Low Noise Microwave Oscillator using Ultra High Q Dielectric Resonator

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Abstract

Dielectric resonator oscillator (DRO) with excellent low single side band (SSB) noise was developed at 16 GHz. BMT ($Ba(Mg_{1/3}Ta_{2/3})O_3$) ceramics with low dielectric loss ($\tan\delta = 3.3*10^{-5}$ at 10 GHz) was used as a dielectric resonator. A conventional GaAs MESFET was used as an active component. SSB noise at 10 kHz from the carrier of -102 dBc/Hz was obtained. This is one of the lowest SSB noise level that has ever reported for a Ku-band DRO. This result implies that the low loss BMT ceramics as a high Q dielectric resonator fairly contribute to the low noise performance of the oscillators.

Introduction

Dielectric resonator oscillators (DRO) have potential advantages for integrated oscillators in microwave frequencies. Digital communication systems require oscillators with low SSB noise and excellent frequency stability. For low SSB noise oscillators, high Q resonators (dielectric resonator, metal cavity, or YIG) have been used as the frequency stabilizing element, because the SSB noise of the oscillator is mainly determined by the loaded Q of the resonator[1]. In these resonators, dielectric resonators have essentially advantages compared with other resonators, because of small size, good temperature stability and easy assembling.

Recently, several papers reported that the dielectric material with complex perovskite compounds exhibited very low dielectric losses in microwave frequencies[2,3]. In 1986, Matsumoto[4], one of the authors, reported the pure BMT ($Ba(Mg_{1/3}Ta_{2/3})O_3$) ceramics which have the minimum $\tan\delta$ of $3.3*10^{-5}$ at 10 GHz band. However, because of its low dielectric constant of about 24, the Q of the dielectric resonator is strongly affected by the proximity of the metal cavity to shield the dielectric resonator. Kobayashi et al[5]. have pointed out that the dielectric loaded metal cavity resonators with excellent high Q value could be realized by the optimization of the dimension of dielectric disc and metal cavity. Also dielectric resonator filters with excellent low insertion loss were realized by the previous investigations[6]. However, low SSB noise DRO using low loss ceramics, such as BMT, has not been presented. In this paper, the development of DRO containing low loss BMT ceramics as a dielectric resonators is described. In order to prevent the degradation of the Q of the dielectric resonator, a large metal cavity to shield the dielectric resonator is used. The DRO presented here indicates excellent low SSB noise performance.

Characteristics of the BMT ceramics

The BMT ceramics consists of complex perovskite compounds of pure $Ba(Mg_{1/3}Ta_{2/3})O_3$. The ceramics fabricated using fast heating method and unique after-heating process[4]. Relative dielectric constant (ϵ_r) is 24. $\tan\delta$ at microwave frequencies and temperature coefficient of resonant frequency τ_f were measured using dielectric rod resonator method. $\tan\delta$ of $3.3*10^{-5}$ and τ_f of 4 ppm/℃ were obtained at 10 GHz. $\tan\delta$ of $3.3*10^{-5}$ at 10 GHz is the lowest $\tan\delta$ value among those reported.

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Oscillator design

A series feedback type oscillator circuit was used in order to miniaturize the oscillator. The block diagram of the oscillator is shown in figure 1. In the figure, drain capacitance C_D was used to obtain a negative resistance. The active component is a quarter-micron-gate GaAs MESFET. A matching circuits was used to minimize the frequency fluctuation by change of the load impedance. The circuit is constructed on 0.015-inch-thick alumina substrate using thin film MIC technique. Oscillator design was carried out using S-parameter method[7]. The rod-shaped dielectric resonator which has a diameter of 4.2 mm and a length of 1.9 mm was used. The dielectric resonator was mounted on the quartz spacer in order to prevent the degradation of the Q of the dielectric resonator. A large metal cavity (about 13*17*5 mm^3) to shield the dielectric resonator was used, because the Q of the dielectric resonator was strongly affected by the proximity of metal walls.

