C-6

X- and Ku-Band YIG-Film Tuned Low Noise Oscillators

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Abstract

X and Ku-band YIG-film tuned oscillators (YTOs) with phase noise below -95 dBc/Hz 10 kHz from the carrier and a high output power of more than +10 dBm without the use of buffer amplifier have been developed. This paper will describe the design criteria used to realize these high performance YTOs. The features of the YTOs are excellent linear tuning, low-phase noise over a relatively wide band, and small frequency drift with temperature. These oscillators are ideal for data and video transmission systems utilizing surface microwave links as well as satellites.

Introduction

Although a 13-GHz low-phase noise oscillator with a tuning range of 500 MHz has previously been developed for VSAT applications, the YIG-film resonator and the matching circuit were not satisfactorily optimized, so the YTO could only operate on a narrow band [1]. Recently, the advantages of using a YTO as a local oscillator for surfce microwave transmission systems for data and video signals as well as VSAT applications have been widely recognized. To meet these demands, we have established design criteria for the resonator and the matching circuit in order to achieve low-phase noise from the X- to Ku-band.

The newly developed YTOs have a very low phase noise below -95 dBc/Hz at 10 kHz from the carrier. By substituting an appropriate amount of gallium in the YIG-film, the temperature dependence of the saturated magnetization of the film was adjusted with the temperature dependence of the magnetic field that produced by the permanent magnet, thus minimizing the temperature drift of the oscillation frequency.[2][3] The tuning range from 10 to 14 GHz was assigned to two different types of YTOs, one from 10 to 11.25 GHz (L-band) and the other from 11.5 to 14 GHz (H-band). These YTOs differ in their matching circuits, each being adjusted to achieve low phase noise in their respective frequency range.

This paper will first describe the necessity of a YIG resonator having enough critical power to avoid the non-linear effect of the YIG. The resonant characteristics of the resonator will be presented. The design criteria of the output matching circuit of a low-phase noise oscillator will then be discussed. Finally, the tuning and the phase noise characteriatics will be presented.

Design

(a) Design of the YIG resonator

As we reported previously, the critical power to the resonator must be high enough to avoid high-power instability of the YIG [1][4]. We dis-

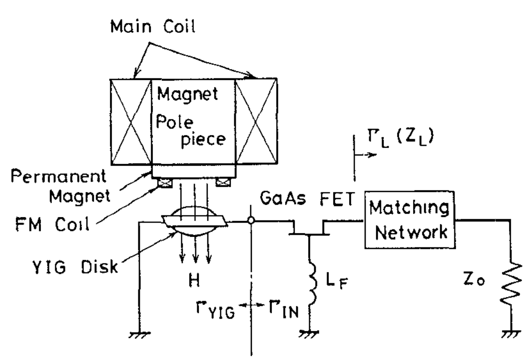

Fig.1 Structure of the YTO.

1989 IEEE MTT-S Digest

covered that a square YIG-film resonator has 4 dB higher critical power than a circular YIG-film resonator, so we applied a square YIG-film resonator to our new YTOs. The specifications of the resonator are as follows: critical power = +22 dBm at 12 GHz, delta H = 0.98 Oe and 4 Ms = 1089 Gauss. The unloaded Q, loaded Q and the loop diameter of the resonator were 3300, 430 and 1.74, respectively.

(b) Design of the output matching circuit

In this section the design criteria to realize the low-phase noise will be presented. The schematic structure of the complete YTO is illustrated in Fig. 1. Lf is gate feedback inductance. The stable oscillation condition is $\Gamma_{in} \times \Gamma_{yig} = 1$. Figure 2 shows the trajectory of the inverse of the input small signal reflection coefficient $1/\Gamma_{in}$ with frequency, and a typical reflection loop Γ_{yig} resonating at 13 GHz. The condition of onset of oscillation is that $1/\Gamma_{in}$ is encircled by Γ_{yig} and stable oscillation is realized when the condition $1/\Gamma_{in}(A) = \Gamma_{yig}$ is satisfied with the increase of signal level A of the GaAs MESFET [5]. In Fig. 3, the calculated locus of the matching circuit realizing low-phase noise are shown where stable oscillation occurs at the high Q area of the resonant loop, particularly at the peak of the loop. The locus of the measured matching circuit designed for a H-band YTO is also presented in Fig. 3.

In Fig. 4, we show the simulated $1/\Gamma_{in}$ of the H-band YTO based on the measured small signal transistor S parameters of the MESFET and the measured locus of the matching circuit

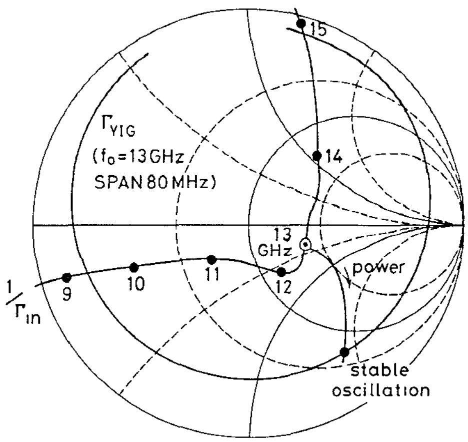

Fig.2 Reflection coefficient Γ_{yig} and trajectory of $1/\Gamma_{in}$.

illustrated in Fig. 3. Here Lf is 0.5 nH and the measured $1/\Gamma_{in}$ locus was plotted onto the same chart as in Fig. 4. According to this figure, a wide-band low-phase noise oscillator appears to be realizable.

