A 6 GHz HIGHLY STABILIZED GaAs FET OSCILLATOR USING A DIELECTRIC RESONATOR

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ABSTRACT

A 6 GHz GaAs FET feedback oscillator stabilized by a dielectric resonator with a new frequency tuning mechanism has been developed. The oscillator has a frequency tuning range of 50 MHz with a frequency stability of about ± 10 PPM (0°C-50°C).

Introduction

Recently, microwave oscillators stabilized by a dielectric resonator have been reported.[1,2,3] These oscillators have a weak point, however, in that because their frequency tuning mechanism is a metal screw, good frequency stability against temperature is obtained only at a very narrow frequency range.

In this paper, we propose a new frequency tuning method for an oscillator stabilized by a dielectric resonator. The method provides a wide frequency tuning range with nearly constant frequency stability against temperature. We also propose an improved configuration for the feedback oscillator using a GaAs FET, which enables easy design and simple structure of the oscillator.

Our experimental oscillator had a tuning range of 50 MHz at 6 GHz with a frequency stability of about ± 10 PPM over a temperature range from 0 to 50 °C, an output power of 24 mW with an efficiency of 15.5 %, and SNR (FM noise) of more than 90 dB at 200 KHz test-tone deviation of 3.1 KHz bandwidth.

Configuration

Figure 1 shows the configuration of this feedback oscillator and a simplified equivalent circuit of the oscillator is shown in Fig.2. The oscillator consists of a GaAs FET amplifier module and a feedback loop including a dielectric resonator. This configuration provides easy design and production of the oscillator, because the amplifier can be designed and evaluated independent of the feedback loop. The dielectric resonator is magnetically coupled to the amplifier. Loose coupling is made through a coupling loop at the input port of the amplifier and a stripline at the output port. The dielectric resonator and the amplifier module are installed in separate cells to reduce the leak coupling between them, allowing a high loaded Q to be obtained with this oscillator.

The dielectric resonator is vertically centered in the housing with a spacer made of forsterite ($2MgO.SiO_2$). This configuration minimizes the effect of the housing metal on the temperature coefficient of the dielectric resonator, thus making design of the frequency stabilization structure very easy.[4]

A new frequency tuning mechanism has been developed to obtain a wide frequency tuning range with no degradation of frequency stability against temperature variation. The configuration is shown in Fig.3. A small hole is made in the dielectric resonator, and a dielectric rod made of the same material as the resonator is inserted into the hole to change the resonant frequency. With this tuning mechanism, disturbance of the resonant mode ($TE01\delta$) and change of unloaded Q of the resonator were negligible . This configuration makes it possible to tune the oscillator frequency without degrading frequency stability against temperature, because the air gap between the dielectric resonator and metal wall of the housing is kept constant in the tuning process.

The RF output and DC bias terminals are pin-type leads.

Design

The amplifier module and feedback loop of the feedback oscillator shown in Fig.1 can be designed independently. Technical points in the design procedure of these circuits are as follows.

Dielectric Resonator

The ring type dielectric resonator, made of a material system of $SnO2$-$TiO2$-ZrO, has a dielectric constant of 37.5 and a high unloaded quality factor (Q0) of more than 7000 at 6 GHz (Q0 of the resonator installed in the brass housing is reduced to about 5500). The material system can be controlled with high precision to have a temperature coefficient around zero PPM/°C . Calculations showed the frequency temperature coefficient, which is dependent on the housing metal and dielectric spacer ,to be about -2 PPM/°C .[4] Therefore, a dielectric resonator with a frequency temperature coefficient of 2 PPM/°C was used to obtain good frequency stability in this experiment.

Amplifier

The amplifier in the feedback oscillator must be designed to have high gain, and a bandwidth which avoids oscillations caused by spurious responses of the dielectric resonator. The frequency band of the experimental amplifier was set at from 5.5 to 6.5 GHz. A packaged GaAs FET, FSC03W, which has a 1 μm gate length and a 300 μm gate width was used in the amplifier. The input and output matching circuits are computer designed using the S parameters of the device. The matching circuits are fabricated by printed circuit techniques on alumina ceramic substrates 0.65 mm thick.

Output power versus frequency and input power characteristics are shown in Fig.4. The amplifier gain is more than 10 dB from 5.6 to 6.5 GHz. Output power at the 1-dB gain compression point is 13.6 dBm at 6 GHz. The oscillator was designed to operate on the +5 VDC supplied by a radio relay equipment. Gate bias voltage was obtained by grounding the source of the FET through a high-permittivity capacitor and a resistor. We set bias voltages at 4 volts for the drain-source, and -1.1 volts for the gate-source. Drain current is 29 milliamperes.

