# BROADBAND HIGH-Q MONOLITHIC OSCILLATOR TUNED BY PLANAR YIG RESONATOR.

A. Cetronio*, P. De Gasperis**, R. Graffitti*, R. Marcelli**, L. Marescialli*, U. Parrucci*, S. Rapisarda*

## ABSTRACT

We have designed and characterised a one-port MSFVW-SER based monolithic oscillator working at X band.
Loaded Q's up to 3600 has been obtained at 9 GHz with tuning band up to 2 GHz.

## INTRODUCTION

Modern systems usually require microwave sources with broadband characteristics and high spectral purity. In this context different kinds of microwave oscillators have been developed showing different performances. Dielectric oscillators show high $Q_{ex}$, but little tunability; varactor oscillators, on the other hand, have a broadband performance but lower $Q_{ex}$. Finally, YIG sphere oscillators are characterised by broadband tunability and reasonable spectral purity.

In this article we illustrate how, by using a planar YIG resonator as a stabilising network, improved oscillator performance can be achieved. To demonstrate this point we have designed an X band oscillator which utilises both GaAs Microwave Monolithic Circuits (MMIC) technology for the oscillating network and Magnetostatic Wave (MSW) devices for the resonant network.

## MONOLITHIC OSCILLATOR

The active section of the oscillator was realised with MMIC technology; one MESFET with a 0.5x300 µm gate and with a serial capacitance on the source which results in a positive feedback, is integrated in common source configuration together with bias circuits (fig.1).

Standard processing techniques were used for the monolithic circuit. The isolation was achieved by selective ion-implantation of the donor species ($N_{Si}$ = $1\text{x}10^{13}$ at 40 keV plus $5\text{x}10^{12}$ at 120 keV). The 0.5 µm gate was realised by conventional hard contact lithography using positive resist. A reactively sputtered $Si_3N_4$ layer (3000 Å thick) was used as the capacitor dielectric material. All other process steps used conventional metalisations, passivation, lift-off and gold-plating techniques.

The gate terminal shows an impedance with real and imaginary parts both negative, which corresponds to a reflection coefficient

$$\Gamma = \Gamma_G \, e^{j\Theta} \qquad (1)$$

with

$$|\Gamma_G| > 1$$

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* SELENIA S.P.A.- DIREZIONE RICERCHE, ROME, ITALY.
** C.N.R.- ISTITUTO DI ELETTRONICA A STATO SOLIDO, ROME, ITALY.

This circuit requires a one-port resonator in the reflective configuration as the frequency selective element.

The quality factor of the resonator and the coupling with the transducer determines the oscillating condition.

## MSW PLANAR RESONATOR

Yttrium Iron Garnet (YIG) films are grown by liquid phase epitaxy (LPE) on Gadolinium Gallium Garnet (GGG) non-magnetic substrates. Magnetostatic waves (MSW's) propagating in YIG films provide a convenient means for performing signal processing functions directly at microwave frequencies. Among the components that can be built by using MSW's propagation in YIG films are delay lines, filters, resonators, convolvers etc.[1].

Planar MSW resonators are among the MSW components with potential applications in instruments and communication systems. These are tunable resonators and can be used as the frequency selective elements in tunable oscillator circuits in a wide frequency range.

The planar structure of the resonator makes integration with MMIC devices easy and attractive. Moreover, because the velocity of propagation of MSW's in YIG films is only two orders of magnitude lower than the velocity of light, the microstrip transducer widths involved in fabricating MSW resonators are of the order of 10 ÷ 100 µm, allowing straightforward photolithographic processing.

The theory of propagation of MSW's in ferrite slabs has been treated by Damon and Eshbach [2]. They considered three distinct orientations of a d.c. bias magnetic field H with respect to the excited wave vector $\underline{k}$. In terms of a unit vector $\underline{n}$ normal to the ferrite slab, three modes of propagation can be considered: 1) Magnetostatic Forward Volume Waves (MSFVW's): $\underline{H} \times \underline{n} = 0$; 2) Magnetostatic Surface Waves (MSSW's): $\underline{H} \times \underline{n} \,//\, \underline{k}$; 3) Magnetostatic Backward Volume Waves (MSBVW's): $\underline{H} \,//\, \underline{k}$ (fig.2)

Our design involves one port straight-edge resonator using MSFVW polarisation. The bias field is perpendicular to the YIG film and the MSW's propagate in the volume of the YIG film and are reflected by the straight edges of the film. Since the MSFVW's are isotropic waves a standing wave pattern results in the rectangle cavity if the following condition is met:

$$k_{n,m}\, l = n\pi \qquad n,m=1,2,3,\ldots \qquad (2)$$

where $k_{n,m}$ are the width mode wavenumbers of the MSFVW's [3].

