GaAs low cost Microwave Monolithic Circuits for high volume television applications.

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Abstract

Two MMICs have been designed and fabricated for television applications. To be compatible with the needs of the market, low cost approaches have been used to design these circuits. The first one, is an image rejection downconverter fabricated on a 2.4mm^2 chip using a 0.5 micron MESFET low cost process. This circuit converts signals in the 10.95 to 12.75GHz band to a lower frequency band (1). The second one is a fully integrated 2GHz downconverter IC fabricated on a 0.9mm^2 chip, using an enhancement mode GaAs process. It converts signals in the 0.95GHz to 2GHz band to the UHF band with its internal local oscillator (2). In both cases, original solutions have been used to reduce the cost of the packaged chips .

Introduction

The market of the GaAs monolithic circuits for consumer applications is rapidly growing, mainly in the television domain. Indeed, this technological approach is an attractive alternative because of its mass production capability and its competitive price. Moreover, these circuits being used in consumer products, they have to be designed to be low cost. The designs have been aimed at optimizing the RF yield of the chips with the help of statistical simulations. In addition, both downconverters only need one positive voltage supply, consequently, this means that the cost of biasing circuits in systems will be reduced.

For the DBS downconverter (figure 1.), we have optimized the RF amplifier and the local oscillator to make it compatible with the Fixed Service Satellite low band (10.95-11.75GHz), the DBS band (11.7-12.5GHz) and the Fixed Service Satellite high band (12.5-12.7GHz). A single chip solution has been chosen to cover these three bands (instead of three for other competing circuits), and to allow a system house to produce complete downconverters compatible with each frequency bandwidth.

In the case of the 2GHz downconverter (figure 2.) the local oscillator has been integrated to allow the design of a balanced structure with a low inherent LO leakage, and to reduce the size and the number of components in the equipments. To reduce current consumption, the low DC power normally off ER07AD process of P.M.L. has been used.

Low cost packages have been used to produce these downconverters.

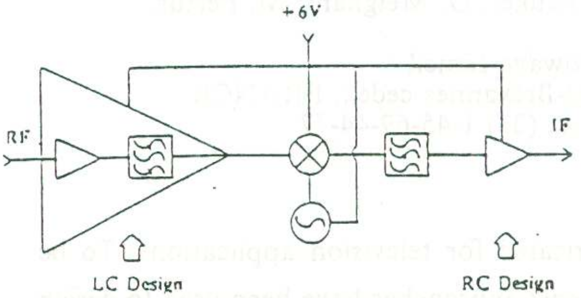

Figure1. Block diagram of the DBS downconverter

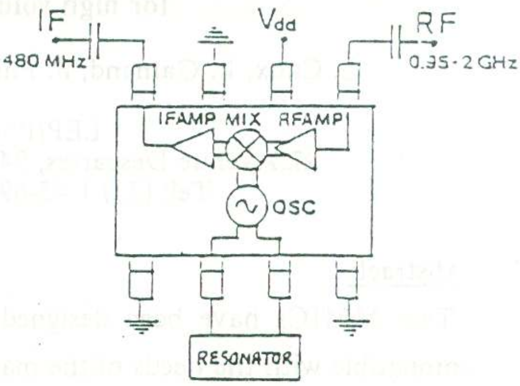

Figure2. Block diagram of the 2GHz downconverter

The DBS downconverter

We have designed a compact structure gathering two kinds of techniques. In contrast to a tuned or "LC" matched RF amplifier, we have chosen a high impedance topology for the low frequency parts of the converter (mixer, IF amplifier). In this way it has been possible to keep a small chip area. In addition, we have paid great attention to the sensitivity of the circuit to process variations, and we have performed statistical analysis to predict the yield of our product. In this way, we have obtained with the first wafers an RF yield of 70%, with a low cost high packing density 0.5um process (7 mask levels) available at the Philips Microwave Limeil foundry.

Circuit design.