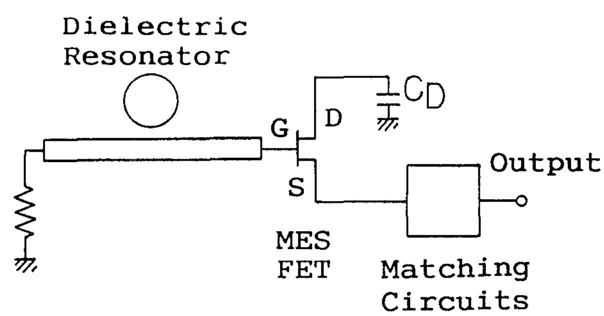

Figure 1. Block diagram of the oscillator.

Experimental results

Figure 2 shows the output spectrum of the oscillator. The resolution bandwidth is 1 kHz. Excellent clean spectrum was obtained. The output power is 10 dBm. The supply voltage is 3 V and the drain current is 20 mA. A dc-RF efficiency of this oscillator is about 17 %.

The SSB noise was measured using Tektronix 2713 spectrum analyzer. Figure 3 shows the SSB noise of the oscillator as a function of the offset frequency. As shown in figure 3, the SSB noise at 5 kHz and 10 kHz from the carrier of -94 dBc/Hz and -102 dBc/Hz were obtained, respectively. This result is excellent good noise performance compared with the published data[8] in the same frequency band. Furthermore, compared with 11 GHz band DRO[9,10], same SSB noise level is obtained at 16 GHz. This low noise performance was mainly attributed to the Q of the dielectric resonator. So it is suggested that the use of a large metal cavity to shield the dielectric resonator is fairly effective for the BMT ceramics. In the low SSB noise oscillators, Si bipolar transistors and AlGaAs/GaAs heterojunction bipolar transistors were commonly used, because these devices have the low 1/f noise. However, it is difficult to obtain the high power output of about 10 dBm for oscillators fabricated with Si bipolar transistors. So, heterojunction bipolar transistors are expected to be applicable to low SSB noise oscillators at microwave and

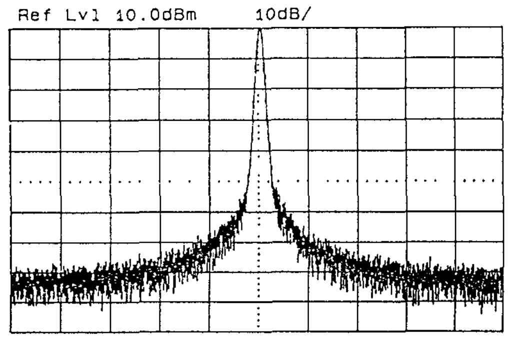

Figure 2. Output spectrum of the oscillator.
V : 10dB/div. Reference level 10dBm
H : Center freq. 16.173GHz, Span 100kHz.

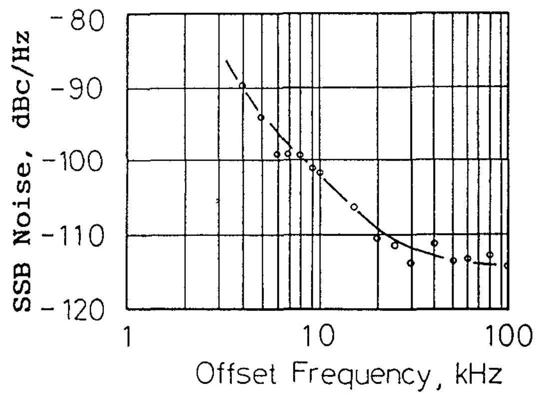

Figure 3. SSB noise of the oscillator as a function of the offset frequency.

millimeter-wave[11]. But, this work suggests that, by using high Q dielectric resonators, the oscillators fabricated with GaAs MESFET's exhibit excellent low SSB noise performance compared with the oscillators fabricated with heterojunction bipolar transistors.

