A SIMPLE BROADBAND MESFET DRO DESIGN FOR MILLIMETER-WAVE APPLICATIONS

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Abstract

The development of an hybrid dielectric resonator oscillator (DRO) based on a MMIC MESFET is described. Only one circuit was designed to cover the K band frequency range. A common source topology with series feedback was employed. The dielectric resonator is coupled to the gate line of the MESFET. Typical results in the K band frequency range with a 4 V supply voltage are an output power between 11 and 13 dBm and a phase noise better than -80 dBc/Hz at 10 kHz from carrier frequency.

Introduction

MESFET dielectric resonator oscillators (DRO) are exhibiting high performance in combination with low cost, low complexity and small size. They are well suited for integration with either MMIC or MIC circuits in millimeter wave systems [1][2][3]. In this paper the design of an hybrid MESFET DRO for the K band frequency range is described. The desired oscillation frequency is obtained by choosing the required dielectric resonator. In the aim of a future monolithic integration, the developed circuit is based on a MMIC MESFET [4]. The circuit was designed using measured small signal S parameters of the transistor up to 30 GHz and in house developed linear CAD software.

Basic concept

DRO are classified as reflection or feedback oscillators according to the relative location of active device, resonator and load [5]. The series feedback configuration (figure 1) was chosen. The dielectric resonator is coupled to a microstrip line placed at the gate side of the transistor and the output port is at the drain side. This type of DRO exhibits a superior frequency stability and pulling and a low phase noise due to the isolation between the frequency determining element and the output.

For a desired frequency the distance between the dielectric resonator and the transistor gate is fixed. Therefore the length of the gate microstrip line is long enough to assure a proper oscillation condition over the K band frequency range.

The choice of the dielectric resonator is critical for obtaining the desired frequency. The value of the resonant frequency is affected by the environment (proximity of the box lid, thickness of the microstrip substrate, conductor losses, and dielectric losses).

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Therefore a characterization of the dielectric resonator in the final environment is needed to determine its dimensions according to the desired frequency. A very good approximation for calculating the resonant frequency taking into account the substrate parameters and the distance between the resonator and the box lid is given in [6].

By varying the composition of the dielectric material it is possible to adjust the temperature coefficient of the dielectric resonator. Therefore DRO offer a very good frequency stability versus temperature. The required temperature coefficient can be determined experimentally with a prototype oscillator.

Oscillator design

The MESFET used has a gate length of 0.35 μm and a gate width of 200 μm. Its equivalent circuit determined by the measured S parameters up to 30 GHz is given in figure 2. The saturation current is 90 mA. The maximum available gain (MAG) at 26 GHz is 6.4 dB. The circuit model of the series feedback DRO with a common source topology is shown in figure 3. The resonator coupled to a microstrip line is modeled as a resonant circuit. The gate microstrip line is terminated by its wave impedance to avoid parasitic oscillation. The stub at the source of the transistor generates the necessary instability over the K band frequency range. The oscillation condition is determined at the drain of the transistor. For every desired frequency another dielectric resonator with appropriate dimensions is required. The oscillation possibility is given by a reflection coefficient greater than 1 looking into the drain of the transistor. The output matching circuit is simply realized by a stub and assures the following oscillation condition over the K band frequency range:

$$|\Gamma_L| > 1/|\Gamma_0| \qquad \arg(\Gamma_L) = -\arg(\Gamma_0)$$

The length between the dielectric resonator and the transistor gate has to be optimized to satisfy the oscillation condition in the K band. The output matching circuit is also chosen to approximately verify the empirical relation for extracting the maximum output power

$$Z_L = R_L + jX_L = -R_0/3 - jX_0$$

where Z_L and $Z_0 = R_0 + jX_0$ are the impedances corresponding respectively to Γ_L and Γ_0. A complete simulation shows that only one oscillation is possible and it is determined by the dielectric resonator.

