A 2 – 5 GHz TUNABLE MAGNETOSTATIC WAVE OSCILLATOR

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ABSTRACT

We developed a prototype 2 – 5 GHz tunable magnetostatic wave (MSW) delayline oscillator. A continuous frequency sweep range is between 1.8 GHz and 5.6 GHz. SSB phase noise characteristics at 10 kHz offset frequency are better than –111 dBc/Hz.

We have carefully controlled an oscillation power level because a saturation of a MSW delayline degrades inherent SSB phase noise of the delayline by 40 dB at 10 kHz offset frequency. The degradation of the the inherent SSB phase noise directly affect to an output signal.

The frequency drift rate changes from 6.8 MHz/K to 2.8 MHz/K for 2 – 5 GHz almost linearly. We stabilized the drift within ±20 MHz for the temperature range from 270 K to 340 K by sensing YIG film temperature and adjusting tuning coil current.

INTRODUCTION

We are researching magnetostatic wave (MSW) delayline oscillator as a low noise tunable source for measuring instruments. YIG sphere oscillators are used usually in this use. We are tring to replace them to MSW oscillators.

MSW oscillators have various advantages over conventional YIG sphere oscillators, for example, a good productivity and a capability of excellent low phase noise characteristics. On the other hand, they also have many considerable problems which contain difficulty of a exact control of MSW delayline transfer functions, interactions between magnetostatic waves and acoustic waves, degradations of inherent SSB phase noise owing to saturations of a MSW delayline, a compensation of changes of transfer functions over temperature and otherwise. The author has reported on the former two problems [1]. This paper describes the saturation effect and the compensation of temperature drift.

SATURATION EFFECT

SSB phase noise of oscillators depends on a signal to noise ratio in the oscillation loop. The signal is a minimum signal level in the loop, and the noise is a greater one of a thermal noise and an intrinsic 1/f noise of active devices.

Hence, a way to improve SSB phase noise is to increase the minimum signal level usually. For MSW devices, however, it is not good means always because a propagation of MSW has considerable saturation effects. Figure 1 shows a saturation characteristic of a transfer function $Mag.(S_{21})$ of a MSW delayline. At the small signal, the transfer function is linear. A saturation of transfer function begins at about –6 dBm and becomes *deeper* for larger inputs.

Figure 2 shows a degradation of SSB phase noise characteristics by –4.9 dBm, –2.8 dBm, –1.9 dBm inputs respectively. At –4.9 dBm, the SSB phase noise characteristic is *quiet*. At a beginning of saturation, –2.8 dBm, some large spurious rise between 10 kHz offset and 100 kHz offset. At a slight *deeper* saturated point, –1.9 dBm, the SSB phase noise characteristic changes drastically. The inherent SSB phase noise of the MSW delayline at 10 kHz offset is degraded by 40 dB. This change is quite abrupt.

A saturation point of transfer functions is defined as 1 dB compression point usually. This saturation point is almost equal to the theoretical saturation level which is calculated as critical power levels to rise spin waves in YIG films [2]. A saturation point of magnetostatic forward volume waves is estimated as + 20 dBm generally [3] [4].

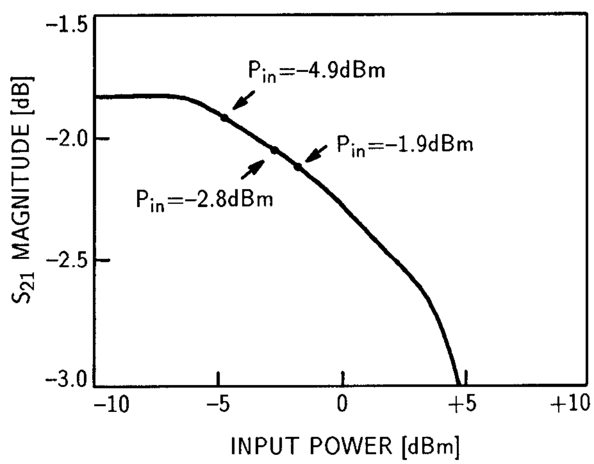

Figure 1 Saturation of transfer function of MSW delayline.

Nevertheless, these obvious saturation points are far greater than the real saturation point in which SSB phase noise begins to degrade. The author is using a 0.1 dB gain compression point as the saturation point. An input signal level of MSW delayline should be lower than the real saturation level, -1.9 dBm.