In this way the YIG film shows a resonant effect with high quality factor ($Q_o$ in order of thousands). The resonant frequency $f_o$ is tunable through H control in a wide range of frequencies (typically from 2 to 20 GHz) and is given by:

$$f_o = \gamma(H - 4\pi M_s) \qquad (3)$$

where $\gamma$ = 2.81 MHz / Oe is the gyromagnetic ratio, and $4\pi M_s$ = 1760 G is the saturation magnetisation of pure YIG.

A top-coupling scheme has been adopted in which a microstrip transducer is realised on alumina or fused silica substrates centered on top of the YIG film (fig.3).

Several microstrip and YIG film widths, and dielectric spacers (between the transducer and the YIG film) were used to achieve a variety of coupling coefficients.

Resonator characterisation has allowed us to correlate the electric performances, in terms of coupling, quality factor, tunability, to the physical dimensions of the resonator, YIG film characteristics and mechanical coupling with the microstrip transducer. The typical frequency response of a two-ports MSFVW-SER is shown in figs.4a and 4b.

Unloaded Q-factor measurements have been performed on a one-port shorted MSFVW-SER.

By measuring both the reflection coefficient and the standing wave ratio, $Q_o$ values have been derived in the frequency range 8÷10 GHz. A slow linear increase of $Q_o$ versus f has been observed, ranging between $Q_o$ = 5200 at 8 GHz and $Q_o$ = 8000 at 10 GHz. From the above results an intrinsic magnetic full linewidth H = 0.55 Oe of the investigated YIG sample has been evaluated. The inferred H value agrees very well with that obtained by direct resonance experiments and it reveals the good quality of the grown film. Furthermore, as recently demonstrated [4], moderate thermal treatments can improve the film response by decreasing the linewidth up to 20%.

## X BAND OSCILLATOR

We assembled the one-port X-band oscillator by connecting the monolithic gate terminal with the microstrip transducer coupled to the planar YIG resonator (fig.5).

The oscillator performances have been evaluated biasing YIG film with a compact electromagnet by checking the broadband frequency response of the device.

We measured tuning bands up to 2 GHz (fig.6). An optimisation of the coupling factor between MSFVW-SER and microstrip transducer with respect to broadband applications can be achieved by changing the transducer impedance.

In order to eliminate the noise superimposed to H bias field (due to current fluctuation in the tuning coil) we used a rare earth permanent magnets structure which allowes accurate single frequency characterisation of the oscillator.

Measurements of frequency pushing at 9 GHz with the MESFET biased by a $V_{ds}$ varying in the range 2.5 ÷ 5 V have given the results shown in fig.7.

The oscillator's loaded Q has been evaluated by the pulling figure measured at 9 GHz by the injection-locking technique. Depending on the YIG film utilised and on its coupling with the microstrip transducer, $Q_{ex}$ values varying between 2000 and 3600 have been obtained. The oscillator's output power levels was found to be 6 dBm.

## CONCLUSIONS

We have designed and characterised a one-port MSFVW-SER based monolithic oscillator working at X-band.

Several oscillating structures have been evaluated, biasing YIG films both with compact electromagnets and with permanent magnets. With fixed polarisation the device characterisation in terms of frequency pushing, pulling figure and $Q_{ex}$ was performed.

The main advantages in using planar YIG resonator in comparison with the spherical are: 1) mechanical alignment in oscillating network is less critical; 2)lower magnetic fields required at a given resonance frequency; 3)simple fabrication; 4) larger loaded Q's.

Looking at its broadband applications, the good performances of the exploited device can be improved by optimising the d.c. magnetic bias circuitry, the R.F. coupling of the YIG resonator and using properly doped YIG films.