The RF amplifier is based on 4 self-biased stages, which provide 16dB gain for a power consumption of 60mA under 6 Volts supply voltage. The 4 stages present a common source topology and their matching has been optimized to achieve significant gain with a low noise figure. In order to save GaAs area we have included the image frequency filters in the output matching. With such filters we achieve at least 15dB rejection from 10.95GHz to 12.75GHz.

The local oscillator is based on series feedback structure and is stabilized with an external dielectric resonator. Its current consumption is 10mA and it shows a typical phase noise of -100dBc/Hz at 100KHz off the carrier (figure 3.).

The mixer comprises one MESFET biased near the pinch-off voltage, with the LO signal injected at its gate and the RF signal at the source. To limit the parasitic injection of LO signal at the IF output, a LC filter has been placed at the drain of the transistor. Such a mixer exhibits a conversion gain of -2dB across the 0.8 to 2GHz IF frequency bandwidth.

The IF amplifier is based on a RC design and consists of 3 common-source common-drain stages followed by a 50 Ohms output buffer. The amplifier, with a feedback resistor used to increase the gain at 2GHz, achieves 22dB gain.

This downconverter does not use negative power bias supply, its gain is shown figure 4. and the overall performances are presented in table 1..

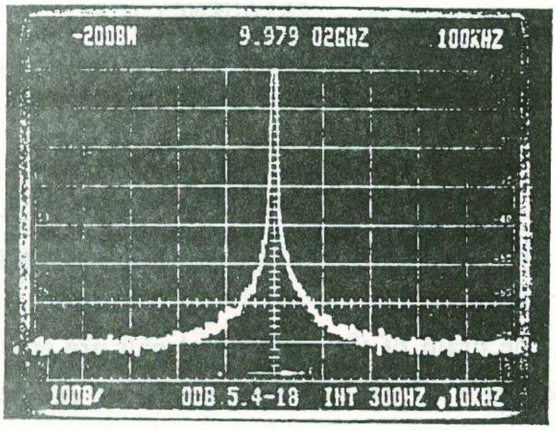

Figure3. Spectrum of the DBS downconverter DRO

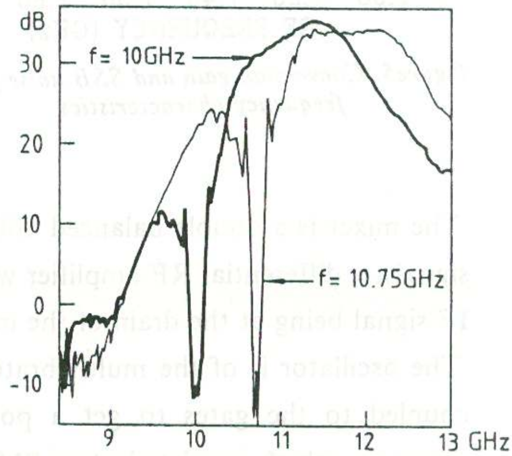

Figure4. Conversion gain of the DBS downconverter DRO for LO at 10 and 10.75GHz

conversion gain	34-36 dB
RF band	10.95 to 12.75 GHz
image rejection	> 25 dB
LO level at RF port	-17 dBm
LO level at IF port	-20 dBm
SSB noise figure	< 10 dB
IP3	+ 9 dB
current consumption	< 130 mA
single bias supply	+ 6 V
I/O VSWR	< 2

Table 1. Performance of the DBS downconverter

The 2GHz downconverter

This downconverter has been fabricated with the enhancement mode GaAs process of P.M.L. : ER07AD. One of the key features of this process is the low DC consumption: this is a fully integrated downconverter IC (the oscillator being on-chip), with less than 30mA DC current consumption. The ER07AD process is especially suitable for low power from L band to C band mixed analog/digital applications (3), (4).

Circuit design.

The RF amplifier shows a common-source structure. To achieve a low input impedance, a voltage shunt feedback has been used; in addition, this feedback limits the variations of the noise figure and of the input matching in the frequency bandwidth (figure 5. and figure 6.).