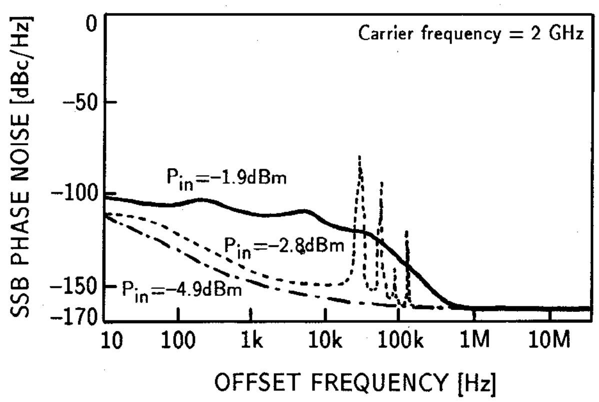

Figure 2 Degradation of inherent SSB phase noise of MSW delayline.

PROTOTYPE MSW OSCILLATOR

Figure 3 shows our latest prototype MSW oscillator. The outward dimensions are 45 mm of diameter and 36 mm of height. The diameter of the polepiece and the gap length are 28 mm and 1.2 mm respectively. The uniformity of the magnetic field is better than 10^{-4} within 10 mm from the axis. Figure 4 shows a circuit diagram of the oscillator. The YIG slab is cut to rectangular shape of 28 mm × 2 mm by dicing saw. The YIG film thickness and GGG substrate thickness are 33 μm and 400 μm respectively.

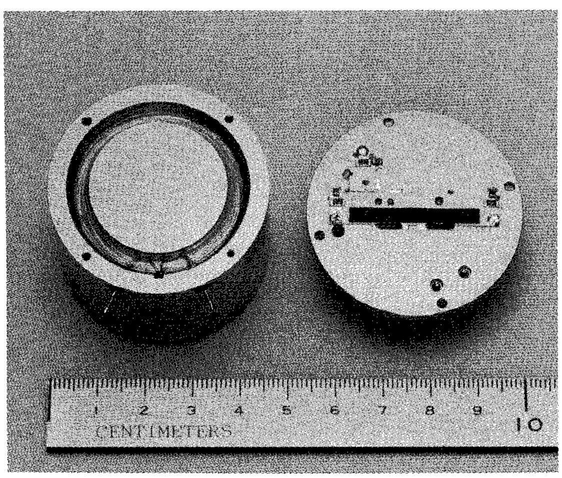

Figure 3 Prototype MSW delayline oscillator.

The saturation magnetization ($4\pi Ms$) is 1760 Gauss, and the ferromagnetic resonance line width (ΔH) of YIG film is 0.6 Öersted at 9 GHz. The MSW absorbers are Nickel Ferrite thin films. A pitch of the transducer is $400\mu m$. Two silicon MMIC amplifiers are used in the oscillation loop. The 1 dB gain compression level of the second stage amplifier is enough lower than the real saturation level of the YIG film to prevent the saturation.

Figure 5 shows the frequency sweep characteristic. The single mode oscillation occurs from 1.4 GHz to 5.6 GHz. The continuous sweep range is from 1.8 GHz to 5.6 GHz. There is a mode hopping at 1.8 GHz. Figure 6 shows the SSB phase noise characteristics. SSB phase noise at 10 kHz offset is better than -111 dBc/Hz from 2.0 GHz to 5.5 GHz.

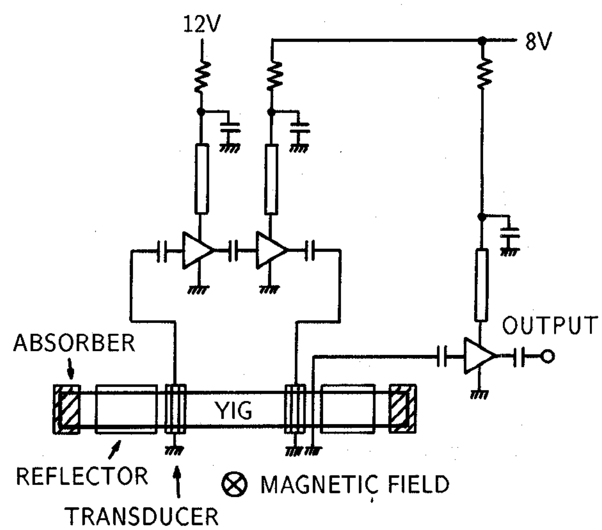

Figure 4 Circuit diagram of MSW oscillator.