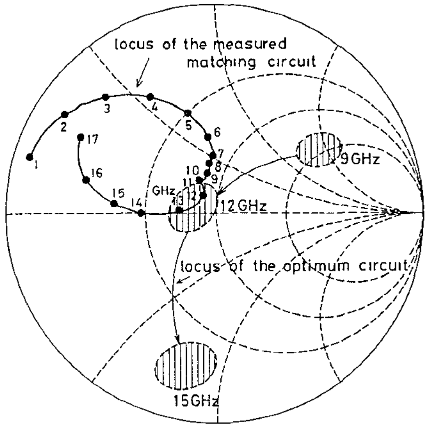

Fig.3 The locus of the optimum matching circuits obtained from the simulation and the locus of the measured matching circuit designed for an H-band YTO.

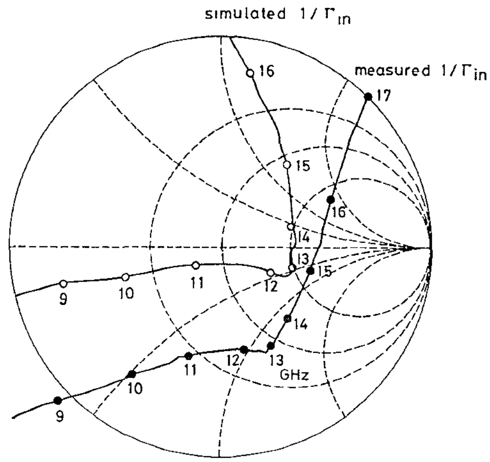

Fig.4 Simulated and measured $1/\Gamma_{in}$ for the H-band YTO.

YTO characteristics

(a) Tuning characteristics

The output characteristics of the YTO are shown in Fig. 5 for the L-band and H-band YTO, both having been designed in the same manner. The main tuning coil was made of 500 turns of copper wire, making the sensitivity about 3.0 MHz/mA. According to Fig.5, output power was over +10 dBm with variations of 1.5 dB over the tuning range with a bias condition of Vds = 3.0 v ± 10 %.

(b) Phase noise characteristics

We tried to realize a wide-band low-phase noise YTO utilizing a YIG resonator and a a GaAs MESFET. To test the accuracy of our design criteria, we measured the phase noise by the delay line discriminator method and employing a carrier noise test set. Figure 6 shows the phase-noise of L- and H-band YTO at 10 kHz from the carrier over the entire tuning range. The phase noise was below -98 dBc/Hz from 10 to 11 GHz for L-band YTO and -96 dBc/Hz from 11.5 to 12 GHz, -99 dBc/Hz from 12 to 13.5 GHz, and -97 dBc/Hz from 13.5 to 14 GHz for H-band YTO.

(c) Temperature dependence of the tuning characteristics

The magnetic field was also a function of a gap length between the higher magnetic pole-piece and the lower magnetic yoke. So the temperature drift of the oscilllation frequency varies with the gap length. Figure 7 shows the variations of the oscillation frequency with temperature at 13 GHz for H-band YTO. In this figure the solid and broken lines were gap lengths of 1.5 and 1.3 mm,

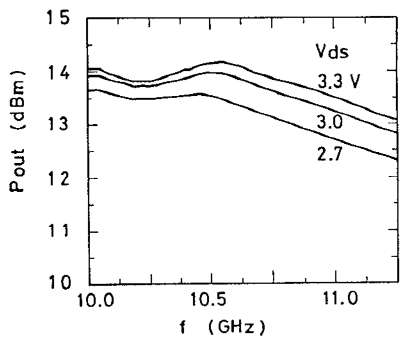

Fig.5 (a) Output characteristics of the L-band YTO.

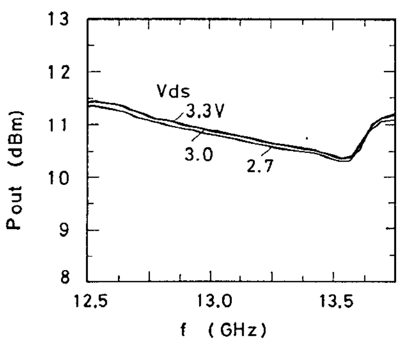

Fig.5 (b) Output characteristics of the H-band YTO.