Realization and experimental results

The layout of the realized DRO is shown in figure 4 with the position of dielectric resonators for different frequencies. The circuit is fabricated on a 0.25 mm thick alumina substrate. The transistor chip has the same thickness as the substrate and is inserted into a hole made in the substrate. This technique allows to reduce the parasitic inductance of bond wires. The transistor gate termination is formed by a 50 Ω microstrip line terminated by a 50 Ω chip resistor.

For design simplicity the oscillator needs only one supply voltage. A chip resistor is inserted into the source of the transistor to obtain a self bias configuration. A broadband bias network is realized with radial stubs. The dimensions of the circuit are 9 mm by 9 mm.

A typical output spectrum is given in figure 5. The measured output power for different dielectric resonators is shown in figure 6. The supply voltage is 4 V. Over the K band frequency range an output power between 11 dBm and 13 dBm is achieved. A phase noise better than -80 dBc/Hz at 10 kHz from carrier frequency over the frequency range was measured. A temperature stability of -5 ppm/^{o}C between -30^{o}C and +80^{o}C using a 0 ppm/^{o}C dielectric resonator was obtained. This value can be compensate by choosing the appropriate temperature coefficient for the dielectric resonator.

Conclusion

A dielectric resonator oscillator covering the K band frequency range was realized. The complete design was based on small signal S parameters. Typical results with a 4 V supply voltage are an output power between 11 and 13 dBm and a phase noise at 10 kHz from carrier frequency better than -80 dBc/Hz. The design is direct transferable to a GaAs technology and can be integrated with other circuits.

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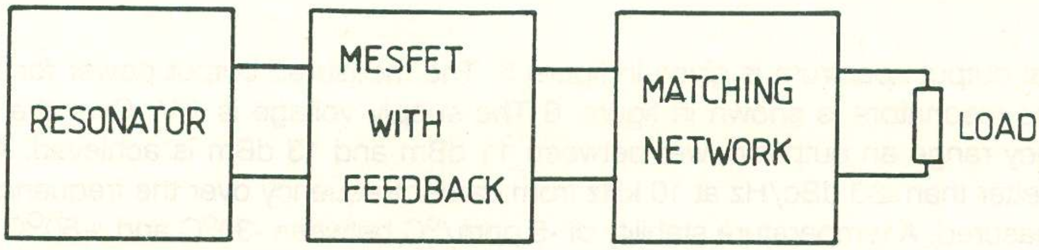

Figure 1: Block diagram of a series feedback dielectric resonator oscillator

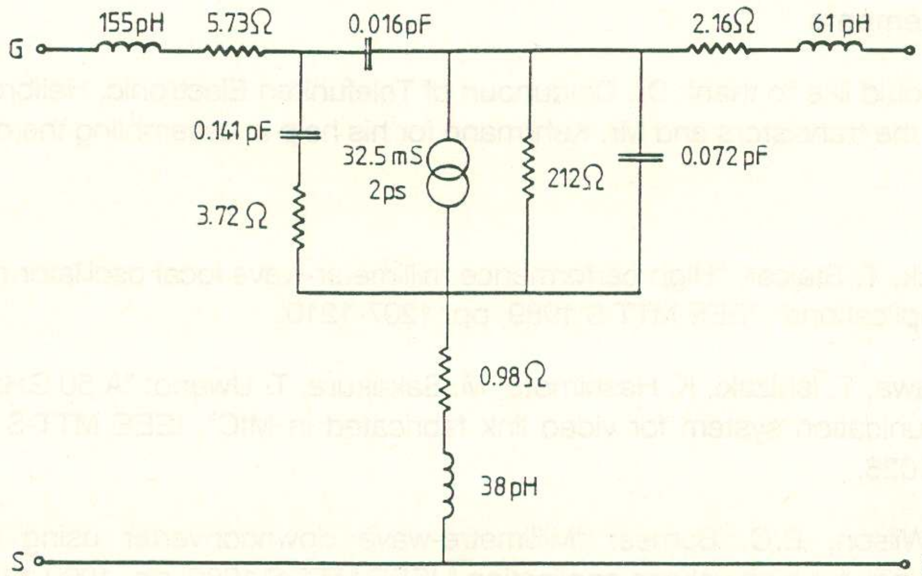

Figure 2: MESFET equivalent circuit (Vds = 3 V, Ids = 45 mA)
Gate area: 0.35 μm x 200 μm
Saturation current: 90 mA