Oscillator

The first step in designing the oscillator was to characterize the open loop (without the semi-rigid cable in Fig.1) which includes the amplifier module, the dielectric resonator, input and output coupling. The transmission gain and phase characteristics of the open loop were measured using a special tester. From the experimental results, dimensions of the input and output coupling loop and placement of the dielectric resonator were determined so as to have a 2-3 dB small signal gain and a high-loaded Q. Next, the length of the semi-rigid cable was determined so that the phase of the feedback wave is in phase at the input of the amplifier module to satisfy the oscillating condition.

Performance

Figure 5 shows the frequency tuning characteristics obtained by the tuning rod of this oscillator. A tuning frequency range of more than 200 MHz was obtained. The ring-type dielectric resonator has an inner-diameter of 3 mm, an outer-diameter of 10 mm, and is 3.2 mm thick. The diameter of the hole is 2.4 mm , and that of the tuning rod is 2.2 mm.

The experimental results of frequency stability against temperature variation of this oscillator are shown in Fig.6. Electrical characteristics of the oscillator are summarized in Table 1. Figure 7 is a photograph of the oscillator . Oscillator output power is 13.8 dBm at 6015 MHz, and frequency stability and deviation of the output power are less than ± 10 PPM and ± 0.5 dB, respectively over temperatures ranging from 0 to 50 degrees centigrade. A 50 MHz tuning range was obtained with a frequency stability of about ± 10 PPM over the same temperature range. The signal-to-noise ratio of FM noise is more than 90 dB at a test-tone deviation of 200 KHz r.m.s. and a bandwidth of 3.1 KHz. The external loaded Q of this oscillator is about 2000. The DC power supply provides + 5 volts at 31 milliamperes and total power efficiency is 15.5 percent.

Conclusion

We have developed a 6 GHz frequency-tunable, miniaturized GaAs FET oscillator stabilized by a dielectric resonator. This oscillator provides a tuning range as wide as 50 MHz, frequency stability of ± 10 PPM, output power of 24 mW, power efficiency of 15.5 percent, and signal-to-noise ratio of more than 90 dB at 200 KHz deviation.

The oscillator's simple mechanical construction, wide tuning range, and easy production make it suitable for use as a local oscillator in radio relay equipment.

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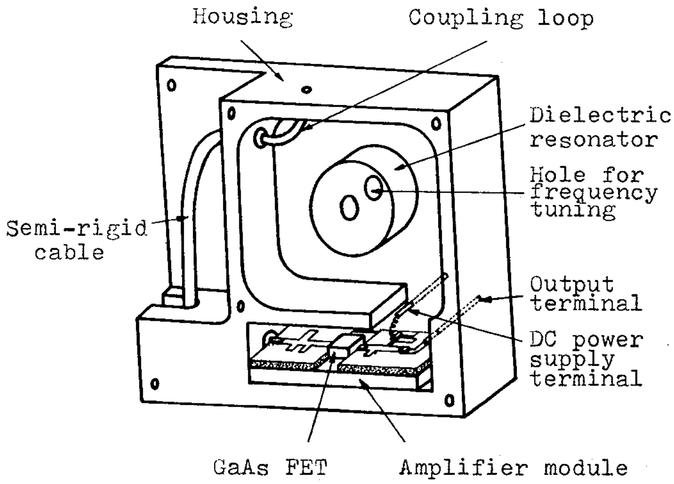

