A FREQUENCY-STABILIZED MIC OSCILLATOR USING A NEWLY-DEVELOPED DIELECTRIC RESONATOR

Y. Komatsu, Y. Murakami, T. Yamaguchi, T. Otobe and M. Hirabayashi
Sony Corporation Research Center
174 Fujitsuka-cho Hodogaya-ku
Yokohama, 240 Japan

ABSTRACT

A GaAs FET MIC oscillator with very high frequency stability has been developed using a newly-developed dielectric resonator. The key to designing the dielectric resonator was to make the temperature dependence of the resonance frequency linear. This characteristic was realized in a stacking-type dielectric resonator with zirconate ceramics. The obtained frequency stability of ±85 kHz in temperatures -20 to +60°C is sufficient for AM SHF TV receivers.

Introduction

Frequency-stabilized GaAs FET MIC oscillators using dielectric resonators have begun to be used in FM SHF TV receivers of satellite broadcasting because of their simple configuration, low operation voltage and high efficiency.[1-3] We are not aware, however, of any reports of these oscillators being used for AM SHF TV broadcasting, which requires very high frequency stability of ±100 kHz in temperatures from -20°C to +60°C.

This paper reports the results of our effort to improve the temperature stability of the oscillation frequency. We analyzed the effect of temperature on the oscillation frequency to obtain the optimum characteristics of a dielectric resonator. These characteristics have been realized in our newly-developed dielectirc resonator. Using this resonator, we were able to develop an oscillator which meets the very high frequency stability requirements of an AM SHF TV broadcasting receiver.

Oscillator Configuration

The configuration of the present oscillator is shown in Fig. 1. The whole circuit is constructed on an alumina substrate measuring 1 x 0.5 inches, 0.025 inches thick. Three microstrip lines on this substrate connect the gate, source and drain terminals of a packaged GaAs FET which has a gate 1 μm long and 300 μm wide. A dielectric resonator is coupled electromagnetically to the gate-side microstrip line to stabilize the oscillation frequency. The drain terminal is used for output. This configuration has the advantage of attaining high frequency stability without sacrificing output power, compared to a self-injection locking-type oscillator in which a resonator is coupled to the output line, with the result that available power is reduced. A chip-type 50 Ω terminator is provided at the end of the gate-side line to prevent spurious oscillations.

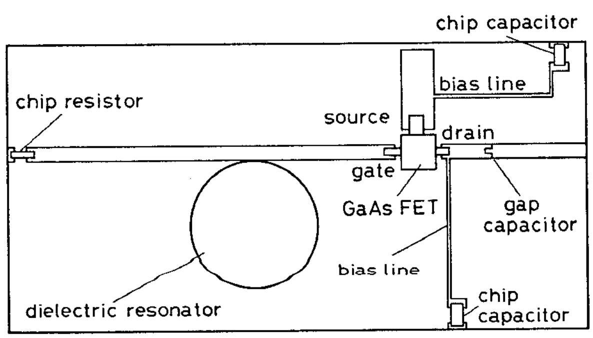

Fig. 1. Configuration of oscillator.

The bias line connecting the source terminal is grounded through a resistor (not shown in Fig. 1), so that the circuit can operate on a single-pole D.C. power supply in order to adapt to the local oscillator in a SHF TV receiver. Small signal s-parameters of a GaAs FET were used as the basis of a computer-aided design from which the initial circuit parameters of the oscillator were derived. A test oscillator with these parameters was made so that the final parameters could be determined from a Rieke diagram. Figure 2 shows typical bias voltage dependence of the oscillation frequency and output power.

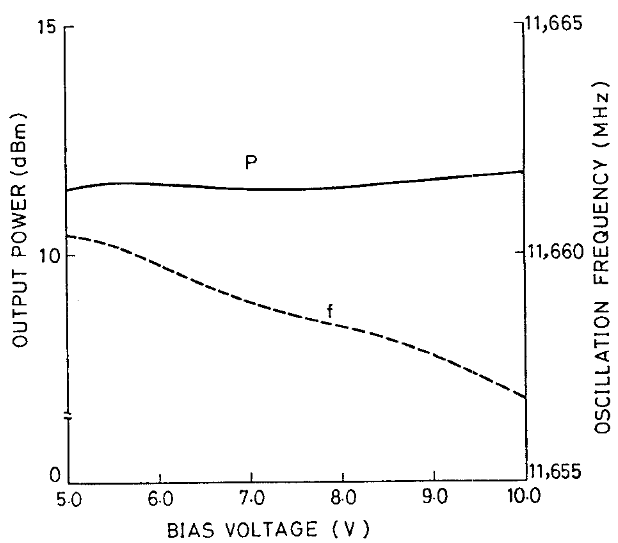

Fig. 2. Bias voltage dependence. P and f indicate output power and oscillation frequency, respectively.

