GaAs MONOLITHIC CIRCUITS MOUNTED OVER HIGH Q DIELECTRIC RESONATORS

E.M. Bastida, P. Bergamini

CISE SpA - PO Box 12081, 20100 Milan (Italy)

ABSTRACT

The coupling of a dielectric resonator through coplanar waveguides is experimentally studied and the feasibility of very selective microwave circuits, where the resonator is placed below the active and passive circuit components, is demonstrated. The design and the operation of high-stability feedback-type coplanar oscillators are reported. The possibility of mounting a monolithic chip over a high-Q dielectric cavity, avoiding unwanted resonator coupling anywhere in the circuit, is demonstrated. This allows the sealing of the overall circuit in a practical low-size case. Finally, the performances of a test monolithic chip carrying two different oscillators are stressed.

INTRODUCTION

Highly selective microwave circuits are difficult to realize in monolithic form, owing to the relatively low Q-factor of the passive networks on the semiinsulating GaAs wafer. A practical way to overcome this limit is to couple a portion of the monolithic circuit with a dielectric resonator, placed near the GaAs chip, via a microstrip-line. In this case, however, the resulting circuit dimensions are very similar to those of a completely hybrid solution, and this prevents the packaging of the circuit in a practical carrier. For this reason, the idea of mounting a monolithic chip directly over the dielectric resonator, has been considered; however the coupling of a microstrip-type monolithic circuit, placed over the resonator, has proved to be unpractical, requiring interruptions on the ground plane that lead to alignment as well as soldering problems, whose complexity increases as the monolithic dimensions are reduced. To avoid these problems, we studied a coplanar-waveguide chip mounting solution (1).

This paper first reports experimental results concerning high-Q bandpass and band-stop filters obtained by coupling a dielectric resonator with coplanar waveguides, and shows that very high resonator quality factors can be achieved using a coplanar circuit topology. This allows the design of very selective circuits in hybrid form, where the resonator is placed in contact with the unmetallized side of the dielectric support, just below the active and passive circuit components. As an example of these circuits, X-band coplanar oscillators are described, showing excellent stability performances. Then, the paper describes a very compact monolithic chip mounting over the dielectric cavity, ensuring a good circuit immunity to undesired resonator couplings. Experimental results are also presented, concerning a test GaAs chip which includes a fully monolithic oscillator as well as the active and most of the passive circuitry of a resonator-stabilized oscillator. Finally, some comments are presented about a practical solution for a monolithic front-end of satellite T.V. home receivers.

COPLANAR WAVEGUIDE FILTERS USING DIELECTRIC RESONATORS.

In fig. 1 a sketch is reported of various possible resonator coupling systems with a single-sided and a double-sided coplanar waveguide. Fig. 2, curve a, gives the measured resonator unloaded quality factors Q_o as a function of the coupling for 1 mm wide 50 Ω double-sided coplanar waveguide over a .6 mm thick Al_2O_3 support. The waveguide was coupled as in case b of fig. 1 and closed in a 1"x1.5"x0.5" metallic box.

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The Q_o values were obtained from reflection measurements of band stop filters loaded by a 50 Ω impedance. The dielectric resonator was a 2.1 mm thick ATD38 disc (Ampex Co.) with a 6.4 mm diameter.

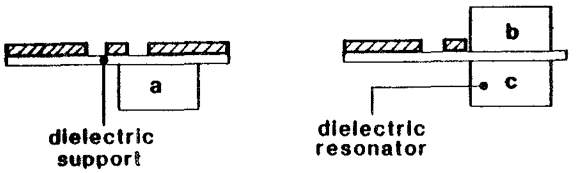


Fig. 1 - Schematic of double and single-sided coplanar waveguide resonator coupling systems.

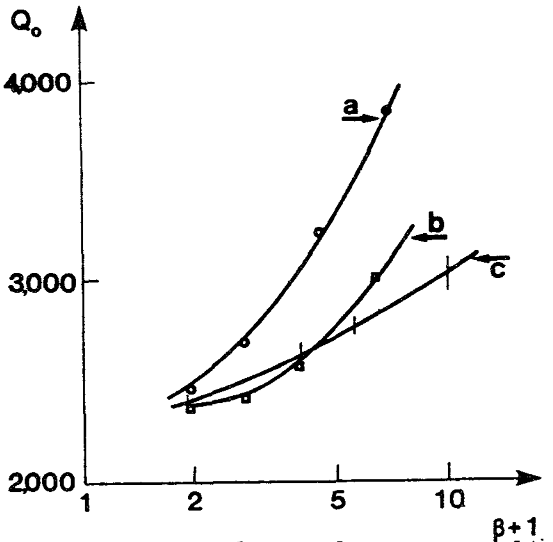


Fig. 2 - Measured Q_o values vs. coupling factor β. a): completely shielded double-sided C.P.W.; b): partially shielded double-sided C.P.W.; c): completely shielded microstrip.

