EFFICIENT LOW-NOISE THREE PORT X-BAND FET OSCILLATOR USING TWO DIELECTRIC RESONATORS.

A.P.S. Khanna, J. Obregon, Y. Garault
Laboratoire d'Electronique des Microondes - E.R.A. au CNRS 535
U.E.R. des Sciences - 123, rue Albert Thomas 87060 LIMOGES Cedex -France-.

Abstract

A new, simple to realize, X band, 3 port stable FET oscillator is presented. The oscillator using 2 identical dielectric resonators as oscillator circuit elements, operates at 8.53 GHz, has an overall efficiency of 22 % and FM noise better than 0.2 Hz/ $\sqrt{Hz}$ at 10 KHz from carrier.

Introduction

A new type of highly stable oscillator using two identical dielectric resonators is presented here {1}. The dielectric resonators coupled to 50 ohms microstrip lines acting as high Q reactances for gate and source terminals of the transistor, are used to realize the oscillation condition. Drain terminal connected to a 50 ohms line, serves as the main RF output port (figure 1). The oscillator presented has a number of interesting features. The microstrip circuit part is simplified to 50 ohms line at each terminal of the transistor, hence the same transistor chip can be used for S-parameter characterisation, theoretical design and final realisation. It has high efficiency, low FM noise, and presents total elimination of parasitic oscillations in addition to possessing 3 output ports (one main and two auxiliary).

Dielectric resonator characterisation

Equivalent circuit of a dielectric resonator coupled to a microstrip line is presented in figure 2 {2} The input impedance Z_{in} and reflection coefficient Γ_{in} are given by :

$$Z_{in} = 1 + \frac{2\beta}{1 + 2j\, Q_o(f-f_o)/f_o}$$

(for $\theta = 0, \lambda/2, \ldots$)

and

$$\Gamma_{in} \text{ at } f_o = \frac{\beta}{\beta+1} e^{-2j\theta}$$

where $\beta = R/2Z_o$ represents the coupling factor of the resonator with the microstrip line and is a function of the distance between the resonator and the line, for fixed shielding conditions {2} . θ represents the electrical length in degrees and Q_o, the unloaded quality factor of the resonator. The dielectric resonator used for the present work, fabricated by THOMSON-CSF, consists of lead doped Zirconium titanate oxide, has a relative permittivity of ≈ 38 and Q_o of ≈ 4,000 at 9 GHz, under the employed shielding conditions.

Dielectric resonator as series feedback element of an F.E.T.

By using the dielectric resonator as a series feedback element at the source terminal, the desired selective instability in an F.E.T. can be simply and effectively created {3} (figure 3). Using the series feedback mapping technique, the impedance presented by the resonator Z_{in} can be mapped into the S-parameters of the two port shown in figure 3. Figure 4 shows for example these parameters for a THOMSON-CSF transistor 15 GF at 8.5 GHz as a function of β_3 and θ_3. The non concentric circles represent the constant coupling factor (β_3) circles while the intersecting arcs are the constant electrical length (θ_3) arcs. It may be noted that instability (S_{11} or $S_{22} > 1$)is created for values of coupling factor as low as ≈ 0.8. The optimum values of the transmission line length θ_3 and coupling factor β_3 can be found from the above mapping.

Oscillation condition

The oscillation condition for the oscillator shown in figure 1, is given by {4} :

$$|\,\text{Det}\,(\{S\}\{S'\} - \{I\})\,| > 0$$

$$\text{Arg. Det.}\,(\{S\}\{S'\} - \{I\}) = 0$$

where {S} and {S'} represent the S-matrices of the transistor and that of the passive embedding network respectively. {I} represents the unit matrix.

The coupling factor β_1 and electrical length θ_1 for the dielectric resonator 1 can now be calculated to optimise the oscillation condition.