We found that the temperature dependence of the oscillation frequency could be expressed as the sum of the resonance frequency changes of the dielectric resonator caused by temperature variation and temperature-frequency characteristics of the associated circuit elements. The second term may be estimated experimentally by employing a resonator in which the temperature dependence of the resonance frequency is already known. We found that the temperature-frequency characteristics caused by the circuit elements varies almost linearly with temperature and that its temperature coefficient can be changed only slightly by varying the circuit elements' parameters. Thus, the temperature dependence of the oscillation frequency can be minimized if a resonator which can compensate for the temperature-frequency characteristics of the circuit elements could be designed. This means that the temperature dependence of the resonance frequency of the dielectric resonator must be almost linear and be adjustable. Conventional resonators cannot provide this capability.

New Dielectric Resonator

Previously, all dielectric resonators in our oscillators had been constructed using a ternary (Ca, Sr, Ba) zirconate ceramic of orthorhombic perovskite-type structure.[2] The ternary zirconate ceramic system yields a suitable medium dielectric constant of from 30 to 35 and a high dielectric Q value of over 3000 at 11 GHz. Since the temperature coefficient of the dielectric constant is adjustable from -50 to +50 ppm/°C by varying the ceramic composition, the temperature coefficient of the resonance frequency can be adjusted over a wide range. An oscillator having a good frequency stability of ±300 kHz in temperatures from -20 to 60°C was developed, since a fairly good compensation for the temperature-frequency characteristics of the circuit elements is achieved by a dielectric resonator having a suitable composition of $Ca_{0.98}Sr_{0.01}Ba_{0.01}ZrO_3$. Figure 3 shows the temperature dependence of the oscillation frequency of this oscillator.

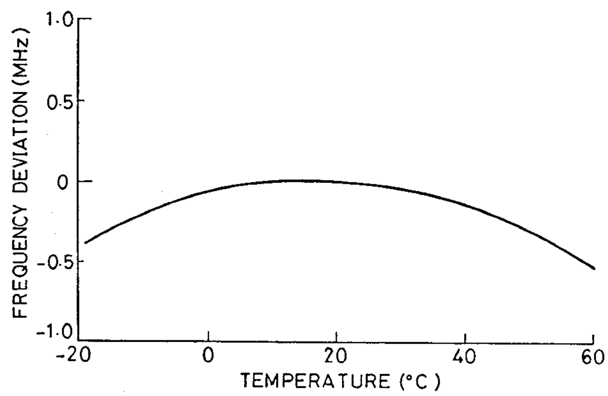

Fig. 3. Temperature dependence of oscillation frequency of an oscillator using a conventional dielectric resonator.

The curved characterictic is attributed to the non-linear temperature dependence of the resonance frequency of the dielectric resonator. It is difficult to further improve the frequency stability of the oscillator using these resonators because of this nonlinearity.

We found that the temperature dependence of the resonance frequency, i.e., that of the dielectric constant, is related to a material's structure. This discovery suggested that a productive search could be made for a material which would produce a temperature dependence which, when plotted with the temperature dependence of the dielectric constant of a ceramic with an orthorhombic perovskite-type structure, would tend to be cancelled out. A zirconate ceramic system with a cubic structure fit this requirement.

Figure 4 shows the new dielectric resonator made by stacking two ceramic discs of zirconate ceramic of orthorhombic and cubic structure. The composition of the ceramic having orthorhombic structure is $Ca_{0.99}Sr_{0.01}Zr_{0.99}Ti_{0.01}O_3$, which has a dielectric constant of 30 and a Q value of over 3000. The

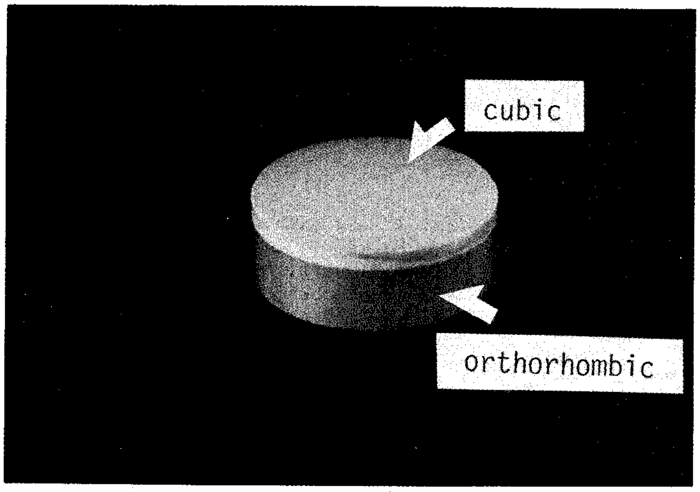

Fig. 4. Picture of a newly-developed stacing-type dielectric resonator.

composition of the ceramic having cubic structure is $(Sr_{0.468}Ba_{0.45})Zr_{0.99}Ti_{0.01}O_{2.918}$. This is made slightly different from stoichiometrical composition. One percent of the zirconium is replaced by titanium. The dielectric constant of this ceramic is 35 and its Q value is 1400. Figure 5 shows the temperature dependence of resonance frequencies of resonators made (A) of zirconate ceramic with orthorhombic structure, (B) of zirconate ceramic with cubic structure and (C) by stacking these materials.

