PARALLEL FEEDBACK FETDRO DESIGN USING 3-PORT S-PARAMETERS

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Abstract

A new approach for the design of parallel feedback FET oscillators has been presented using 3-Port S parameters. The linear analysis accurately determines the reflection gain at any port as a function of the parameters of the dielectric resonator parallel feedback network between the other two ports of the FET. An example of design and practical realization of FETDRO is presented at 9 GHz.

Introduction

With the advent of the miniature high Q and temperature stable dielectric resonators, the interest in their utilization in the active and passive Microwave Integrated circuits has been fast increasing [1]. A number of interesting configurations of FET oscillators using dielectric resonators (FETDRO) have been presented in the past [2] - [4]. Some of these oscillators use dielectric resonator as a parallel feedback element between the two ports of the transistor while taking the RF output at the third port of the same (fig. 1a) e.g. [2]. The feedback two-port can as well be placed between any two ports as shown in figure 1b and 1c. No analytical approach has so far been presented to determine the optimum postition of the dielectric resonator or to calculate the reflection gain at any port of the transistor as a function of the parameters of the two port feedback network connected between the other two ports of the transistor. In this paper we present:

i) S-parameters characterization of the dielectric resonator coupled simultaneously to two microstriplines and ii) a linear approach to calculate the reflection gain at any port of the transistor as a function of its 3-port S-parameters and the S-parameters of the two port connected between the other two ports. The method of analysis presented also allows the designer to determine the preferred output port of the transistor. The approach presented is easily extendable to Dual Gate FET applications.

Dielectric Resonator Characterization:

The dielectric resonator coupled simultaneously to two microstrip lines and its equivalent circuit is shown in figure 2. At resonant frequency the S-parameters of this two-port can be shown to be given by [5].

$$\left[S_r\right] = \begin{bmatrix} \dfrac{\beta_1 - \beta_2 - 1}{\beta_1 + \beta_2 + 1} \cdot e^{-2j\theta} & \dfrac{2\sqrt{\beta_1 \ \beta_2}}{\beta_1 + \beta_2 + 1} \cdot e^{-2j\theta} \\ \dfrac{2\sqrt{\beta_1 \cdot \beta_2}}{\beta_1 + \beta_2 + 1} \cdot e^{-2j\theta} & \dfrac{\beta_2 - \beta_1 - 1}{\beta_1 + \beta_2 + 1} \cdot e^{-2j\theta} \end{bmatrix}$$

where β_1 and β_2 represent the coupling coefficients of the resonator with the microstrip lines on both sides and are given by:

$$\beta_1 = \frac{Y_{01}}{G_o} \text{ and } \beta_2 = \frac{Y_{02}}{G_o}$$

and θ represents the electrical length $= \beta 1 = \frac{2 \pi l}{\lambda g}$

Transistor Characterization

The FET, a three port device, is generally characterized by its 2-port S-parameters with one of its leads (generally source) grounded. The use of three port S-parameters though introduced quite sometime ago [6] has not been often used mainly due to the complexity of the analysis involved. The availability of desktop computers and CAD has now made their use practical. The use of 3-port S-parameters eliminates the otherwise necessary conversion to and from Z or Y parameters to analyse the feedback effect and due to the property of 3P-S-matrix of a transistor that the sums of rows and columns is equal to 1, the systematic errors in the measurement or analysis can be determined and eventually corrected. It may also be noted that the problen presented in this paper can be solved only by the use of 3-port S-parameters. The FET 3P S-matrix can be directly measured or determined from the generally available 2-port S-parameters [6].

Theory

Figure 3 represents the generalized form of the parallel feedback FET oscillator configuration. The three-port network "A" represents the FET and the two port network "B" represents the feedback network for example a dielectric resonator coupled simultaneously to two microstrip lines. The relations for the three port and two port can be presented as:

$$b_{1A} = S_{11A}\, a_{1A} + S_{12A}\, a_{2A} + S_{13A}\, a_{3A}$$

$$b_{2A} = S_{21A}\, a_{1A} + S_{22A}\, a_{2A} + S_{23A}\, a_{3A}$$

$$b_{3A} = S_{31A}\, a_{1A} + S_{32A}\, a_{2A} + S_{33A}\, a_{3A}$$

$$b_{1B} = S_{11B}\, a_{1B} + S_{12B}\, a_{2B}$$

$$b_{2B} = S_{21B}\, a_{1B} + S_{22B}\, a_{2B}$$

when port 1 and 2 of the two port are connected to port 1 and 2 of the three port we have:

$$a_{1A} = b_{1B} \quad a_{2A} = b_{2B} \quad a_{1B} = b_{1A} \quad a_{2B} = b_{2A}$$