Figure 4 shows the frequency deviation of the oscillator as a function of the ambient temperature. Temperature coefficient of oscillation frequency of 1.0 ppm/℃ was obtained. Figure 5 shows the frequency deviation of the oscillator as a function of the drain voltage. By means of the optimization of the output matching circuit, the favorable pushing figure of 33 kHz/V was obtained.

30 GHz DRO was also fabricated using BMT ceramics. SSB noise as a function of the offset frequency is shown in the figure 6. The SSB noise of -75 dBc/Hz was obtained at 10 kHz from the carrier.

Conclusion

Low SSB noise DRO using low loss BMT ceramics as a high Q dielectric resonator was developed at 16 GHz. The SSB noise of -102 dBc/Hz is achieved at 10 kHz from the carrier. This result indicates that the BMT ceramics with the low dielectric loss fairly contribute to the low SSB noise performance.

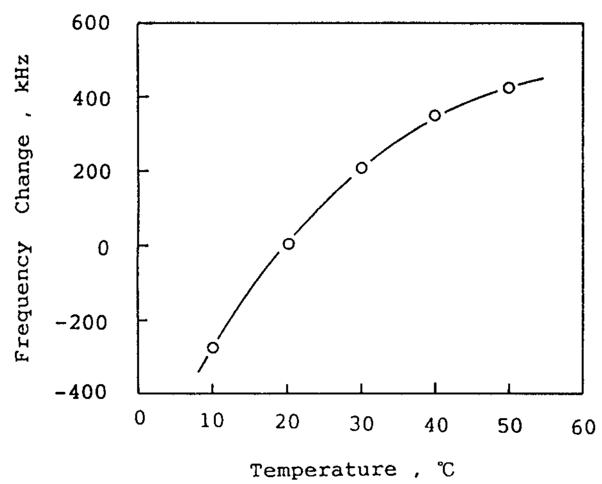

Figure 4. Frequency deviation of the oscillator as a function of ambient temperature.

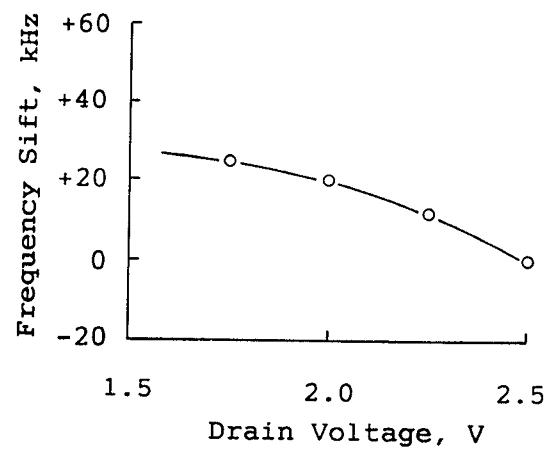

Figure 5. Frequency deviation of the oscillator as a function of drain voltage.

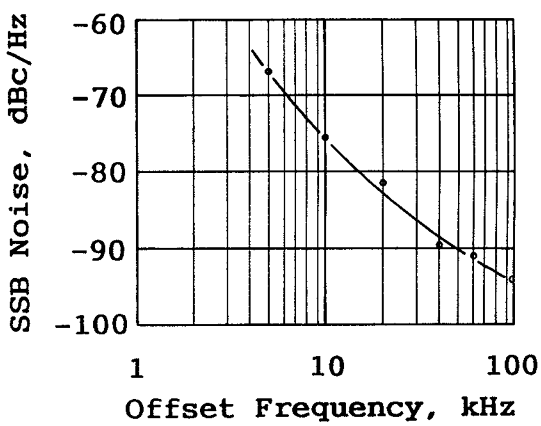

Figure 6. SSB noise of 30 GHz oscillator as a function of the offset frequency. Center frequency : 30.35 GHz

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