Fig. 1 Structure of the Oscillator

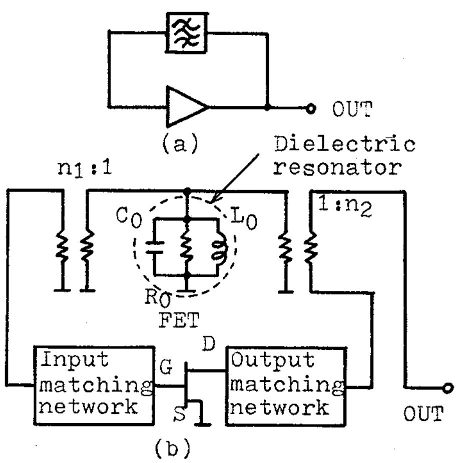

Fig. 2 (a) Schematic Diagram
(b) Simplified Equivalent Circuit

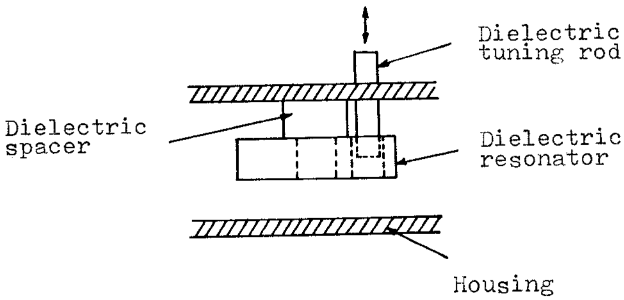

Fig. 3 Frequency Tuning Mechanism

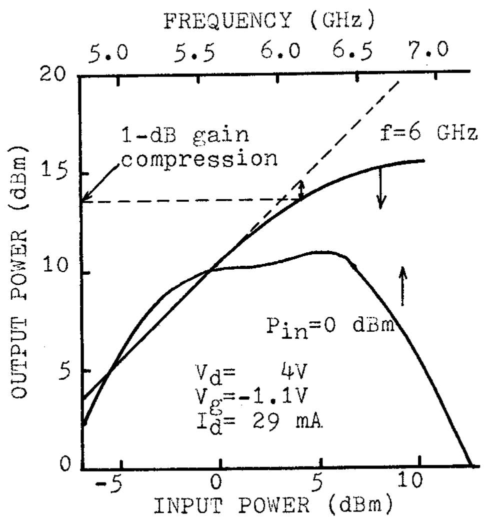

Fig. 4 Amplifier Performance

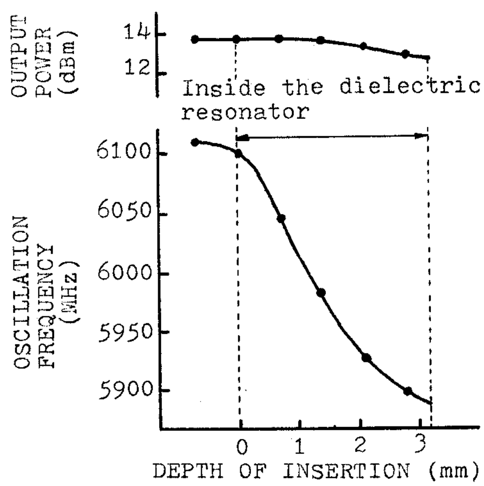

Fig.5 The Oscillator Frequency and Output Power Against Insertion Depth of the Dielectric Tuning rod.

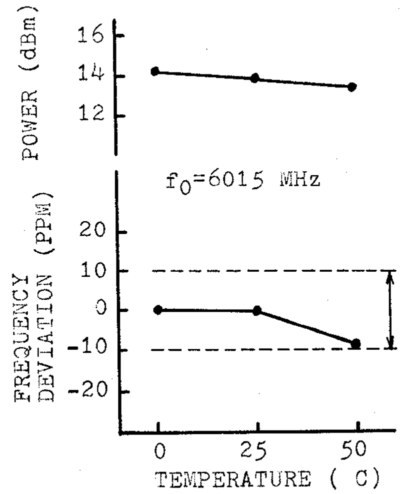

Fig. 6 Temperature Dependence of the Oscillator

Frequency	6015 MHz
Output power	13.8 dBm
Freq. stability	< ±10 PPM(0°C-50°C)
FM noise S/N	> 90 dB S=200 KHz B=3.1 KHz
Q_{ex}	2000
Pushing figure	30 KHz/V
Tuning range	50 MHz
DC voltage	+5 Volts
Current	31 mA
Efficiency	15.5 %
Dimensions	30 x 30 x 16 mm

Table 1 Oscillator Performance

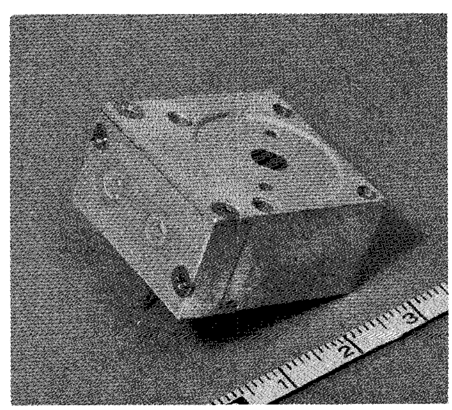

Fig.7 Photograph of the Oscillator