Curve b) in fig. 2, refers again to the double-sided coplanar waveguide, which, however, is shielded only at the side where the resonator is mounted.
Finally, curve c) in fig. 2 gives the measured Q_o values for a 50 Ω microstrip over a .6 mm thick Al_2O_3 support, completely shielded in a similar box.
The transmission characteristics of double-sided coplanar-waveguide bandpass-filters were also measured and high-quality performances were obtained also when the filters were shielded only at the resonator side.

THE HIGH-STABILITY COPLANAR OSCILLATORS

The above results allow the design of very selective coplanar circuits, as, for example, various types of high stability oscillators using dielectric resonators to form bandstop reflecting filters (2) or bandpass feedback filters (3). In order to experimentally verify this statement, some 8.3 GHz feedback-type oscillators, using low-noise GaAs FET devices and double-sided coplanar-waveguides were designed and constructed. Fig. 3 gives a sketch of such oscillators. .9 μm x 300 μm gate home-made FET devices, with a saturation current of ∿60 mA and a transconductance of ∿40 mS as well as NEC 244 devices were used.

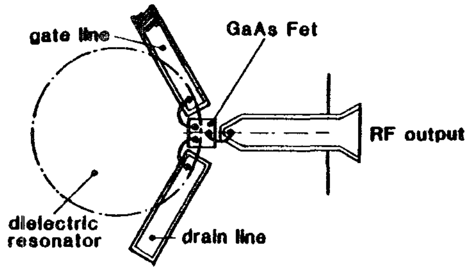
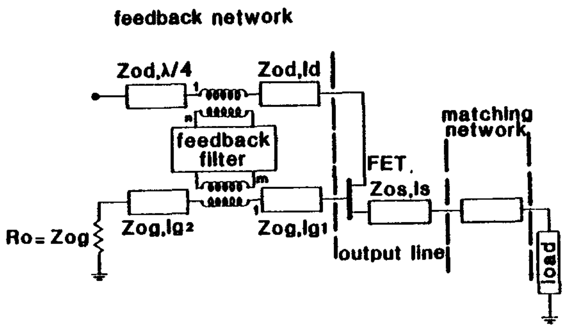


Fig. 3 - Schematich of the coplanar oscillator.

In fig. 4 a, b the oscillator basic topology as well as its equivalent circuit are given. A matched resistor R_g is connected to the gate line, in order to avoid undesired oscillations due to energy accumulation on the line itself.
Starting from the circuit maximizing the loop gain for the FET considered as unilateral and with grounded source, the feedback network was computer-optimized in the aim of extending, as much as possible, the Smith chart load-impedance area where oscillations occur. This was done through the calculation of the oscillator output impedance from the Y matrices of the FET and of the feedback network. By a proper choice of the reference plane at the oscillator output line, an active subnetwork with a simple equivalent circuit was defined, from which the loaded and the external quality factors of the oscillator, as a function of the load conditions were easily evaluated. More accurate information about the active subnetwork, in nonlinear working conditions, was obtained, only in the case of one home-made device, by direct load-

pulling measurements.



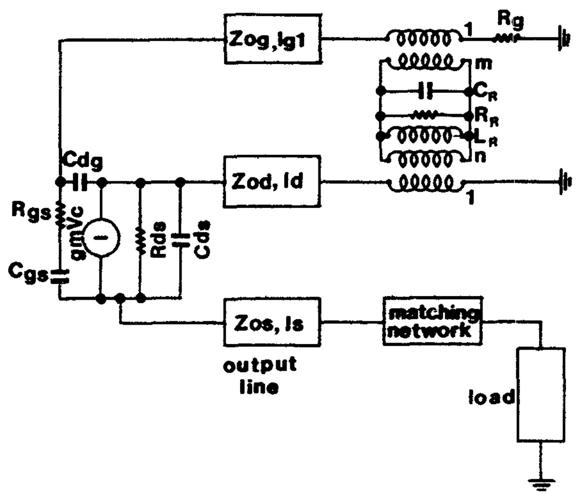


Fig. 4 - a: The oscillator basic topology;
b: The detailed oscillator equivalent circuit.

High-quality stability performances were measured for all the constructed oscillators. In figs. 5, 6 and 7 the frequency vs. temperature plot, the injection-locking results as well as the pushing-figure for an oscillator using a home-made device and stabilized with an ATD-38 cylindrical resonator are reported,respectively. An external quality factor of ∿3,800, a pushing figure of ∿8 ppm/V and a temperature frequency drift of ∿4 ppm/°C (about the same as that of the dielectric cavity's resonant frequency) are noticed.

