deliver up to 300 mW around 5 GHz. Frequency tuning for stabilization is obtained by means of a varactor capacitively coupled to the oscillator circuit. The varactor circuit can also be used for FM modulation in a frequency range above the cutoff frequency of the feedback loop. Fig. 3 shows the circuit configuration.

IV. Frequency-Stabilization Loop

A small fraction of the output signal of the oscillator (about -20 dB) is coupled to the microstrip discriminator. The oscillator, varactor, and discriminator circuits are deposited on the same silica substrate, as shown in Fig. 4. The discriminator output signal is amplified about 40 dB by a linear IC amplifier and fed with the proper phase to the varactor bias terminal. The IC amplifier output signal saturates at about ± 5 V over a frequency range much larger than the basic discriminator response, as shown in Fig. 5. This feature provides self-capture of the oscillator frequency to the discriminator center frequency over a frequency range which is many times wider than

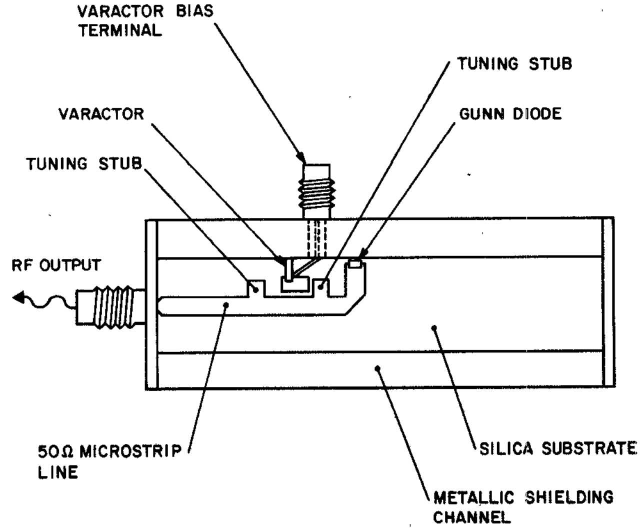

Fig. 3. Circuit configuration of the microstrip oscillator including the varactor circuit.

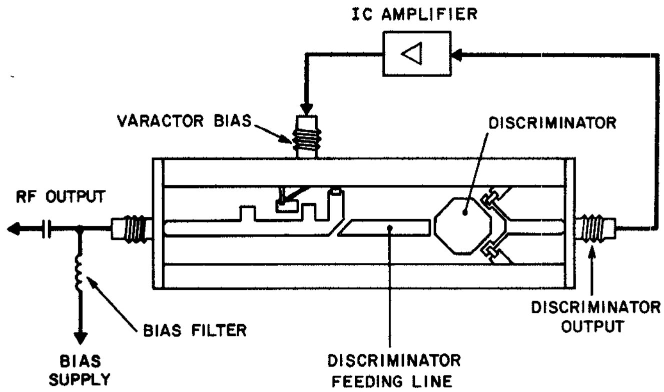

Fig. 4. Circuit configuration of the oscillator including the stabilization loop.

the discriminator locking range and eliminates the need of a search voltage to acquire the initial frequency lock.

V. Stabilization Measurements

The Gunn oscillator just described was adjusted to oscillate at 5.2 GHz. Its output power was very close to the diode maximum rated power of 300 mW. In order to test the stabilization loop, a 30-Hz ac voltage was applied in series with the dc bias circuit of the Gunn diode. The oscillator frequency was swept by 6 MHz around 5.2 GHz with an open feedback loop. The residual FM dropped to 6 kHz when the loop was closed, giving a stabilization factor of 1000 [3]. The stability factor was constant up to 1 kHz and then decreased due to the frequency gain response of the IC amplifier.

The frequency stability with temperature variations is currently limited by the temperature coefficient of the dielectric constant of the silica substrate. Its value is 28×10^{-6}/°C, giving a frequency drift of about 70 kHz/°C or 0.0013 percent/°C. Efforts are currently directed towards finding a silica glass with a substantially lower temperature coefficient.

VI. Summary

It has been shown that the frequency stability of microstrip oscillator can be greatly improved by means of a microstrip stabilization circuit. This circuit, which consists of a discrim-