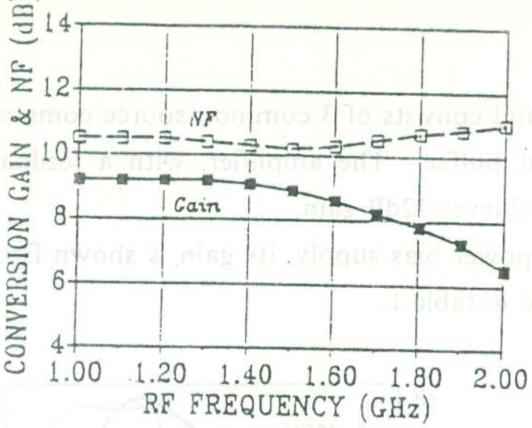

Figure5. Conversion gain and SSB noise figure frequency characteristics

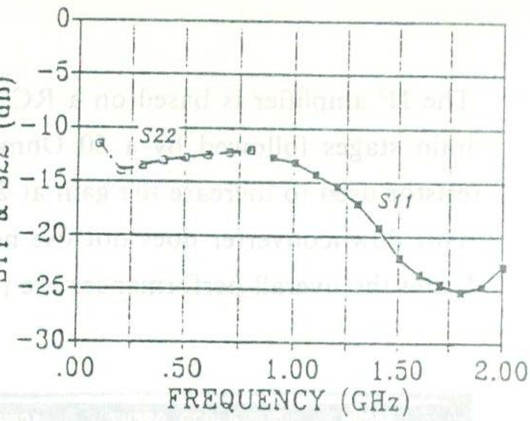

Figure6. Input/Output matching characteristics

The mixer is a double balanced Gilbert cell, and therefore, to obtain two balanced RF signals, a differential RF amplifier with one grounded input has been used, the balanced IF signal being at the drain of the mixing transistors.

The oscillator is of the multivibrator type, the drain of the differential pair are cross-coupled to the gates to get a positive feedback. This oscillator needs an external resonator which consists in two SMD varicaps placed on a printed circuit board. This oscillator tank allows a wide tuning capability (from 1.4 to 2.6GHz) with a frequency linearity of 1% over a 1GHz band and a phase noise range between -95 and -100dBc at 100KHz frequency offset. With the mixer described just before, we obtain a LO power leakage of -30dBm at the IF port and about -30dBm at the RF port in the 1-2GHz band.

The balanced IF signals are combined in a low output impedance push-pull stage placed at the input of the IF amplifier.

In table 2., is presented the overall performance of the circuit based on test data of 90 samples monted in a plastic package (SO8). This very good performance has been obtained with a very low power consumption of about 140mW under a 5 Volts supply voltage. The size of the circuit is 0.84mm x 0.84mm (0.9mm^2 with the dicing streets).

parameter	mean value	std dev
gain at 1 GHz	9 dB	1 dB
gain at 2 GHz	6.2 dB	0.9 dB
NF(SSB) at 1 GHz	11 dB	0.4 dB
S11 at 1 GHz	-10 dB	0.3 dB
Pout(-1dB) at 1 GHz	-3 dBm	1 dBm
LO in RF at 1 GHz	-30 dBm	1.2 dBm
LO in IF at 1 GHz	-30 dBm	1.7 dBm

Table 2. Performance of the 2GHz downconverter

Circuits for high volume television application

Both, DBS and 2GHz downconverters, have been designed to adress low cost high volume GaAs IC markets. For that, the size of each of them has been minimized. We have selected low cost packages, used well mastered design techniques and the circuits were fabricated with low cost processes.

Conclusion

This paper has presented two downconverters for satellite TV applications. These circuits offer much more than their MICs counterparts, indeed, the 2GHz downconverter presents perfect double balanced structures and thus allows a very good rejection the undesirable signals. These circuits can reduce the assembling time, their tuning beeing very simple, and in the case of a high volume production, they can lead to an important reduction of the costs. Moreover, they also demonstrate the capability of Philips Microwave Limeil to come up with high performance low cost X band and L band products.

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