## REFERENCES

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FIG. 1

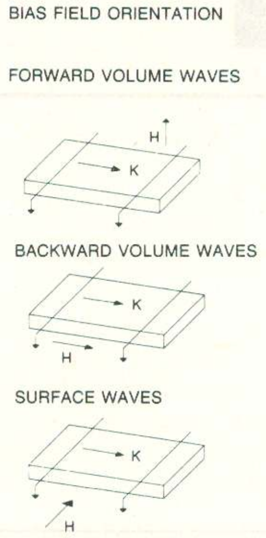


FIG. 2

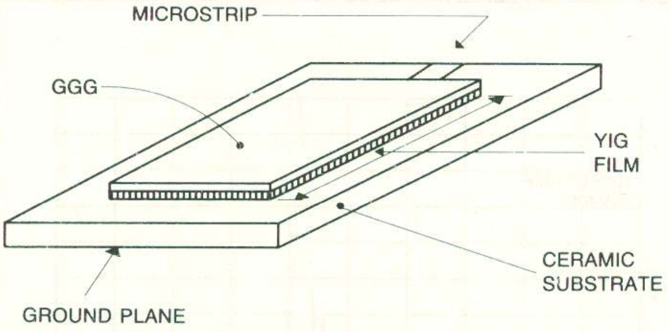
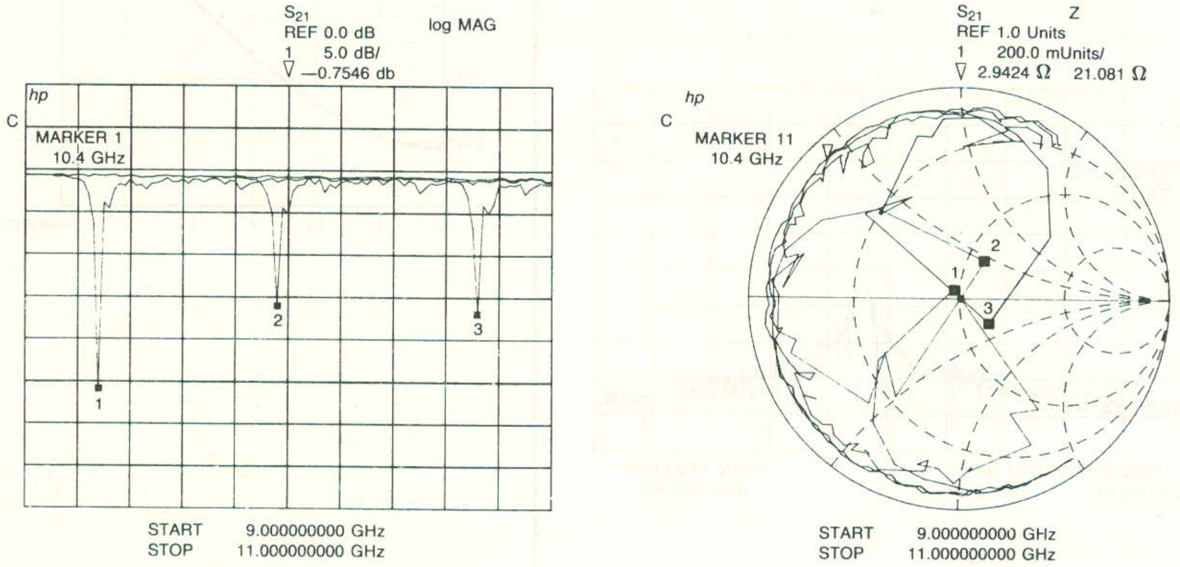


