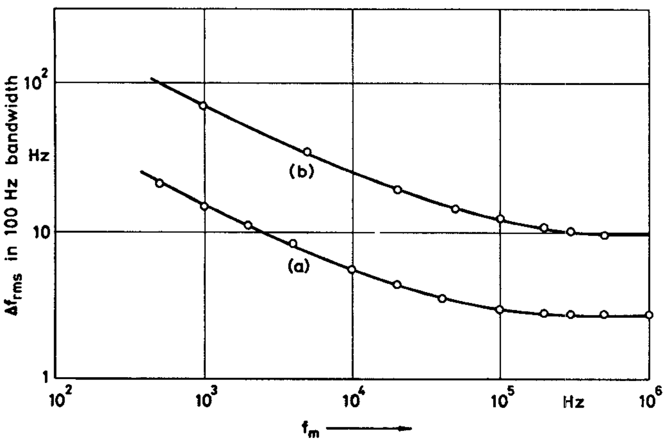

Fig. 2. Mean frequency deviation Δf_{rms} versus modulation frequency f_m; measuring bandwidth 100 Hz, bias voltage $V_B = 7$ V, and frequency $f_0 = 12$ GHz; (a) optimum power output $P_0 = 60$ mW, $Q_{ex} = 150$; (b) power output $P_0 = 14.7$ mW, $Q_{ex} = 122$.

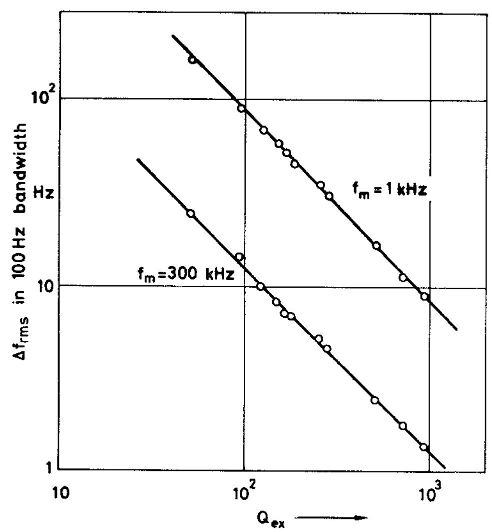

Fig. 3. Δf_{rms} in bandwidth 100 Hz versus external quality factor Q_{ex} for $f_m = 1$ kHz and $f_m = 300$ kHz.

near the carrier frequency and helps to avoid errors which can occur because of asymmetric synchronizing ranges when using the conventional method reported by Adler [10]. The quality factor was varied with an external high-Q reaction cavity coupled to the oscillator by a 10-dB or a 3-dB directional coupler (see Fig. 1). With the tunable phase shifter the angle between $Y_D(A)$ and $Y_L(f)$ on the complex plane could be varied [11], [12], which resulted in a change of Q_{ex}.

The FM noise was measured with a direct detection system employing a high-Q transmission cavity as a discriminator. The Gunn oscillator used had an optimum output power of 60 mW at 12 GHz. It was fabricated from GaAs epitaxial material grown in this laboratory. The FM noise spectrum is represented by curve (a) in Fig. 2 for modulation frequencies between 500 Hz and 1 MHz. The dependence on f_m is just as described above. In order to be able to keep V_B, P_0, and f_0 constant when varying Q_{ex}, it was advantageous to tune the oscillator to a lower power output. Curve (b) in Fig. 2 shows the FM noise obtained at this operating point.

The mean frequency deviation Δf_{rms} was measured at 1 kHz and 300 kHz off the carrier, well within the range of predominating upconverted noise and intrinsic noise, respectively. Q_{ex} was in the range between 50 and 1000. These values are much greater than the quality factor of the Gunn element itself, which is of the order of unity. Therefore, the load quality factor can be taken to characterize the oscillator behavior. This agrees with the neglection of frequency dependence of the device admittance in (1).

The results are given in Fig. 3. Both the upconverted noise and the intrinsic noise decrease as $1/Q_{ex}$ as predicted by theory. FM–AM conversion is of no importance, at least in this particular case. The Q_{ex} dependence observed could not be obtained by only changing Q_{ex} without taking care of the other parameters mentioned above. As far as intrinsic noise is concerned this means that the high-frequency noise source indeed depends on output power and device admittance. Further work is in progress to investigate this dependence.

Acknowledgment

The authors wish to thank Prof. W. Harth for stimulating discussions.

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Temperature Stability of an MIC Gunn-Effect Oscillator

JEROME COHEN AND M. GILDEN

***Abstract*—A technique to temperature stabilize a Gunn-effect CW oscillator (*C* band) in microstrip, has been developed.**

An asymmetric dielectric loading technique has been used to minimize the temperature dependence of frequency of a microstrip Gunn oscillator. This technique compensates for the temperature dependence of the dielectric constant of the microstrip and GaAs. A titanate[1] ceramic disk ($\epsilon = 150$) with a diameter of 0.25 in and 0.025 in thick provided the means of temperature stabilization. This material has good microwave properties and exhibits a strong increase in permittivity with decreasing temperature.

Reflection measurements were made on a straight-line microstrip resonator $\lambda/2$ long at 7.46 GHz. A conventional 99.5-percent pure 0.025-in-thick alumina substrate was used. The variation in resonant frequency was monitored over a temperature range of -55 to $+70$°C. The resultant slope was -0.4 MHz/°C and is shown in Fig. 1. Placement of the disk on the microstrip (Fig. 2) to achieve optimum temperature stability was determined by trial and error. The best slope obtained was -0.032 MHz/°C.

