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A TUNABLE MAGNETOSTATIC VOLUME WAVE OSCILLATOR

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ABSTRACT

A 3.4 GHz to 7.0 GHz tunable oscillator using a magnetostatic volume wave resonator as the frequency selective element and GaAs FET chips for gain in the feedback loop has been achieved and tested. Oscillator circuit has been designed using the theoretical model of a GaAs FET and the equivalent circuit of the resonator. This oscillator delivers a + 7 dBm output signal at 7 GHz with a low FM noise of - 90 dBc/Hz, 10kHz removed from the carrier.

Introduction

Microwave tunable oscillators generally use yttrium iron garnet (YIG) sphere resonators for the frequency selective element. But each sphere must be individually oriented by hand and those devices are difficult to be mass produced. For years, engineers have been trying to find a planar technology to replace those hard-to-handle YIG spherical resonators in microwave systems. The use of epitaxial YIG grown on gadolinium gallium garnet (GGG) substrate and planar photolithographic processing can remove these relatively dextrous steps of resonator construction and offers the possibility of a range of low cost filters in an MIC format. But microwave filters relying on ferrimagnetic resonance in epitaxial films experience several difficulties such as spurious suppression, low tunability, temperature compensation, magnet design and packaging. Another way around a flat YIG replacement is to use magnetostatic wave propagation in epitaxial YIG films. The first attempts with magnetostatic surface wave (MSSW) resonators [1,2,3] were blocked by problems related to the inherent saturation level, temperature coefficient and magnet design. Magnetostatic forward volume wave (MSFVW) resonators [4] do not present this power saturation and their positive resonance frequency temperature coefficient can be cancelled by the temperature variation of bias field induced by rare-earth cobalt permanent magnets as shown by J.D.Adam [5] and J.P.Catéra [6].

Moreover, MSFVW unlike MSSW, for which the magnetic field is applied in the plane of the YIG film, are produced by a magnetic field perpendicular to the plane of the magnetic film, so that the gap between the magnets can be as small as the thickness of the film and the substrate. With a small gap, high fields are readily obtained.

This paper describes a hybrid tunable microwave oscillator based on two-port MSFVW resonator filter of the type described by J.P.Castéra, et al[4] . The resonator used as the frequency stabilizing element in the feedback loop of a solid-state amplifier consists of two MSFVW Fabry-Pérot interferometric cavities coupled together through a reflective grating. The resonator frequency is a function of the magnetic field applied perpendicular to the plane of the YIG film. An equivalent circuit of the resonator has been determined from physical considerations and from external S-parameter measurements. The use of this equivalent circuit and of the theoretical model of a GaAs field-effect-transistor to design the matching circuits is described. A realization in the 3.4 GHz - 7 GHz frequency range is reported. Performances about tunability, output power and FM noise are presented and discussed.

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Two-port MSFVW resonator

The resonator to be considered is shown schematically in Fig.1.

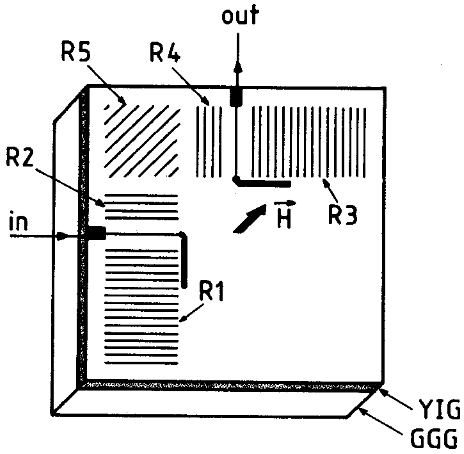

Fig.1- MSFVW resonator schematic.

The basic element of this device is a periodic grating which reflects the MSFVW at specific wavelengths. The arrays of reflectors are formed from thin ion beam milled grooves. Mirrors R_1 and R_2 and mirrors R_3 and R_4 define two resonators which are coupled together through the 45° oblique incidence reflective track changing filter (mirror R5). For the resonator used in the experiment, the grooves of the distributed mirrors, etched in a 23µm thick YIG film, are 0.35µm deep, 37.5µm wide and 3mm long. Transduction of MSFVW's is efficiently achieved through the use of shorted narrow microstrip couplers. 20µm wide and 3mm long, these transducers are deposited within both cavities directly on the YIG film. Shown in Fig.2 is the frequency response of this device. The insertion loss is 22dB at 2.7 GHz, near the resonance the out-of-band rejection