Using the above relations the modified reflection coefficient at port 3 $S'_{33} = b_{3A}/a_{3A}$ can be determined. The generalized relation of reflection coefficient S'_{kk} at any port can be written as:

$$S'_{kk} = S_{kkA} + \frac{s_{iiB}s_{ikA}s_{kiA} + s_{ijB}s_{jkA}s_{kiA} + s_{jiB}s_{ikA}s_{kjA} + s_{jjB}s_{jkA}s_{kjA} + \Delta_B\,\Delta'}{\Delta_B\,\Delta_{kkA} - \left(s_{iiB}\,s_{iiA} + s_{ijB}\,s_{jiB} + s_{jiB}\,s_{ijA} + s_{jjB}\,s_{jjA}\right) + 1}$$

where $\Delta' = S_{jkA}\,\Delta_{jkA} + S_{ikA}\,\Delta_{ikA}$

$$\Delta_{kkA} = S_{iiA}\,S_{jjA} - S_{ijA}\,S_{jiA}$$

$$\Delta_{jkA} = S_{ijA}\,S_{kiA} - S_{iiA}\,S_{kja}$$

$$\Delta_{ikA} = S_{jiA}\,S_{kjA} - S_{jjA}\,S_{kiA}$$

$$\Delta_{B} = S_{iiB}\,S_{jjB} - S_{ijB}\,S_{jiB}$$

and i, j, k can be known from the following table:

Reflection Coefficient at	i	j	k
Port 3	1	2	3
Port 2	2	3	1
Port 1	3	1	2

For simplicity the port number for the two-port is the same as the connecting port of the three port. Using the above relation and knowing the S-parameters of the FET and dielectric resonator feedback network the reflection coefficient at all the three ports of the FET can be determined as a function of θ and β of the network and the preferred output port can be easily determined to achieve the maximum reflection gain. As an example the reflection coefficient at the drain port of a half micron FET as a function of feedback network parameters between gate and source at 9GHz is presented in figure 4. This can be used to determine the feedback parameters to maximize the reflection gain S'_{22}. The matching circuit at the drain port can be determined to realize the oscillation condition by using the well known empirical relations or the load pull measurement technique. A damping resistance is generally required at one of the FET ports (Fig.1C) in order to avoid spurious oscillations. This converts the two port resonator to a three port one and redistributes the S-parameters.

Practical Realization:

Using a half micron FET and a Thomson CSF dielectric resonator at 9GHz a parallel feedback oscillator was realized. With the drain as output port following results were obtained:

Frequency:	9010 MHz	RF Power:	12dBm
Efficiency:	18 %	Pushing:	260KHz/V_{DS}
Qext:	1700	FM Noise:	90 dBC/Hz @ 10 KHz

References:

1.) J.K. Plourde and C.L. Ren, "Application of Dielectric Resonators in Microwave components," IEEE Trans MTT Vol 29, No 4, pp 754-769 August 1981.

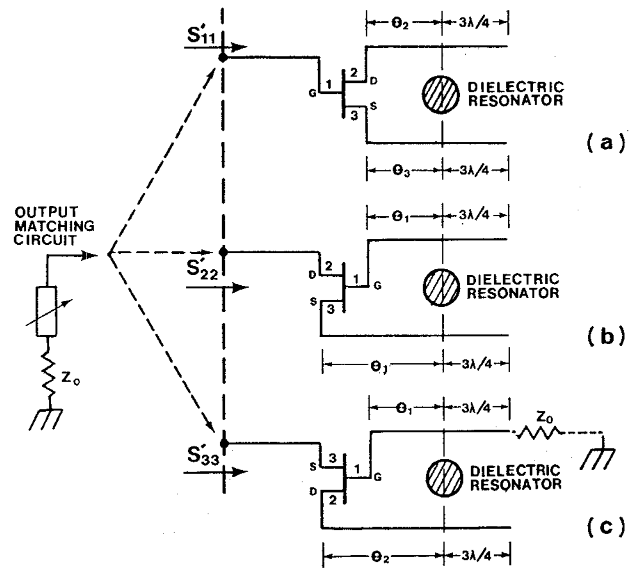

Fig. 1. Configurations for parallel feedback FETDRO.