The dielectric loading technique was then used with a microstrip CW Gunn oscillator by placing the disk over the frequency-dependent tuning element. The best result obtained was -40 kHz/°C over a temperature range of -55 to $+70$°C as shown in Fig. 3. Critical coupling was characterized by a reduction of 240 MHz in the oscillator frequency. The reduced center frequency was 6.3 GHz. Similar results were achieved from 5.8 to 6.8 GHz by properly adjusting the

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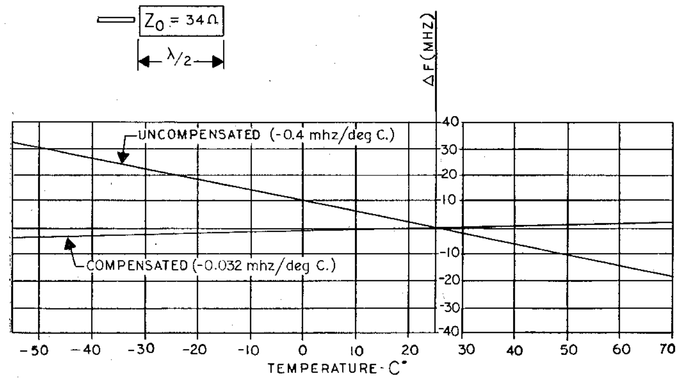


Fig. 1. Temperature slope of microstrip resonator.

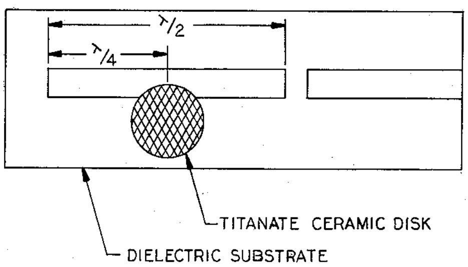
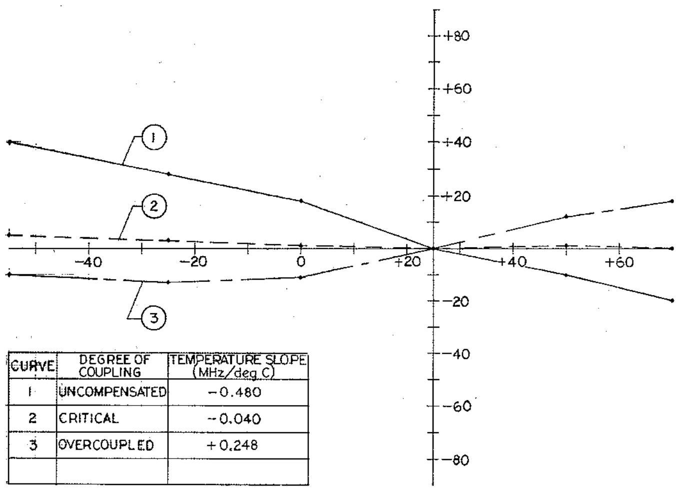


Fig. 2. Top view of resonator.



CURVE	DEGREE OF COUPLING	TEMPERATURE SLOPE (MHz/deg C)
1	UNCOMPENSATED	−0.480
2	CRITICAL	−0.040
3	OVERCOUPLED	+0.248

Fig. 3. Results of temperature stabilization.

length of the open-circuited stub. A photograph of the oscillator circuit with its electrical characteristics is shown in Fig. 4.

A model incorporating the disk critically coupled to the tuning stub of the Gunn oscillator was developed using computer-aided techniques to simulate the reflection coefficient measurements taken with the HP network analyzer. The results are shown in Fig. 5. The characteristic impedance of the stub was 34 Ω and the length was 0.25 in. The equivalent circuit is dependent on the degree of coupling to the stub. The model agrees with the experimental results.

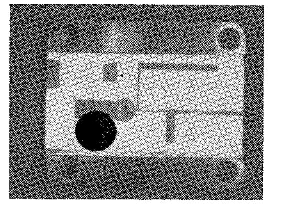


Fig. 4. Electrical parameters. Frequency—6.3 GHz; power output—20–40 mW; voltage—11 V dc; current—300 mA; pulling (max for VSWR = 1.3:1)—±5 MHz; pushing—50 MHz/V.

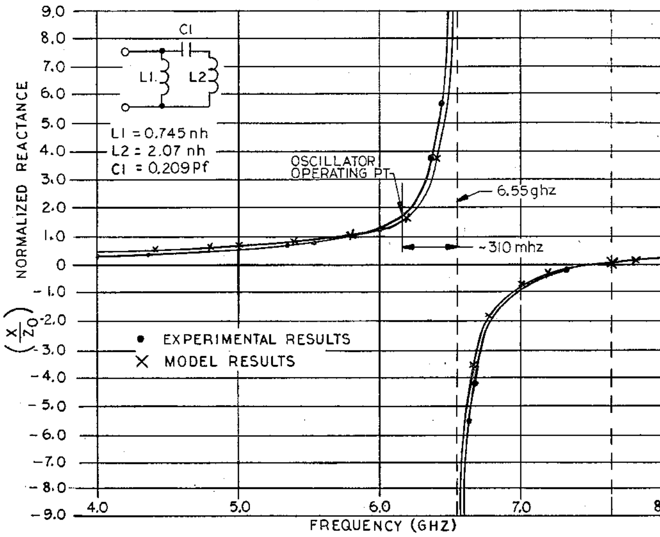


Fig. 5. Tuning response of model.

Cleverley and Norbury [3] achieved 1.4 kHz/°C with injection locking of a high-Q waveguide cavity at 9.3 GHz. While Kooi and Walsh [4] reported stabilities of 1.4 kHz/°C with titania loading of waveguide.

In conclusion, a dielectric loading technique was developed to improve the temperature stability of a microstrip CW Gunn-effect oscillator. Performance comparable to that obtained with high-Q waveguide cavities has been demonstrated.

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