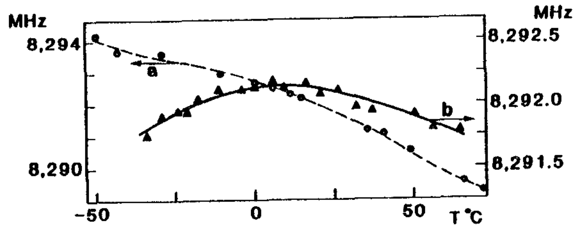


Fig. 5 - Oscillator frequency vs. temperature diagrams. a) uncompensated; b) thermally compensated.

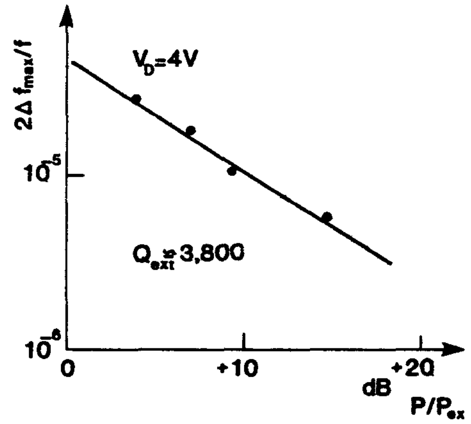


Fig. 6 - Injection locking bandwidth vs. the normalized locking signal amplitude.

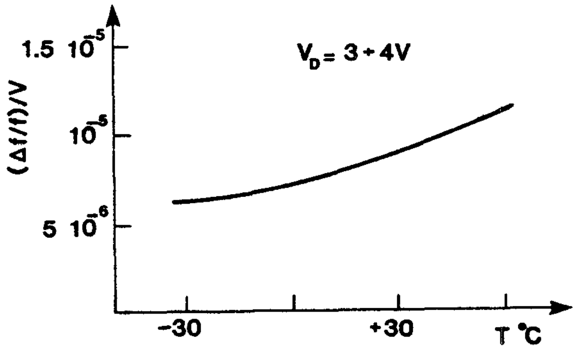


Fig.7 - Oscillator drain pushing figure vs. temperature.

Looking at the mechanical tuning curve (fig. 8), the oscillator case was subsequently modified in order to compensate, with its thermal expansion, the measured frequency drift for a given tuning-screw position. The related results are given in fig. 5, curve b, where an average frequency variation of ± .2 ppm/°C over 100°C is noticed.

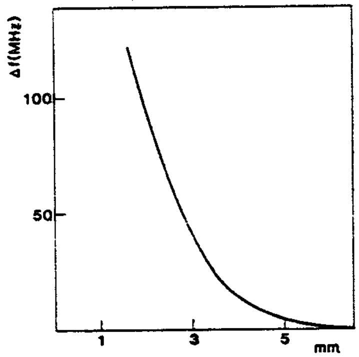


Fig. 8 - Oscillator mechanical tuning curve.

An output power ranging between 5 and 12 dBm was obtained, form home-made devices, by varying the bias voltage for 3V to 4.5 V. Excellent stability values were also measured with the N.E.C. 244 FETs, obviously used in low bias conditions (∿3V). The f.m. noise performance, measured for the highest power oscillator we constructed, is shown in fig. 9.

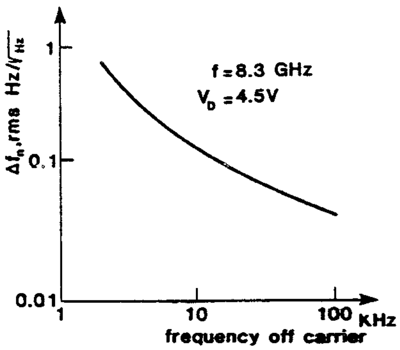


Fig. 9 - Measured f.m. oscillator noise.

THE MONOLITHIC CIRCUIT MOUNTING OVER THE DIELECTRIC RESONATOR.

The experimental results presented in fig. 2 have shown the possibility of coupling, without consistent radiation losses, a resonator to a coplanar waveguide circuit shielded only at the resonator side. This was used to devise a compact monolithic chip mounting where unwanted resonator couplings are practically avoided anywhere in the circuit.
The basic idea for such a mounting is sketched in fig.10. A microstrip monolithic chip is soldered over the ground plane of a coplanar-waveguide coupled to a resonator placed below the monolithic itself. Input-output microstrip lines are also soldered to the coplanar waveguide ground planes, all the connections being made via wire bondings.
The resonator side must be sealed in a small metallic cap possibly carrying a tuning screw; the side with the monolithic chip should preferably be sealed in a metallized cap acting as a cutoff waveguide.