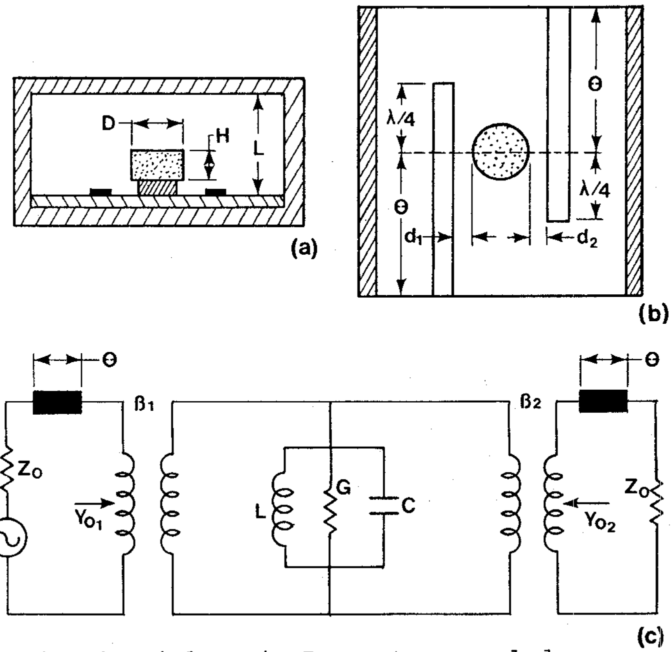

Fig. 2. Dielectric Resonator coupled simultaneously to two microstriplines.

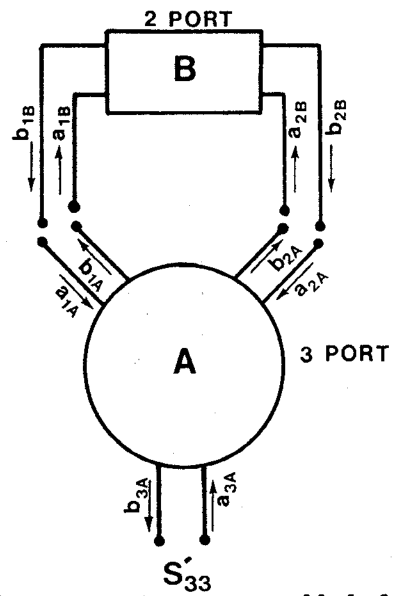

Fig. 3 Two-port as a parallel feedback network to a three-port.

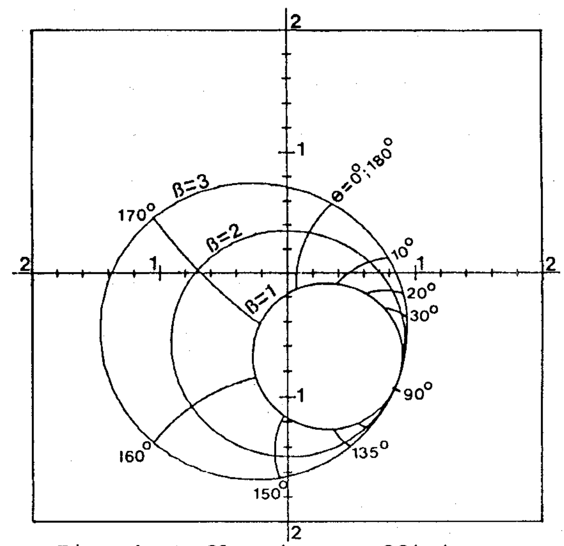

Fig. 4. Reflection coefficient at Drain as a function of feedback parameters θ & β $(\beta=\beta_1=\beta_2)$

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5.) B.A. Galwas, "Scattering Matrix Description of Microwave Resonators," IEEE Trans. MTT vol.31 No. 8 pp. 669-670 August 1983.

6.) G.E. Bodway, "Circuit design and characterization of transistor by means of three-port scattering parameters," Microwave Journal vol. 11 No.5 May 1968