Short Papers

Microwave Oscillator Noise Measuring System Employing a YIG Discriminator

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Abstract—A microwave oscillator noise measuring system employing a YIG discriminator has been developed. The resonant frequency of the YIG discriminator is automatically tuned to follow the drift of the carrier frequency of the oscillator under test. This arrangement permits an accurate measurement of FM noise spectra near the carrier frequency as close as several tens of Hz off the carrier. The drift of the carrier frequency is measured over a wide range by monitoring fluctuations of the feedback current in the compensation coil that supports a part of the biasing magnetic field for the YIG discriminator.

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I. INTRODUCTION

The direct-detection systems developed by Ashley *et al.* [1] and Ondria [2] have been widely used for measurements of microwave oscillator noise. FM noise measurements using these systems require elaborate adjustments of the discriminator in order to avoid

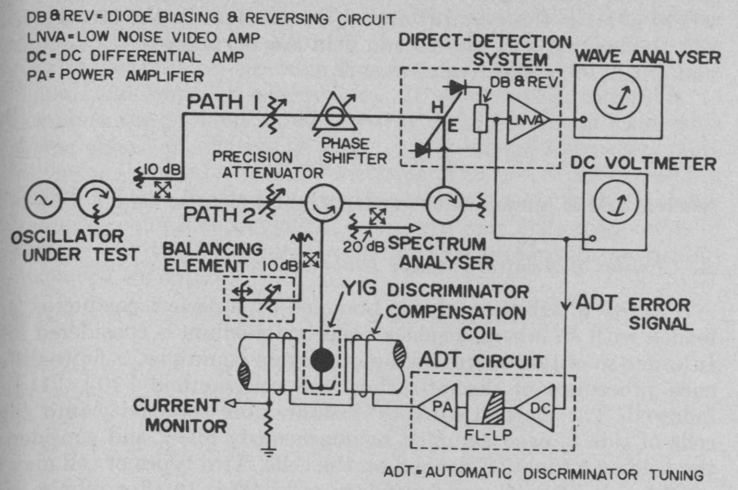

Fig. 1. Complete microwave oscillator noise measuring system.

errors due to the discriminator detuning from the carrier frequency of the oscillator under test.

We have developed a noise measuring system for X-band oscillators which employs an yttrium iron garnet (YIG) sphere as the discriminator. The resonant frequency is automatically tuned to follow the drift of the carrier frequency, thereby avoiding the adjustment problem. This automatic discriminator tuning (ADT) permits an accurate measurement of the FM noise spectra over a wide frequency range, from tens of Hz to several MHz off the carrier. The drift is measured by monitoring fluctuations of the compensation coil current that tunes the YIG discriminator.

II. SYSTEM CONFIGURATION

The configuration of the noise measuring system is shown in Fig. 1. The basic arrangement and operation of the system are the same as those described in [1] and [2], but the YIG discriminator is incorporated into the present system for automatic frequency following.

The YIG discriminator is a magnetically biased YIG sphere placed in a length of waveguide short-circuited at one end. Resonant frequency f_0 of the YIG sphere is given by $f_0 = 2.8H_0$, where f_0 is given in megahertz and H_0, the applied magnetic field, in gauss. Unloaded Q of the discriminator is about 6000. Coupling coefficient is nearly unity, but can be adjusted by varying the distance between the YIG sphere and the shorted end. The residual carrier component due to the reflection from the YIG discriminator and the circulator feedthrough is reduced to the lowest possible value by adjusting the balancing element.

When the oscillator frequency drifts, an unbalanced carrier wave is detected by the phase sensitive detector in path 1, and the output is fed into the ADT circuit consisting of a dc differential amplifier, a low pass filter, and a power amplifier. The detector output contains both the FM-noise and frequency-drift components, but only the latter goes through the low pass filter to reach the compensation coil. The resonant frequency of the YIG discriminator varies linearly with a slope of 234 kHz/mA against the current in the compensation coil. Since the feedback system has a high gain, the resonant frequency of the YIG discriminator follows the drift of the carrier frequency closely. Thus the fluctuation of the feedback current in the compensation coil measures the drift of the carrier frequency, which is monitored and recorded.

The calibration of the FM–AM conversion sensitivity of the YIG discriminator is accomplished by the dc method: incremental changes in dc output voltage measured by a dc voltmeter are plotted against incremental changes in the resonant frequency of the YIG discriminator, which are deliberately introduced by means of varying the current in the compensation coil. The slope gives the FM–AM conversion sensitivity. The sensitivity of the present system when the incident power on the discriminator is 10 mW is 1 μV/Hz.