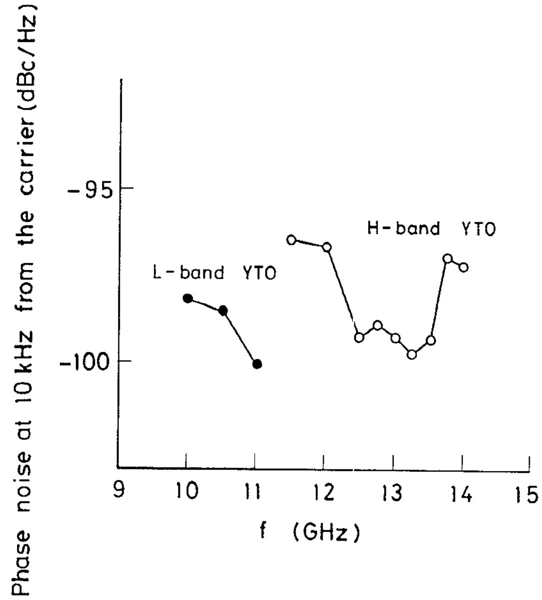

Fig.6 Phase noise characteristics of the L-and H-band YTO.

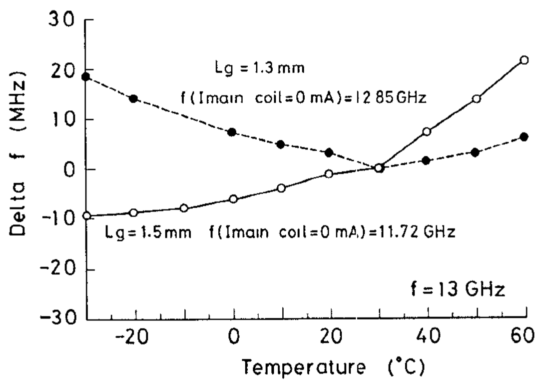

Fig.7 Temperature dependence of the oscillation frequency drift at 13 GHz for the H-band YTO.

corresponding to oscillation frequency of 11.72 and 12.85 GHz when the I (main coil) = 0 mA. The variations were 30 and 18 MHz when the gap length were 1.5 and 1.3 mm, respectively. Considering the slope of each line in Fig. 7, the optimum gap length was between 1.3 and 1.5 mm, in which case minimum frequency variation would be 10 MHz.

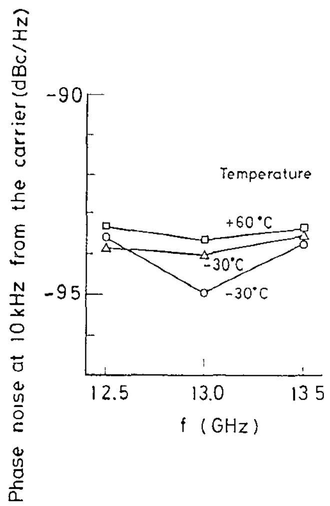

Fig.8 Phase noise of the PLYTO with temperature variation.

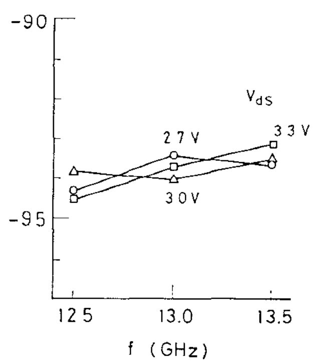

Fig.9 Phase noise of the PLYTO with drain bias variation.

(d) Phase noise characteristics of the phase-locked YTO (PLYTO)

We incorporated the YTO into the phase-locked loop (PLL). The temperature and bias voltage dependence of the phase-noise were then measured when the H-band YTO was tuned to 12.5, 13.0 and 13.5 GHz. Figure 8 shows the phase noise at 10 kHz from the carrier of the PLYTO when the temperature was -30 °C, +30 °C and +60 °C. As can be seen in this figure, the phase noise was below -93 dBc/Hz. The drain bias dependence of the phase noise at 10 kHz from the carrier is as in Fig. 9. When the Vds was adjusted to 2.7, 3.0 and 3.3 V, the phase noise variation was within 1.0 dB over the tuning range from 12.5 to 13.5 GHz at room temperature.

(e) Specifications

The case dimensions are 25 X 25 x 20 mm and the specifications of the oscillator are summarized in Table I.

Conclusion

X and Ku-band YIG-film tuned oscillators with low-phase noise below -95 dBc/Hz at 10 kHz from the carrier have been developed. The design criteria leading to the realization of the high-performance temperature have been presented. With their excellent linear tuning capability, these oscillators are ideal for use as a local oscillator in microwave systems, such as satellite communication systems or surface data/video transmissions.

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Table I

Frequency Range	10.0 - 14.0	GHz
Output Power	10	dBm
Output Power Variation	1.5	dB
SSB Phase Noise at 10 KHz offset	-95	dBc/Hz
Frequency Drift Over Temperature (-30 °C to +60 °C)	18	MHz
Main Tuning Port Characteristics		
Sensitivity	3.0	MHz/mA
3 dB Bandwidth	20	KHz
Hysterisis	1	MHz
Input Impedance(1 KHz)	6 Ohm with series 20 mH	