This oscillator configuration results in a three output ports stable oscillator. Output ② (drain) represents the main output while output ① (gate) and ③ (source) represent auxiliary outputs where a fraction of the main output power is available. Due to the presence of the dielectric resonators in series with the output lines, the outputs ① and ③ present a very high external Q {3} .

Practical realisation

Using the above approach two oscillators were realised. An oscillator using NEC 13700 delivered 8 mW at 10.5 GHz at the main power output port with a total efficiency of 21 %.

Another oscillator using a Thomson-CSF transistor 15 GF has the following characteristics :

Oscillation frequency f_o : 8530 MHz

Bias : V_{DS} : 4V ; ID : 23 mA

Efficiency : 22 %

Pushing figure 300 KHz/V_{DS}

DSB FM Noise :

at 10 KHz : < . 2Hz / $\sqrt{Hz}$

100 KHz : < .07Hz / $\sqrt{Hz}$

	Port 1	Port 2	Port 3
Power Output	. 5 mW	20 mW	. 9 mW
External Q	28,000	1650	17,200

Discussion

In addition to high efficiency and low FM noise, the oscillator presented above has a number of interesting features :

.) simplification

The microstrip part of the oscillator has been simplified to 50 ohms lines on every terminal of the transistor and the oscillation condition is optimised by placing the two dielectric resonators at predetermined distances (d and θ) from the gate and source terminals. This also indicates the broadband nature of the passif circuitry, as changing the oscillator frequency calls only for changing the dielectric resonators and placing them at the calculated distances for the particular frequency.

..) elimination of parasitic oscillations

Another advantage of the oscillator configuration presented is the total elimination of the parasitic oscillations due to highly selective transistor instability created by using dielectric resonators. The oscillation condition is satisfied only at the resonator centre frequency and all the transistor terminals are loaded by 50 ohms impedances at all other frequencies.

...) multiple Output Ports

This oscillator has one main and two auxiliary output ports. This aspect is generally a desired feature for system applications, as this can help in reducing the number of passive components like couplers and power dividers. Both the auxiliary outputs have a very high external Q factor, making thus the oscillator frequency, immune to their respective use in the system.

....) maximum power output

It may be noted that the power output can be further optimised by using a quarterwave impedance transformer at the drain terminal (figure 1).

Acknowledgement

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References

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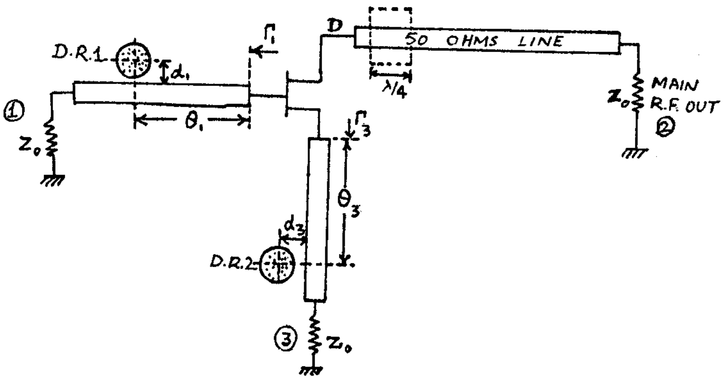

Figure 1 Three port stable oscillator using two Dielectric Resonators (D.R.1 & D.R.2)