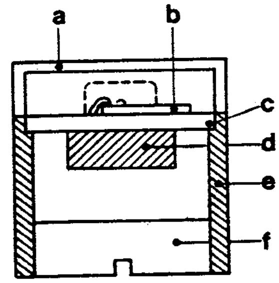


Fig. 10 - Schematic of a possible mounting for monolithic chips. a) Ceramic or metallic cap; b) Microstrip monolithic circuit and i/o microstrip lines; c) Dielectric support; d) Dielectric resonator; e) Metal case; f) Tuning screw.

THE MONOLITHIC CHIP AND THE RELATED EXPERIMENTAL RESULTS.

To prove the validity of the suggested mounting, a monolithic test circuit was designed and fabricated. Two separate oscillators were realized over every 2.5 mmx2.5 mm GaAs chip, using .6 μmx300 μm gate ion-implanted FET devices, realized with a self-aligning process. Passive circuit metallization was 2 μm thick electrolytic gold, selectively grown over the first 300 Å Ti - 1000 Å Au metallization, obtained by lift-off process. .4 μm SiO_2 MOM capacitors were used as r.f. bypass.
Only one oscillator, working at 8.0 GHz, was connected to a resonator-coupled passband coplanar filter forming the feedback network presented in the coplanar-oscillator description. The second oscillator, fully monolithic was designed for 7.2 GHz operation. The overall circuit topology was selected in the aim of assuring a good isolation between the oscillators, which were, to this end, separated on the chip by a narrow grounded microstrip line length. In fig. 11 a picture of the monolithic chip mounted over the ground plane of the coplanar-waveguide resonator-coupling network is shown.
The fully monolithic source showed 13 dBm output power, but, as expected, the stability parameters were very poor: $\Delta f/\Delta t$ > 300ppm/°C $\Delta f/\Delta v$ >70 MHz/V.
Viceversa, the cavity coupled oscillator showed excellent stability performances ($\Delta f/\Delta t \sim$ 4. ppm/°C $\Delta f/\Delta v \sim$100 kHz/V, $Q_{ext} \sim$3500)

with acceptable output power level (4 dBm). An isolation between the output of the two oscillators always better than 37 dB was measured in the tested circuits.

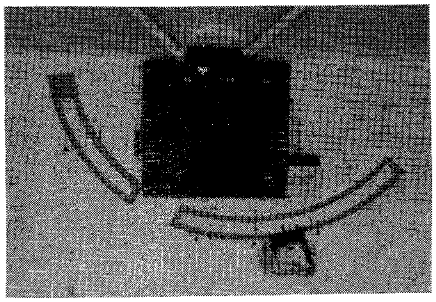


Fig. 11 - A picture of the mounted monolithic chip.

The above results seem to have an interesting application to the monolithic GaAs circuits for the front-end of satellite T.V. home receivers. In fact, the major problem of a fully monolithic front-end solution (4) is the temperature stability of the local oscillator (± 300 ppm over a -30÷+50 °C temperature range for a 10.75 GHz l.o. frequency has been recently proposed. To reach such a stability, various complicated systems, e.g. a phase-locking loop with an external quartz source placed in the indoor receiver unit or a multiplied SAW oscillator have been proposed. Since, for mass production, the monolithic chip has to be probably sealed in a practical carrier, it seems reasonable to utilize the presented solution, which, as demonstrated by our experiments, can easily meet all the system requirements for the first l.o. of satellite T.V. home receivers.

CONCLUSIONS

The feasibility of high-selectivity microwave circuits, where a dielectric resonator is placed below the circuit itself, has been demonstrated and high-stability coplanar oscillators have been described. A practical monolithic mounting where the chip is placed over the resonator is presented together with experimental results concerning a GaAs monolithic test chip carrying two separate oscillators.

REFERENCES

(1) Italian Patent N.o. 22817A/81

(2) H. Abe, Y. Takayama, A.Higashisaka, H. Takamizawa: "Highly stabilized low-noise GaAs FET integrated oscillator with a dielectric resonator at C band", IEEE Trans. MTT-36, No.3, pp.156-162, March 1978.

(3) O.Ishihara, T.Mori, H. Sawano, M.Nakatani: "A highly stabilized GaAs FET oscillator using a dielectric resonator feedback circuit in 9÷14 GHz", IEEE Trans. MTT-28, No.8, pp.817-824, August 1980.

(4) J.A. Turner, R.S. Pengelly, R.S.Butlin, S. Greenhalgh: "Direct TV broadcasting via Satellite", GaAs I.C. Symposium, S.Diego 1981, Paper No. 40.