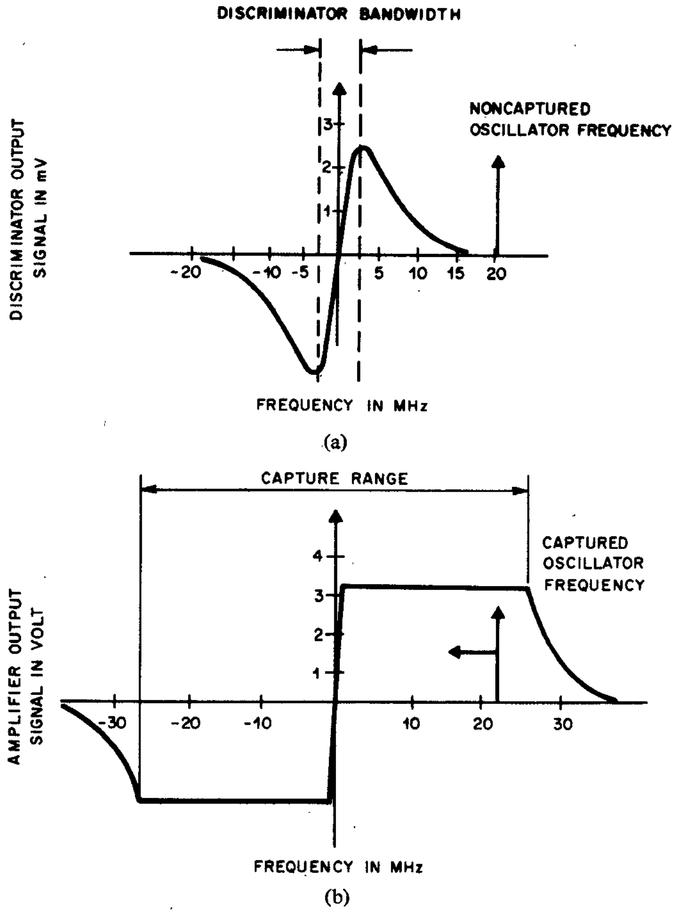

Fig. 5. (a) Discriminator output voltage. (b) Discriminator output voltage after amplification by the saturated IC amplifier.

inator, an IC amplifier, and a varactor, can be integrated with the oscillator circuit on a single dielectric substrate resulting in a compact device. This device can be mass-produced with high reliability at relatively low cost by using thin-film techniques and can be readily scaled to high frequencies. The stabilization circuit also provides self-capture of the oscillator frequency over a large frequency range.

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Posttuning Drift of a Transferred-Electron-Device Voltage-Controlled Oscillator

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***Abstract*—An experimental study was done on the parameters affecting the frequency drift of a transferred-electron-device (TED) voltage-controlled oscillator (VCO) after tuning from one frequency to another within its tuning band. For the VCO measured, reduction in frequency drift was observed and measured when: 1) the output power was reduced either by decoupling the load or by using a lower power TED; 2) the voltage swing was restricted so as to draw less than 10 μA forward or reverse current; and 3) when a varactor with a high Q was used. With 5-mW output the TED VCO had a frequency drift less than 2.5 MHz from 1 μs to 100 ms when step tuning the frequency anywhere in the frequency band from 6.8 to 9.1 GHz.**

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Introduction

For many systems it is becoming increasingly important to control accurately the frequency of a voltage-controlled oscillator (VCO) after a step change in tuning voltage has been applied to its tuning port. This is particularly true with the use of digital signals to control the frequency of the VCO. After a step change in tuning voltage the frequency does not immediately reach its "steady state" or final value, but there is some frequency drift, called the posttuning drift (PTD) which may continue for many hours. Often the PTD is distinguished from the settling time of the VCO; the settling time being the time required for the VCO to reach within a fixed percentage error of some fixed-frequency value after the application of a step change in tuning voltage. The settling time usually has reference to time periods shorter than 10 μs, whereas the PTD is applied to time periods after 1 μs. Usually, PTD is separated into long- or short-term drift depending on the time from which the drift is measured. For long-term drift the time is typically 100 ms.

This short paper will concern itself with short-term PTD as measured from 1 μs to 100 ms. The reason for choosing 100 ms is that by this time most thermal effects associated with the active devices have reached a very small value. The circuit studied is a VCO using a transferred-electron device (TED) with a single varactor as the tuning element. There are many factors affecting PTD arising from the driver amplifier, varactor diode, the active TED device, and circuit characteristics including harmonic termination. These effects are quite difficult to separate except those involving the driver amplifier. The approach in this short paper is to first discuss the measurement technique used. Then the experimental measurements will be described which were performed to study the effects of various parameters on the VCO PTD. Finally, some general comments will be made suggesting the causes of the various PTD drifts observed.

Measurement Technique

There are several possible methods for measuring the settling time of a microwave VCO. These include: 1) use of a stable oscillator with a precisely known frequency whose output is mixed with the VCO output to get a beat note that may be observed on a scope; 2) use of a microwave discriminator to convert the frequency to a voltage which again may be measured on an oscilloscope; and 3) use of a spectrum analyzer to observe the shift in spectral line as pulsewidth is increased.

These techniques have various advantages and disadvantages which will not be described here. The technique used in this study is the spectrum-analyzer approach, which possesses the advantage of being able to "see" the entire drift across a pulse that appears as a broadening of the spectral line. Fig. 1 shows a block diagram for this approach.

The pulse is passed through a diode-clamp circuit in order to obtain an accurate drive voltage for the VCO. Any droop or overshoot in the driver pulse will result in a frequency error in the VCO output. Two typical diode-clamp circuits are shown in Fig. 2. Combinations of series and shunt diodes may be used to more precisely fix the frequency. The output from the diode clamp passes into the VCO driver amplifier to develop the necessary 40 V to tune the VCO through its entire range. Usually, some