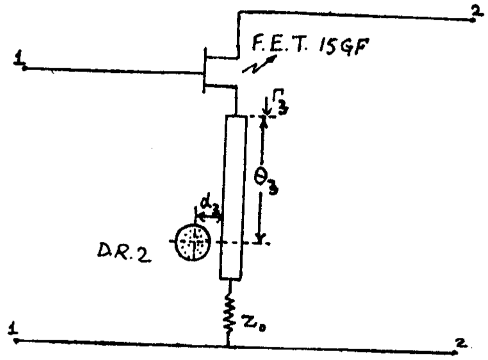

Figure 3

Dielectric Resonator as a series feedback element

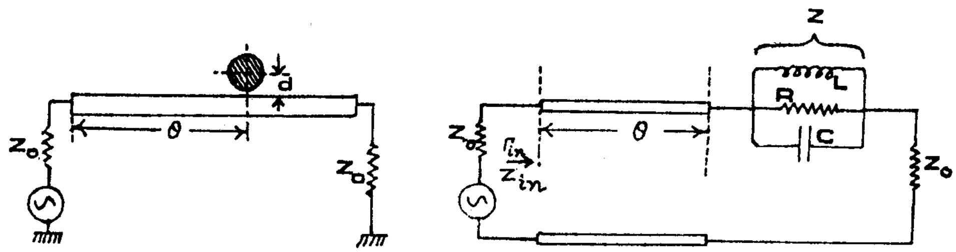

Figure 2

Dielectric Resonator coupled to a microstrip line and its equivalent circuit

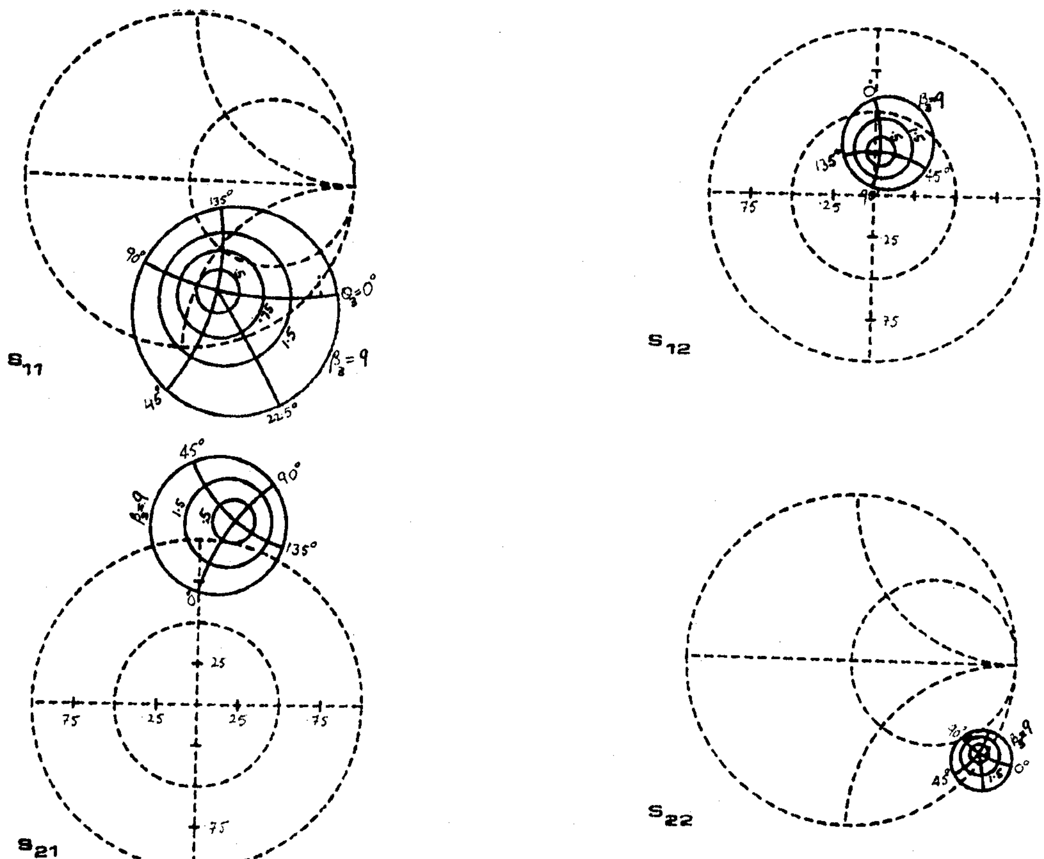

Figure 4

Transistor two port S-parameters as a function of dielectric resonator (D.R.2) coupling (β_3) and transmission line length (θ_3) parameters.