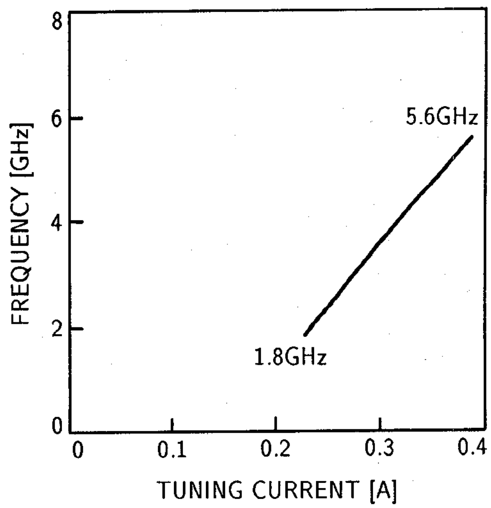

Figure 5 Frequency sweep characteristic.

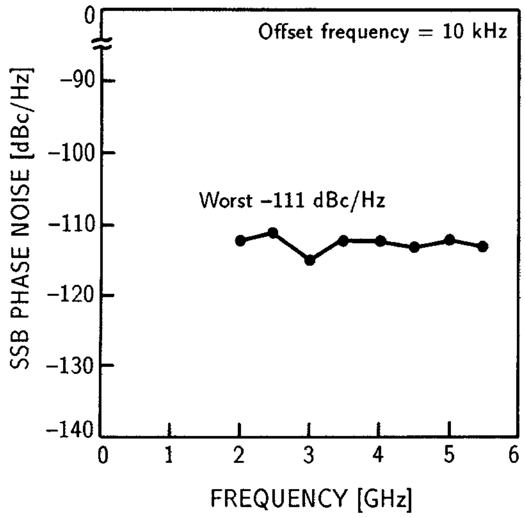

Figure 6 SSB phase noise characteristic.

THERMAL COMPENSATION

MSW devices have very poor temperature drift characteristics because a saturation magnetization of YIG film ($4\pi Ms$) has large temperature coefficient. An internal magnetic field of YIG films which decides oscillation frequency is the difference between an applied magnetic field and the saturation magnetization. Therefore, changes of YIG film temperature directly affect to the internal magnetic field and cause oscillation frequency drifts.

Figure 7 shows a temperature frequency drift characteristics. The horizontal axis shows an absolute temperature of a YIG film. The temperature drift is almost linear to the YIG film temperature when temperature change is slow, less than 1 K/min. (SLOW). When an abrupt change of ambient temperature is given to the oscillator, the linearity is degraded, and the frequency hopping rises conditionally (STEP). Figure 8 shows relationship between carrier frequency and temperature frequency drift rates. This large temperature drift is a serious disadvantage of MSW devices because MSW devices don't have effective self compensation method as YIG sphere oscillators[5].

However, the temperature frequency drift is able to be stabilized by sensing a YIG film temperature and compensating a tuning coil current. A compensating current is given

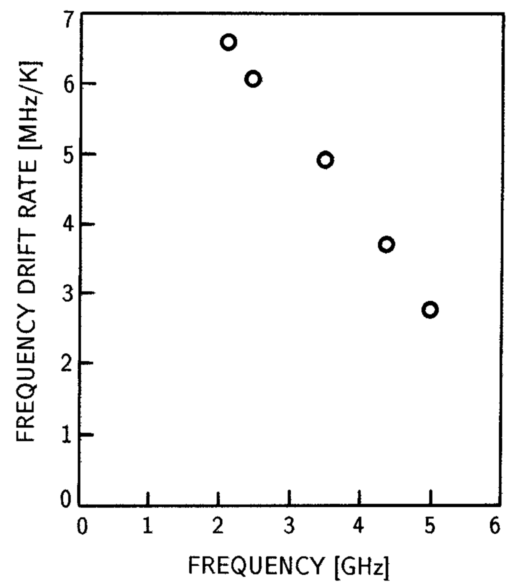

Figure 8 Relationship between carrier frequency and frequency drift rate.

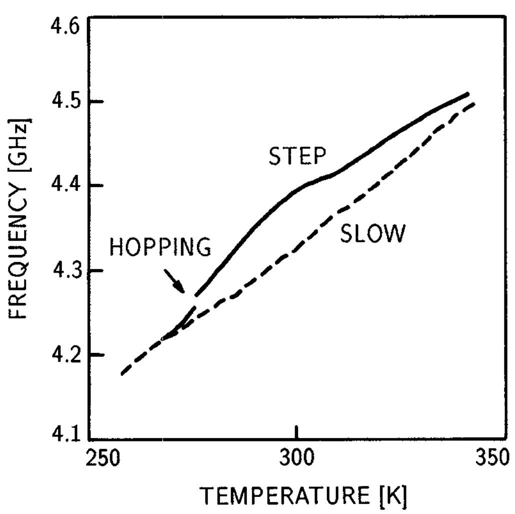

Figure 7 Temperature frequency drift characteristics.