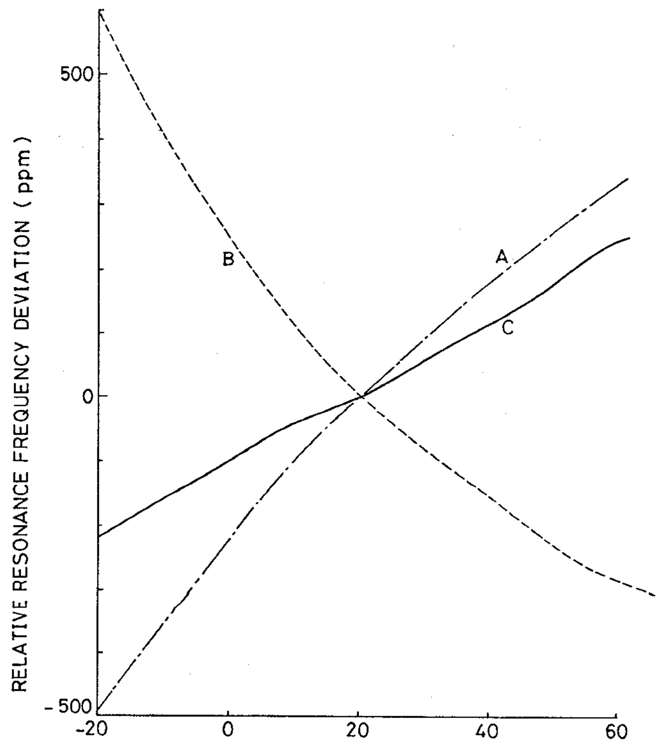

Fig. 5. Temperature dependence of resonance frequencies of dielectric resonators. (A) orthorhombic, (B) cubic, (C) stacking-type

The new resonator was employed in a MIC oscillator. The almost linear temperature dependence of the resonance frequency effectively compensates for the temperature dependence of all other parameters. Fine adjustment is possible by changing the electromagnetic coupling between line and resonator and/or by varying other circuit parameters, e.g., the resistance between the FET's source terminal and the ground. Figure 6 shows the resultant temperature dependence of the oscillation frequency. A very high frequency stability of ±85 kHz at -20 to +60°C around 11.66 GHz can be obtained. Output power of 14 mW is sufficient for the local oscillator of an AM SHF TV receiver.

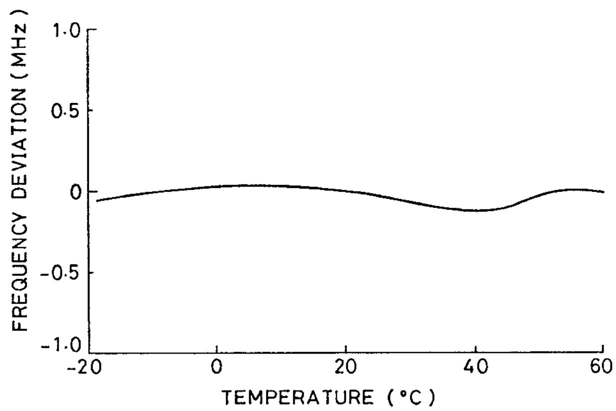

Fig. 6. Temperature dependence of oscillation frequency of an oscillator using a newly-developed dielectric resonator. The oscillation frequency at room temperature is 11.66 GHz.

Conclusion

A GaAs FET MIC oscillator exhibiting very high frequency stability has been constructed using a newly-developed dielectric stacking-type resonator. Linear temperature dependence of the resonance frequency was obtained with this new resonator, whose two stacking dielectrics had dielectric constants whose temperature dependence effectively cancelled each other out. The oscillator's frequency stability of ±85 kHz at -20 to +60°C is sufficient for the local oscillator of an AM SHF TV receiver.

Acknowledgement

The authors wish to express their thanks to Mr. Aoki in the Semiconductor Division for preparing GaAs FETs. They also thank Dr. Y. Makino, the head of Materials Research Laboratory, and Dr. T. Yamada for their encouragement.

Referances

1. O. Ishihara, T. Mori, H. Sawano and M. Nakatani, "A highly stabilized GaAs FET oscillator using a dielectric resonator feedback circuit in 9-14 GHz," IEEE Trans. Microwave Theory Tech., vol. MTT-28, pp. 817-824, 1980.

2. T. Yamaguchi, Y. Komatsu, T. Otobe and Y. Murakami, "Newly developed ternary (Ca, Sr, Ba) zirconate ceramic system for microwave resonators," Ferroelectrics, vol. 27, pp. 273-276,1980.

3. "Integrated SHF converter simplifies satellite broadcasting," Microwave Systems News, pp.55-57, June, 1979.