III. MEASUREMENT AND ERROR

Two factors contribute to errors in FM noise measurements when using a direct-detection system: the detuning of the discriminator from the carrier frequency and the FM noise measuring threshold of the system. In a conventional system, the major factor is the discriminator detuning, while, in the present system, it is the FM noise measuring threshold, since the detuning is eliminated.

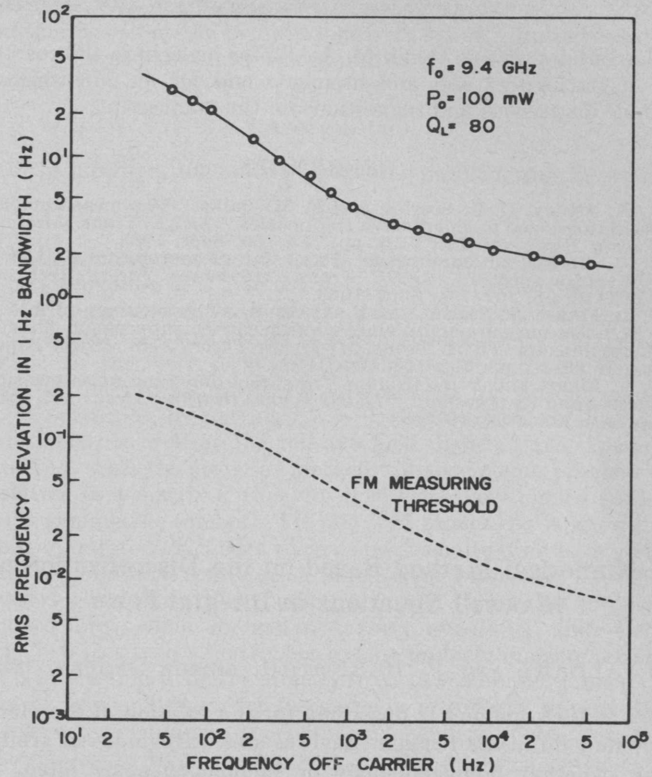

Fig. 2. FM noise spectra of the X-band Gunn oscillator (solid curve) and FM noise measuring threshold of the system (dotted curve). The incident power on the discriminator is 10 mW.

The FM measuring threshold is determined by three sources: 1) the noise generated in the direct-detection system; 2) the residual AM noise due to the mismatch of two detector diodes and the unbalance of the magic T [2], [4]; and 3) the random fluctuation of the resonant frequency of the YIG discriminator due to the noise in the biasing magnetic field and the ADT circuit, which is a drawback of the present system.

The FM measuring threshold Δf_{thr} due to 1) and 2) is shown by the dotted curve in Fig. 2, when the discriminator sensitivity is 1 μV/Hz. The contribution of 3) is estimated to be about one tenth of Δf_{thr}. Thus the fractional error ϵ_{thr} in FM noise measurements with using the present system is given by $\epsilon_{\text{thr}} = \Delta f_{\text{thr}}/\Delta f_{\text{rms}}$, where Δf_{rms} is the measured FM noise of the oscillator under test expressed in terms of the rms frequency deviation.

A free-running Gunn oscillator, 9.4 GHz, 100 mW, was subjected to FM noise measurement with using this system and the result is given by the solid curve in Fig. 2. The Gunn diode was mounted in a rectangular cavity with a loaded Q of 80. The incident power on the discriminator was 10 mW. The cutoff frequency of the low pass filter was 1 Hz. The measuring error ϵ_{thr} due to the FM measuring threshold Δf_{thr} was about 7 percent. The measured off-carrier frequency range is limited by the wave analyzer used in this measurement, which can be extended by employing a wide-band analyzer.

The recorder output of the current monitor showed that the frequency of the oscillator drifted and decreased by about 15 MHz in a half hour after the start of operation to settle down at a steady state value. FM noise measurement was possible during this turn-on transient, which is not possible with the conventional method.

IV. CONCLUSIONS

A microwave oscillator noise measuring system employing a YIG discriminator is described. The factors contributing to errors in FM noise measurements with using the noise measuring system are discussed. The system capabilities are also demonstrated by the measured FM noise spectra for a typical X-band Gunn oscillator. The noise measuring system permits precise and easy measurements of microwave oscillator noise, in particular, measurements of FM noise spectra close to the carrier frequency.

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