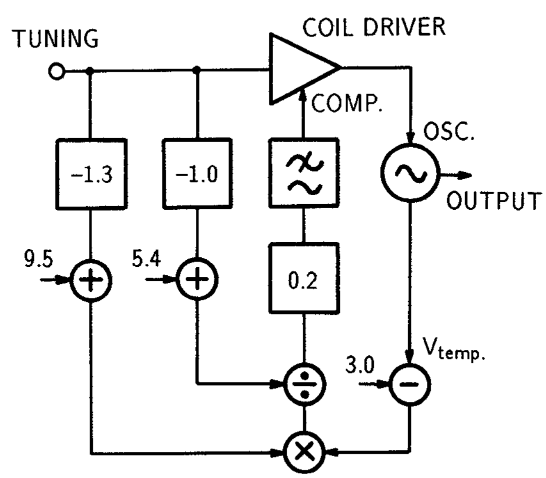

Figure 9 Schematic diagram of temperature frequency drift compensation.

by following expression,

$$compensation = \frac{(9.5 - 1.33f)(V_{temp.} - 3.0)}{10(27 - f)} [A]$$

where f is the frequency in GHz and $V_{temp.}$ is the output of temperature sensor which is proportional to the absolute temperature. Figure 9 shows the schematic diagram of the temperature compensation.

Figure 10 shows an example of the compensation on a point frequecy. Figure 11 shows the compensated overall temperature frequency drift characteristic with the compensation circuit. The temperature frequency drift is stabilized within ±20 MHz on the temperature range 270 K - 340 K.

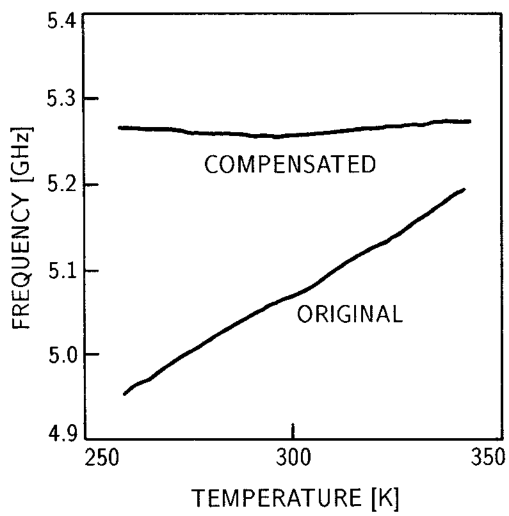

Figure 10 Compensation of temperature frequency drift on a point frequency.

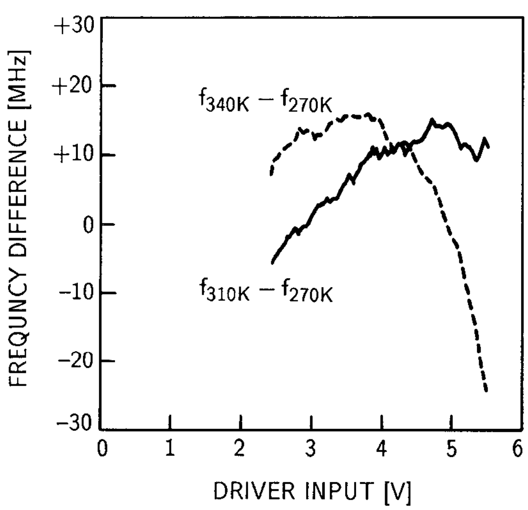

Figure 11 Overall compensated temperature frequency drift characteristics.

CONCLUSION

This paper described the drastic increase of SSB phase noise of MSW oscillator owing to a saturation of MSW delayline. An intrinsic SSB phase noise of MSW delayline is degenerated abruptly as same as the delayline begin to saturate by excessive input. This saturation degrades the SSB phase noise at 10 kHz offset by 40 dB.

We made a 2 – 5 GHz prototype MSW delayline oscillator. The single mode continuous sweep range is from 1.8 GHz to 5.6 GHz. The SSB phase noise characteristics are better than -111dBc/Hz at 10 kHz offset frequency.

We tested the stabilization of the temperature frequency drift by sensing YIG film temperature and compensating the tuning coil current. We realized the compensating technique to one board hardware. The circuit compensates the temperature frequency drift of the oscillator within ±20MHz on the temperature range between 270 K and 340 K.

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