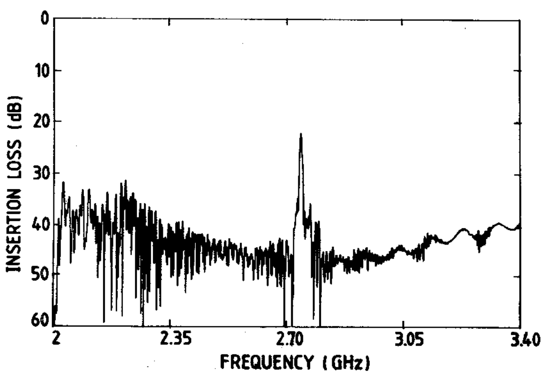

Fig. 2- Frequency response of a 150µm wavelength MSFVW resonator.

is close to 15dB and the loaded Q at this frequency is 500.Transmission at large magnetostatic wavelengths has been attenuated so as to obtain a rejection of these waves better than 10dB. The tuning range of this component is given in Fig.3 where a multiple trace has been obtained by variation of the bias magnetic field intensity.

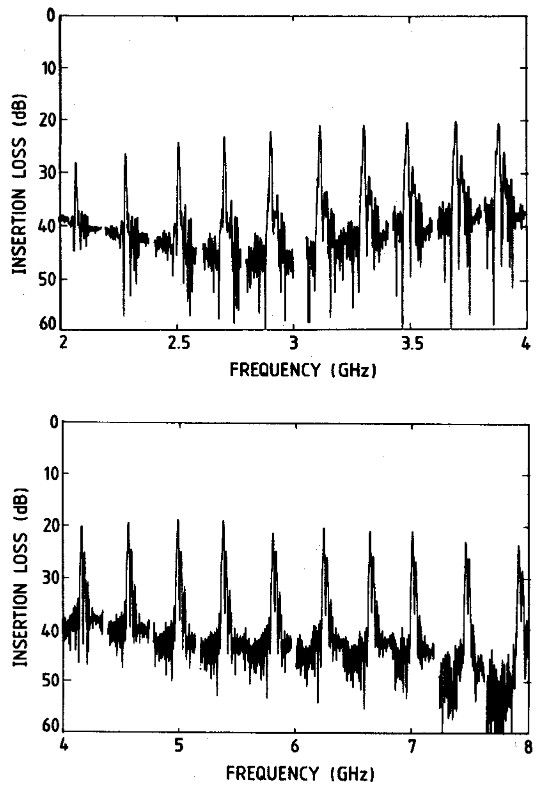

Fig. 3- Magnetic field tuning characteristics of an MSFVW resonator.

From physical considerations and from S-parameter measurements performed on this type of resonator, an equivalent circuit has been deduced. The model and the values for the circuit elements are given in Fig.4.

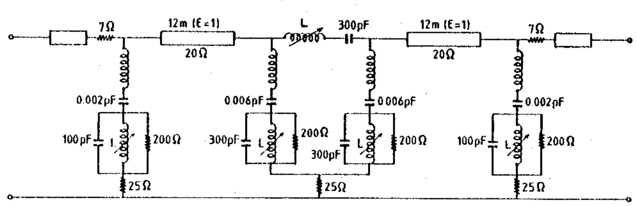

Fig. 4- Two-port MSFVW resonator equivalent circuit valid in the vicinity of the resonance frequency.

The resonance frequency determine the inductance L. Theoretical and experimental insertion loss and phase versus frequency shown in Fig.5 are, owing to the approximations made, in good agreement.

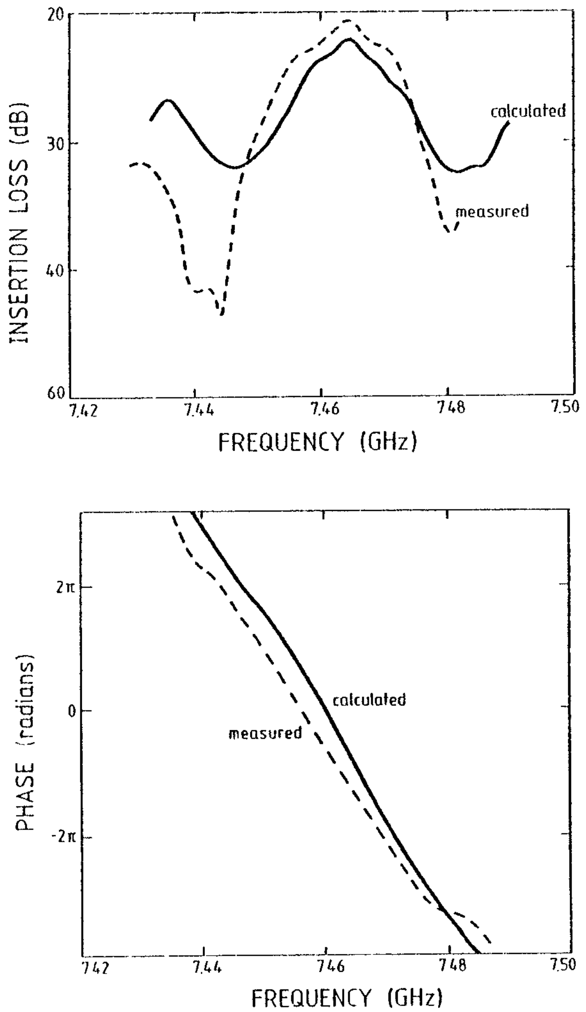

Fig. 5- Insertion loss and phase versus frequency of a two-port MSFVW resonator. The theoretical values correspond to the model shown in Fig.4.

