A 94 GHz LOW NOISE GaAs FET OSCILLATOR USING WHISPERING-GALLERY DIELECTRIC RESONATOR MODES AND A NEW PUSH-PUSH CONFIGURATION REDUCING 1/f CONVERTED NOISE(¤)

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ABSTRACT

In this work we present results obtained in the design of a 47-94 GHz GaAs MESFET oscillator-doubler using a dielectric resonator.

A new push-push configuration was used for the generation of fundamental frequency at 47 GHz in the drain at the output. This new topology allows build noiseless oscillators-doublers.

As a resonant circuit at fundamental frequency we use, in a first version, the conventional $TE_{01\delta}$ mode of cylindrical dielectric resonator and in a second version we use a whispering-gallery mode of a planar dielectric resonator.

The results obtained show the potential utilization of: GaAs MESFET and whispering-gallery mode of dielectric resonator for the conception of millimeter-wave sources with low-noise and low-power requirements.

INTRODUCTION

The improvements in GaAs FET device technology have introduced a potentially superior device technology at mm-wave band, which is currently dominated by diode technology. For mm-wave D.R. oscillator applications, GaAs FET devices requires less DC power and consequently, exhibit less thermally induced frequency drift and are more stable (low FM-moise) than their diode counterparts [1], [2].

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The GaAs FET in a push-push topology was used for generation of microwaves as oscillator-doubler with dielectric resonators $TE_{01\delta}$ modes[3]. Here we use this topology for a oscillator-doubler in mm-wave band (47 to 94 GHz). The push-push oscillator have potential usefulness for application to mm-wave circuits because it are low phase noise and easy to design.

We are used as a resonant circuit the cylindrical dielectric resonator with a $TE_{01\delta}$ resonant mode at 47 GHz and the planar dielectric resonator with whispering-gallery mode (PWGM) at the same frequency. In addition, the PWGM has the advantage that is easy to manufacture and couple to the FET oscillator circuits.

DESIGN APPROACH

The push-push FET oscillator doubler is illustrated in Fig. 1. It consists on two FET devices in a push-push circuit coupled to a high Q dielectric resonator for control the frequency of oscillation. The FET device employed was a EC-1840 (THOMSON-CSF). He is a super low-noise with an N-channel Schottky barrier gate of 0.3 x 64 microns and a typical fmax of 120 GHz. The output power is obtained in a microstrip-ridge waveguide transition WR-10.

Two versions of this configurations was manufactured with:

1) $TE_{01\delta}$ mode cylindrical dielectric resonator: the resonator dimensions were calculated using the computer solutions based on the method described in [8], for a fundamental frequency of 47 GHz.

2) Planar Whispering-Gallery modes, [6]: The

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whispering-gallery modes (WGM) of dielectric resonators are a promissing solution in the millimetric wave range. When used in their WGM these cilindrical resonators have high Q values and oversized dimensions for millimeter wavelength. They offer advantages to their microwaves counterparts, as well as good suppressions of spourious modes. These spourious modes axially leak out of the resonator and can be absorbed without perturbing the desired mode. The WGM in an electromagnetic configuration are located against the concave side of cylindrical boundaries of the resonator. The waves essentially moves in a circular pattern around the dielectric resonator. Most of the modal energy is confined between a radius called the caustic and the resonator boundary; and these modes propagate axially with a small propagation constant so that the dielectric resonators used can be planar one's. The WGM are categorized as either $WGE_{n.m.2}$ in which the electrical field is essentially transversal, and $WGH_{n.m.2}$ for which the magnetic field is essentially transversal; n,m,1 denote the azimuthal radial and axial variations. Excitation of WGM dielectric resonators is done by synchronizing the dielectric resonator with an external traveling wave source. For example, in our oscillator the best excitation was obtained at the point, as indicated in Fig. 1(B). For the computation of the WGM dielectric resonators frequencies, the theory developped in [7] was used.

WHY THIS PUSH-PUSH CONFIGURATION IS NOISELESS

When a source-grounded GaAs MESFET chip, with the gate terminal kept open in a DC manner, is embedded in an appropriate external circuit, it oscillates and becomes self-biased. By using the self-bias mode operation, it is possible to build a GaAs FET oscillator, operable with a single posive DC bias voltage source, [10]. It is analyzed by[9]. However, its inherent FM low-noise feature has not been understood. Two fundamentals reasons explain that the self-bias mode configuration is inherently noiseless. The first is that the gate being opened at low frequencies and DC, the 1/f gate noise voltage generator of the FET is also opened, as we can see in Fig. 2; so, theoretically, it cannot induce a noise current on the gate and cannot be transposed around the oscillating frequency. The second reason comes from the fact that if the gate-voltage swing grows and becomes important at the fundamental frequency of oscillation of(as it happens in push-push oscillator-doubler, since the fundamental frequency is not resistively loaded), the self-gate bias comes more and more negative as indicated in Fig. 3: the rectified gate current align it self to zero and prevents the voltage to go in the non-linear forward part of the Schottky-diode characteristic. This automatic alignement reduces the conversion noise mechanism in the gate Schottky-diode. The Fig.4 shows the optimum low-frequency circuit eliminating 1/f noise conversion in a push-push oscillator-doubler. The low-frequency circuit: C_{FL} constraints both 1/f noise generators e_1^{-2} and e_2^{-2} which are uncorrelated, to induce opposite gate currents on each transistor; push-push configuration generates, by non-linear conversion, in phase currents at 2fo and anti-phase FM-noise side-bands around 2fo. Currents at 2fo add in the output load, while FM-noise side-bands cancel, due to the previous phase-relations, [5].