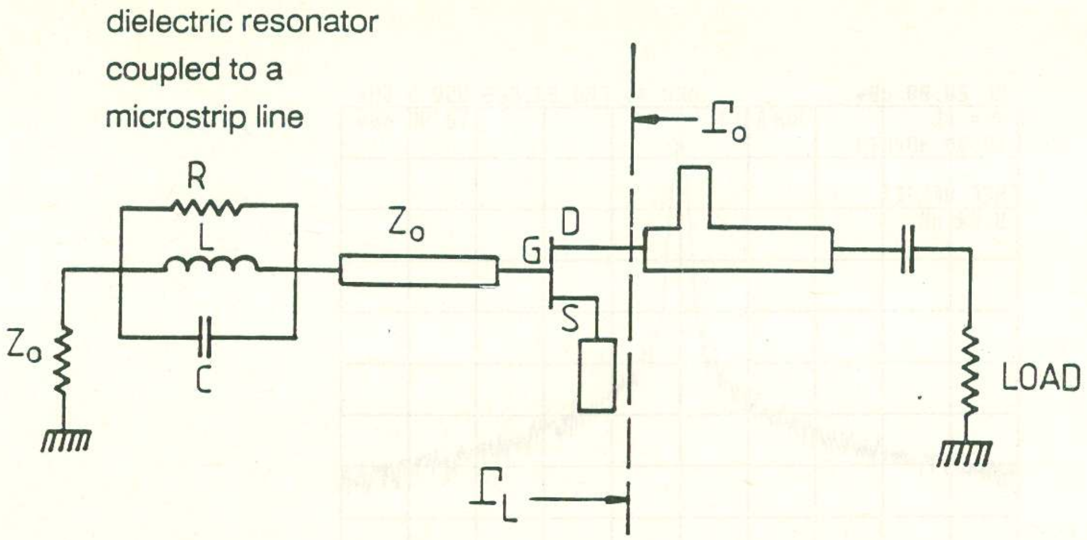

Figure 3: Circuit model of the MESFET dielectric resonator oscillator

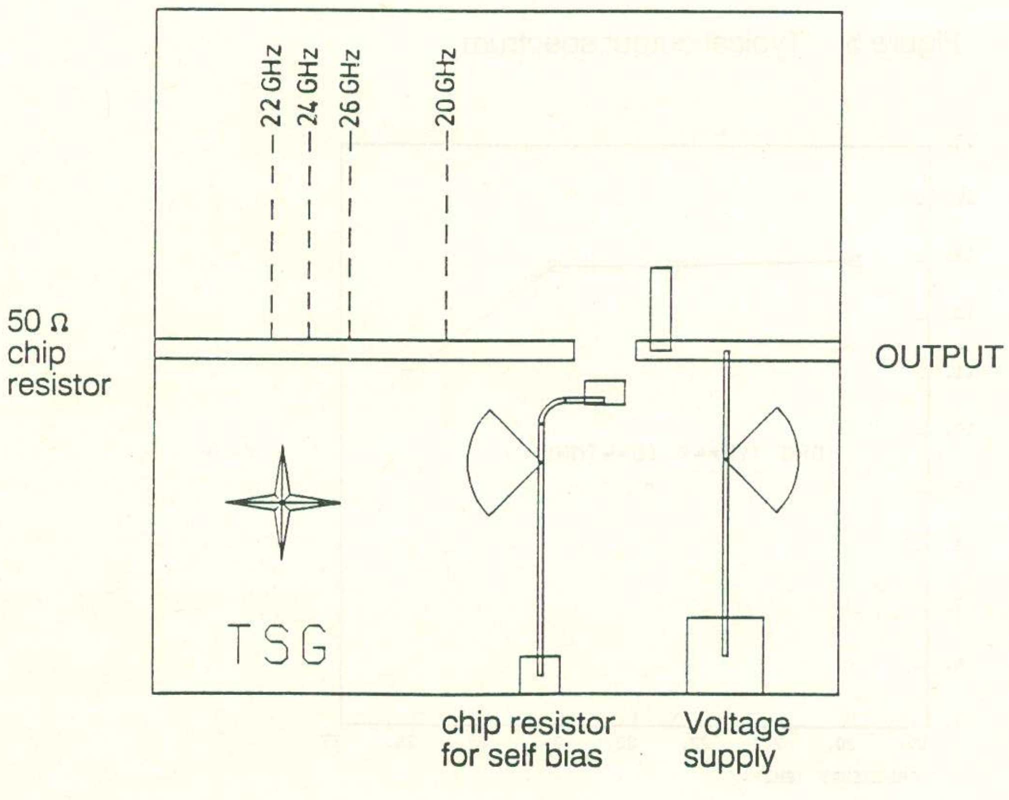

Figure 4: Layout of the DRO
The position of the dielectric resonator