FIG. 3



A

B

FIG. 4

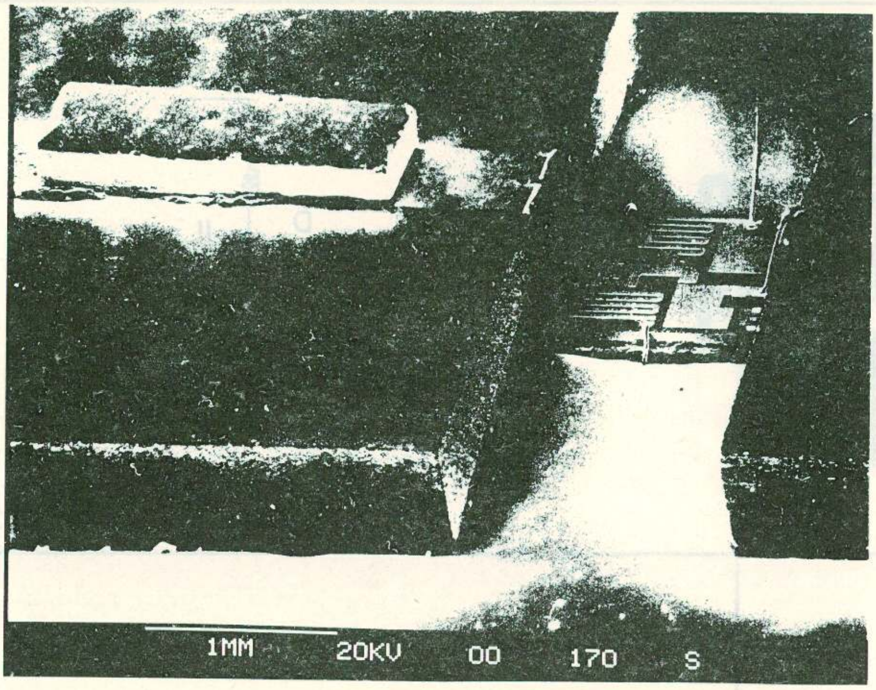
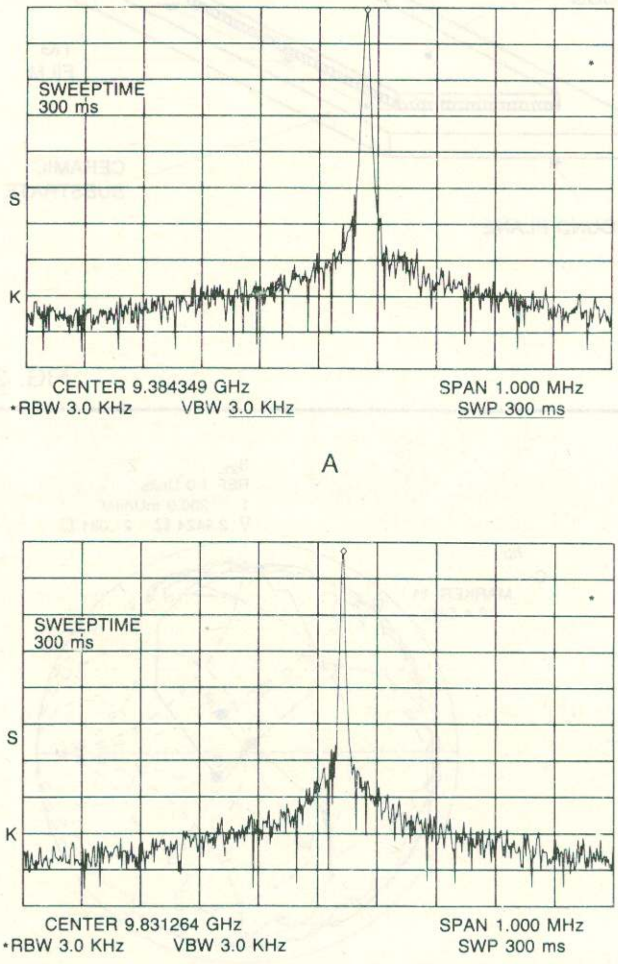


FIG. 5



A

B

FIG. 6

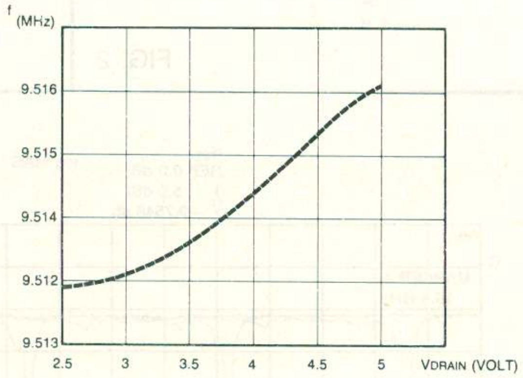


FIG. 7