MEASURED RESULTS

The push-push oscillator-doubler is implemented in a microwave integrated circuit with alumina substrates of $\varepsilon_r = 9.6$ and t = 0.254 mm.

The output power was obtained at the FET drain using a WR-10 waveguide with a microstrip-waveguide ridge transition.

The bias circuitry (for Vds) consists of $\lambda/4$ high impedance lines with $\lambda/4$ shunt stubs for RF rejection at $2f_o$.

Two versions of prototypes has been fabricated and tested: one with cylindrical DR($TE_{01\delta}$), ε_r=36 from THOMSON-CSF and another with PWGM, $\varepsilon_r = 9.6$, (in house manufactured).

The results obtained are:

1) For $TE_{01\delta}$ cylindrical DR:

   f_o = 47.009 GHz

   $2f_o$ 0 94.019 GHz

   $P(2f_o)$ = 0.2 mW

$V_{ds} = 5.0$ V

$I_{ds} = 30.0$ mA

The Fig. 5 shows the oscillator-doubler spectral performance obtained for this type of DR.

2) For WGM planar DR:

fo = 46.029 GHz

2fo = 92.058 GHz

P(2fo) = 0.1 mW

$V_{ds} = 4.8$ V

$I_{ds} = 28.0$ mA

The Fig. 6 shows the oscillator-doubler spectral performance obtained for this type of DR.

Since the purpose of this work is to demonstrate the potential of the GaAs FET device operation around 94 GHz, no effort has been made to minimise the circuit losses in this prototypes.

CONCLUSIONS

With the improved FET technology that is now available, we are constructed a 47-94 GHz dielectric resonator stabilized FET oscillator-doubler.

The feasibility of the low-phase noise circuits with the GaAs FET at a frequency as high as 94 GHz is demonstrated with the utilisation of DR as a resonant circuit.

With further improvement in the device and circuit implementation technique the output power can be improved.

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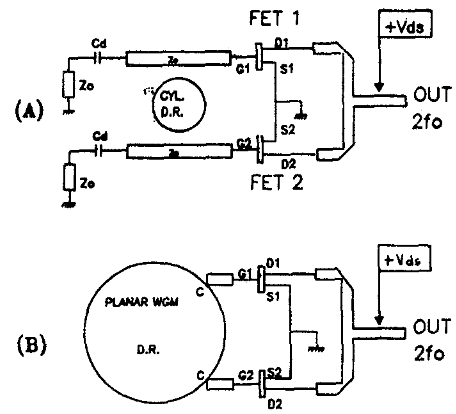

Fig. 1 - PUSH-PUSH OSCILLATOR-DOUBLER CONFIGURATIONS.
(A) WITH $TE_{01\delta}$ D.R. MODES
(B) WITH W.G.M. PLANAR DIELECTRIC RESONATORS

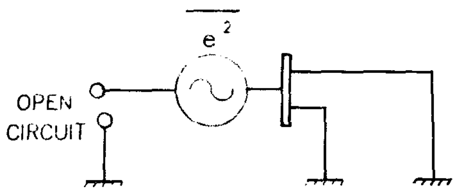

Fig. 2 - LOW FREQUENCY CONFIGURATION REDUCING 1/f NOISE INDUCED ON THE GATE FET.

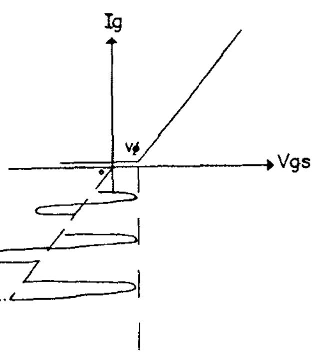

Fig. 3 - SELF ALIGNEMENT MECHANISM IN A SELF-BIAS MODE OPERATION

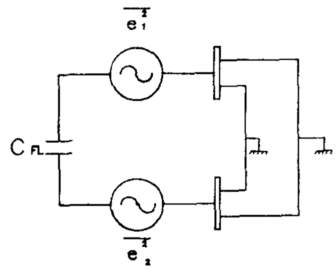

Fig. 4 - OPTIMUM LOW-FREQUENCY CONFIGURATION ELIMINATING 1/f NOISE CONVERSION IN A PUSH-PUSH OSCILLATOR-DOUBLER

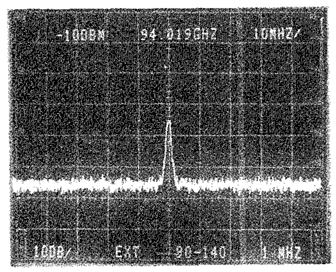

Fig. 5 - PHOTOGRAPH OF THE SPECTRAL PERFORMANCE FOR THE CYLINDRICAL D.R. OSCILLATOR-DOUBLER.

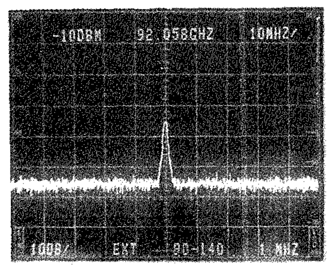

Fig. 6 - PHOTOGRAPH OF THE SPECTRAL PERFORMANCE FOR THE W.G.M. D.R. OSCILLATOR-DOUBLER