along the gate line for different frequencies is marked

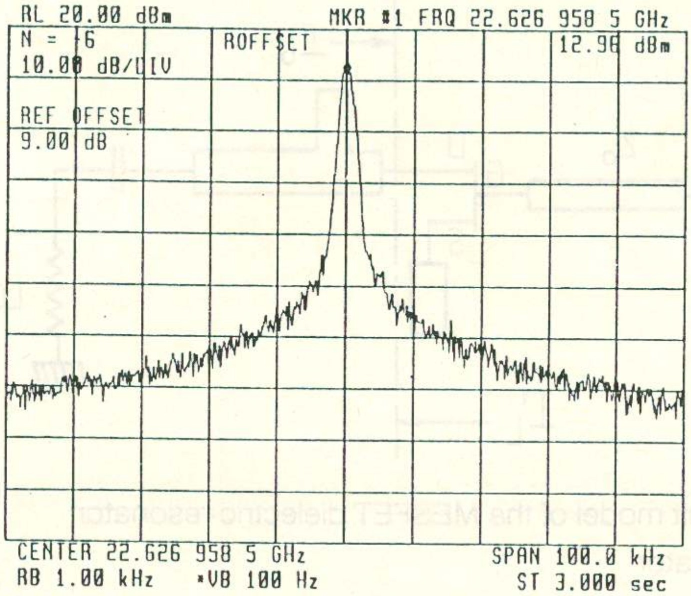

Figure 5: Typical output spectrum

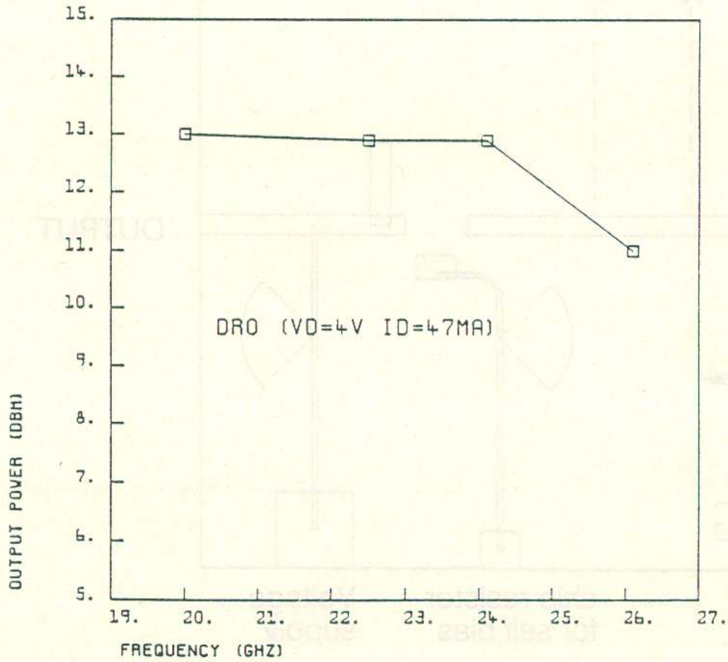

Figure 6: Output power versus frequency