# A Stable Microwave Integrated Circuit X-Band Gunn Oscillator

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***Abstract*—A stable microwave integrated circuit (MIC) X-band Gunn oscillator is described. Frequency stability is achieved by use of a modified Pound stabilizing system. An average short-term frequency stability of $2 \times 10^{-7}$ at room temperature and a thermal stability of $9 \times 10^{-7}$/°C between −15 and 30°C have been obtained.**

In the course of development of a lightweight expendable microwave radio refractometer, a very stable X-band oscillator has been designed. Frequency stability is achieved by the use of a modified Pound stabilizing system [1]. The oscillator and its frequency discriminating circuit are fabricated in microwave integrated circuits (MIC's). The $TE_{011}$ resonator used as reference cavity for the Pound system is constructed of a section of metallized silica tube with thermally compensated brass end plates [2].

The MIC oscillator uses an AEI dc 1231D Gunn device mounted at the center of a microstrip cavity having a characteristic impedance of approximately 15 Ω and an equivalent length of 3/2 wavelengths at the design frequency of 10.588 GHz. A low-pass filter for the dc bias to the Gunn device is included together with a dc block at the 50-Ω line output. The latter is made by a thin film technique. An AEI dc 4273 tuning varactor diode in a LID pack is coupled in parallel with the Gunn microstrip cavity to provide frequency tuning for the stabilizing circuit.

The stabilizing circuit is shown in block diagram form in Fig. 1. Unlike the Pound system, no attempt was made to suppress the carrier at the output of the modulator, since the low intermediate frequency of 10 kHz used makes double sideband suppressed carrier modulation impossible to achieve. This modification only shifts the zero error datum from the resonant frequency of the cavity ($f_0$) to a slightly higher frequency ($f_1$). The new error datum is determined by

$$E_e = K_1 \sin \omega_m t (A - |\Gamma_1| \sin \theta_1) = 0$$

which compares with $E_e = K_2 |\Gamma_0| \cos \omega_m t \sin \theta_0 = 0$ in the Pound system. $K_1, K_2$, and $A$ are constants depending on the circuit parameters, $\omega_m$ is the modulating frequency, and $E_e$ is the output of the detector (Fig. 2). The magnitude of the reflection coefficient of the coupling circuit of the cavity [1]

$$|\Gamma_1| = |\Gamma(f_1)| = \frac{[\alpha^4 + a^4 + 1 + 2a^2\alpha^2 + 2a^2 - 2\alpha^2]^{1/2}}{\alpha^2 + a^2 + 1 + 2\alpha}.$$

The phase angle of the reflection coefficient

$$\theta_1 = \theta(f_1) = \tan^{-1} \frac{2a\alpha}{1 + a^2 - \alpha^2}$$

and

$$a = \frac{2Q(f_1 - f_0)}{f_0}$$

where $Q$ is the unloaded $Q$ of the reference cavity and $\alpha$ is the coupling factor of the coupling circuit of the reference cavity. The error signal $E_e = 0$ when $A = |\Gamma_1| \sin \theta_1$. When $f > f_1$, $E_e < 0$ and when $f < f_1$, $E_e > 0$.

By determining the phase and magnitude of the error voltage output from the detector of the modified Pound system, the frequency discrepancy of the oscillator with respect to the reference cavity can be found. In the present oscillator this discrepancy is 500 kHz compared with a theoretically expected discrepancy of 1.2 MHz and is constant with respect to change of resonant frequency of the reference cavity. The electronically tuned oscillator, 10-dB directional coupler, hybrid ring, modulator, detector, and matched termination are all fabricated on a 2- × 2- × 0.02-in alumina substrate by a photo-etching method. A Schottky diode in a LID pack (AEI dc 1303) is used in the modulator, and a back diode in the same type LID pack (AEI dc 3012) is used for the detector.

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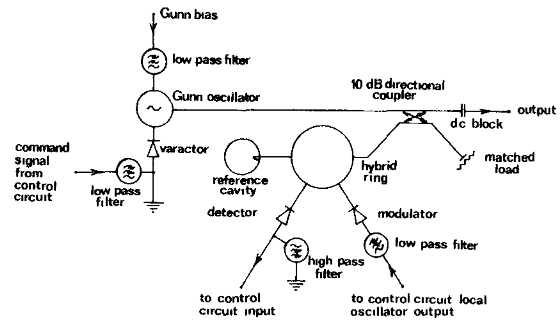


Fig. 1. Schematic diagram of a modified Pound stabilized MIC Gunn oscillator.

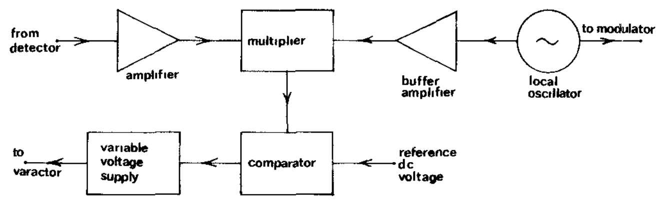


Fig. 2. Block diagram of the electronic control circuit.

The error voltage is processed by an electronic circuit [3], the block diagram of which is shown in Fig. 2. The control voltage from the circuit is applied to the varactor so that the error voltage in the control loop is always brought to zero by changing the oscillation frequency in an appropriate direction electronically.

To measure the stability of the oscillator the whole system was screened from draughts but was subject to the normal drift in temperature of the laboratory. The oscillator frequency was measured with a Hewlett Packard (HP 5245L with 5256A plug in) frequency counter. Measurements were made with the gate time of the counter varied from 0.1 ms to 1 s at 2-s intervals. Consecutive samples of 500 oscillation frequencies were noted for each gate setting. The stability of the oscillator was calculated using the method due to Allan [4]. An average short-term stability of $2 \times 10^{-7}$ was obtained.

The frequency of oscillation was measured when the temperature of the oscillator and its frequency discriminating circuit were varied over the range −15–+30°C. The effect of the variation of the refractive index of the contents of the reference cavity was eliminated by enclosing the cavity, with the solid end plates replaced by open end plates, in a sealed container filled with dry nitrogen [5]. The temperature stability measured was 9.4 kHz/°C. This value includes the effect of temperature on the microstrip oscillator and circuit as well as the cavity but is independent of the refractive index of the atmosphere within the cavity. This can be compared with a value of 15.7 kHz/°C obtained when the reference cavity was sealed and contained air having a relative humidity of about 50 percent. An output power of 10 mW was obtained from this oscillator.

## ACKNOWLEDGMENT

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