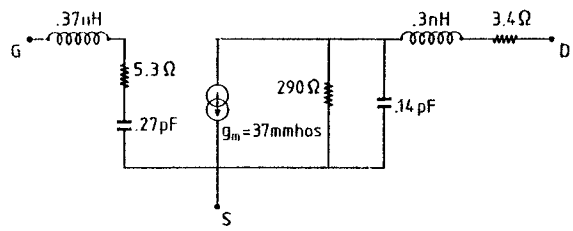

Fig. 6- Simplified GaAs FET model for amplifier design.

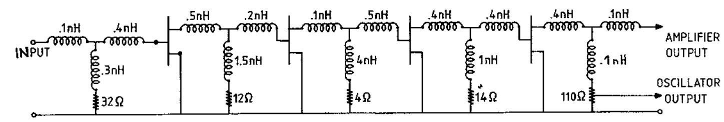

Fig.7- Schematic circuit of four stages amplifier.

The measurements of amplifier gain and insertion phase are presented in Fig.8.

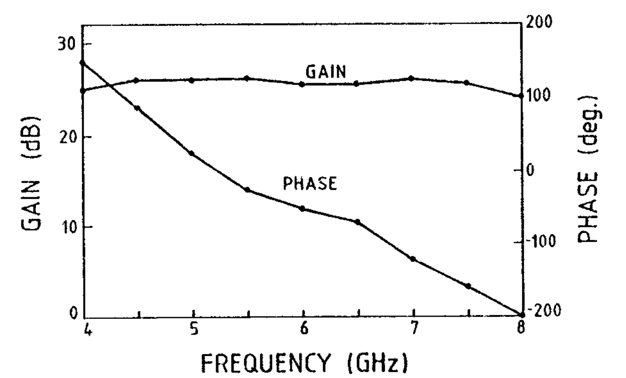

Fig. 8- Gain and phase frequency response of four stages amplifier.

Amplifier

The amplifier is realized with four GaAs FET chips and lumped elements implemented on an alumina substrate. The FET equivalent circuit and the schematic four stages amplifier are shown in Figs.6 and 7.

Input, interstage and output matching circuits were optimized using computer-aided design techniques.

The FETs are mounted on a gold-plated molybdenum pedestal to obtain good heat sinking and the gate and drain pads are bonded to adjacent substrates. The FETs are used in a common-source self-biased configuration.

It is possible after the adjustment and the measurement to commute the same circuit in the loop of the oscillator.

MSFVW oscillator

The oscillator considered here consists of a tunable MSFVW resonator in the feedback loop of a solid-state amplifier. The conditions required for oscillation of a feedback loop oscillator are that the path length along the loop corresponds to a phase shift of

2π n radians, n being an integer, and that the loop gain exceeds unity at the operating frequency. To obtain a tunability over a wide frequency range without mode jumping, the transit time in the amplifier and connections has to be as low as possible. The two-port MSFVW resonator and the microelectronic amplifier above-mentioned meet this requirement. The output of the transistor stages is split into two paths by a power splitter. One path leads to the output, the other path lightly couples the signal to the MSFVW resonator input.

Performance

The oscillator output characteristics were measured as function of frequency by variation of the bias magnetic field.Single mode operation with a linear tuning response was observed from 3.4 GHz to 7.0GHz as can be seen in Fig.9 representing the variation of oscillator frequency versus the applied magnetic field.

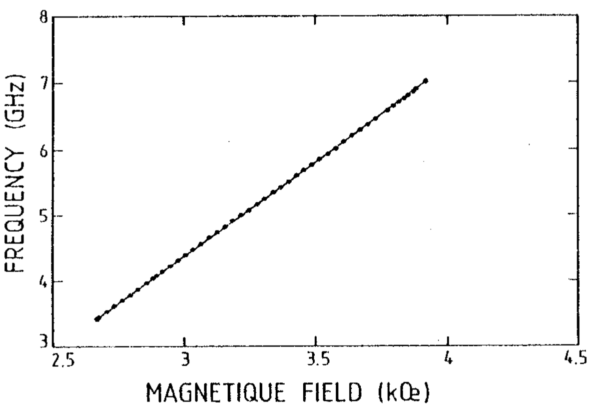

Fig. 9- Measured MSFVW oscillator frequency versus applied magnetic field showing the wideband and linear tuning response of this device.

Typical oscillator line spectrum at 5.0 GHz is shown in Fig.10.The phase noise characteristics of this type of oscillator,represented in Fig.11, are excellent, as obtained from a Pound discriminator measuring set :-90 dBc/Hz,10kHz removed from the carrier with a 30dB/decade slope has been measured on this device. 1 MHz offset from carrier, the FM noise reaches - 150 dBc/Hz. Fig.12 shows the power output of the oscillator versus frequency. The power varies between - 16 dBm and + 7 dBm but no particular attempt was made to obtain a constant output power level.Moreover, the oscillator worked perfectly first time with no adjustment.

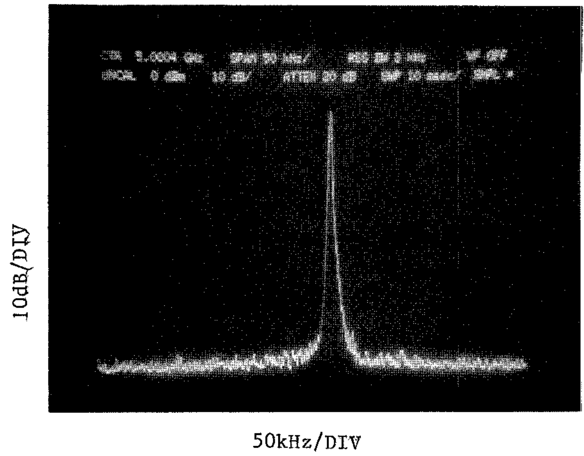

Fig. 10- MSFVW resonator based oscillator line spectrum at 5GHz.

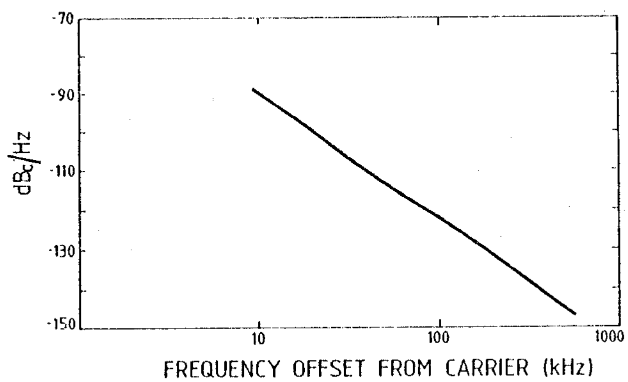

Fig. 11- Phase noise characteristics of an MSFVW resonator stabilized oscillator.

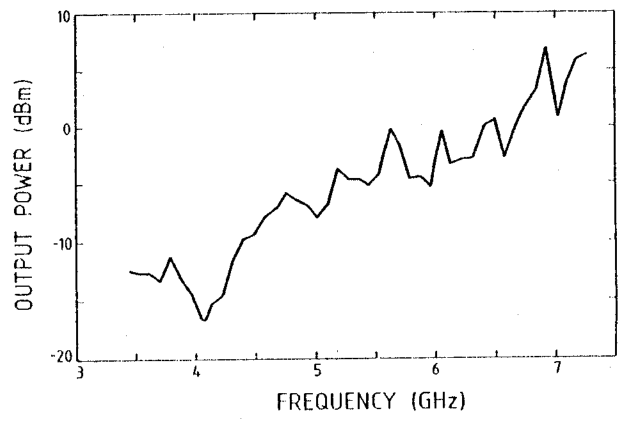

Fig. 12- Output power versus frequency of an MSFVW resonator stabilized oscillator.

Conclusion

A microwave tunable MSFVW resonator stabilized oscillator has been realized and tested. It uses a two-port resonator and a GaAs FET chip amplifier in a hybrid configuration. The device is continuously tunable from 3.4 GHz to 7.0 GHz with a linear tuning response. Output power reaches + 7dBm at 7 GHz with a low FM noise of - 90 dBc/Hz, 10 kHz removed from the carrier. The performance specifications for this oscillator have been met without difficulty, and the advantages can be seen of this MSFVW resonator stabilized oscillator over conventional YIG sphere oscillator.

Tunable microwave oscillators using a MSFVW resonator implemented on a YIG film and semiconductor elements in a hybrid configuration seem very attractive. The planar geometry of these components overcome several problems encountered with YIG sphere such as the operation of orienting the crystalline sphere within the external magnetic field. Transducer and periodic structure dimensions permit the use of conventional microelectronic techniques. Planar geometry allows for better integration and better performances under vibrating conditions. These technologies promise accuracy and reproducibility of fabrication compatible with batch production and hence cost reduction.

Acknowledgments

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