A LARGE-BAND 2.8÷4.25 / 5.6÷8.5 GHZ FREQUENCY DOUBLER MMIC FOR DIGITAL RADIO LINK APPLICATIONS

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Abstract: — **This paper describes the design and the development of a frequency doubler GaAs MMIC for digital radio link applications. The operation frequency band is 2.8÷4.25GHz for the input signal, converted into the 5.6÷8.5GHz doubled band for the output signal. With +16dBm RF power level at the output port, the spurious suppression results better than 15dB for the 1st harmonic, 25dB for the 3rd and the 4th harmonic. The conversion loss is close to 0dB with a ripple in band of ±1.5dB, and the saturated output power is better than +18dBm over the whole operation band. The overall chip dimension is 3.556x3.012mm^2 (140x120mils^2).**

I. INTRODUCTION

Fiber optic has increasingly become the preferred medium for high capacity transmission systems, but the benefit of microwave radio link such as security, speed of deployment and economics, are still strongly appreciated by networks planners. The introduction of SDH technology in transmission networks has represented a new interesting challenge for digital radio system to allow a successful integration into modern synchronous networks. More sophisticated radio equipment designs are so requested with higher performances and miniaturisation, but lower manufacturing cost. A new family of cost-effective digital radio relay equipment, characterised by a very high level of integration, is now under development with the following main requirements: design unification, component standardisation, size reduction, manufacturing modularity and testing time reduction. In paper [1] the efforts for assembling some techniques and methodologies addressed to fulfill these requirements are presented, with the development of a new MMIC-based power amplifier structure for transmitters. The next step undertaken is the integration of the up-converter into the Power amplifier structure. In paper [2] a design of a new high linear SSB mixer for C band, at present in development, has been presented.

The new transmitter under development in Alcatel will be provided of a modular structure covering the C and X band depending only on the MMICs included into the micro-modules. The first micro-module of the chain performs the up-converter function and the second one the variable gain function. The up-converter micro-module is split in the 3.4-5.0GHz and 5.6-8.5GHz sub-bands. For the lower sub-band the LO commands directly the MMIC mixer while for the upper one the MMIC mixer needs a frequency doubler. For the X band case, a further frequency doubler, to have the LO frequency multiplied by 4, is needed before the mixer. This allows a reduction of the LO assortment needed in C/X band transmitters. Moreover, the new frequency converter MMICs structure can be re-used as down-converter in the receiver module.

II. CONFIGURATION

A doubler is a non-linear device used as a multiplier to generate harmonics, suppressing all the spurious and extracting the 2nd one.

The design of the new MMIC for C band requires splitters and phase networks that have been built using lumped elements to save the MMIC area. In order to cover the 5.6-8.5 GHz output band, from a 2.8-4.25 GHz LO, a balanced structure is needed to reject the 3rd harmonic, which otherwise goes through the broadband micro-module. Moreover, at the output port, the fundamental LO is also rejected because of the balanced structure, which tends to cancel all the odd harmonics.

The input LO is divided by a 180° splitter realised by a lumped Wilkinson network followed by a phase network that allows the desired opposite phases [3]. Two section all-pass network pairs are needed for the required broad band. Moreover, the balanced structure allows a good tolerance for the right phase difference against process related variation. Despite the fact that the balanced structure requires more GaAs area than unbalanced one, it doesn't need external filter that requires a greater micro-module area. The non-linear core of the MMIC frequency doubler is a couple of MESFETs biased near their pinch-off voltage to exploit their non-linear behaviours; at their input these are matched on the fundamental frequency while in output on their 2nd harmonic, in order to optimise the power conversion. A 300μm width MESFET is sufficient to obtain the desired performances. At their output, lumped Wilkinson network sums up the even harmonics and cancels the odd ones generated by the non-linear MESFETs. In order not to have conversion loss and provide a higher signal level to the following mixer, that means more linearity for the micro-module RF output signal, an output amplifier stage is included. In a compromise between ripple in band, gain and on the other hand consumption, the amplifier is matched in output for the maximum power and works near the saturation. The amplifier stage is centred on a 420μm width MESFET to provide the needed minimum output power saturation. The MMIC is designed and developed with the TriQuint Semiconductor (TQS) HA2/0.5μm MESFET process technology with backside via hole ground technology.

III. MMIC DESIGN

The HP/EEsof Series IV Electrical and the HP/Momentum Electromagnetic simulators have been used to centre the design. The active and passive lumped elements were simulated using the standard cell library and electrical models given in the TQS design manual [4]. The circuit was simulated taking into account all the parasitic effects due to metal interconnections, discontinuity, bond pads, external bond wires and optimised to be strong enough to operate over some reasonable range of process distribution. The layout was drawn with care to the parasitic coupling effects valued with the aid of the E.M. simulator. Special attention was posed also in the definition of the bias circuits for good choke filters at the bias pads and bias point flexibility versus the gate resistor choice. Input/output Ground-Signal-Ground coplanar microwave probe pads are used to permit an on wafer 100% RF testability.

The final chip dimensions are $3.556 \times 3.012 mm^2$ ($140 \times 120 mils^2$), 100μm thin. The MMIC chip has been soldered into an internal designed package, interconnected with input/output Alumina substrates and finally tested.

IV. MEASUREMENTS

The packed MMIC was measured using a Spectrum Analyzer in order to look at all the harmonics over the band.

The bias points are Vgs= -1.6V, near the pinch-off, for the non-linear MESFETs, Vgs=-0.6V, in the middle of the Ids-Vds characteristics, for the amplifier stage and Vds=5V for both the drain. The current consumption is 45mA for the amplifier stage and 30mA (in presence of the RF signal) for the multiplier stage. This results in a total consumption of the MMIC of 75mA. The input RF power level is +16dBm over the 2.8÷4.25GHz band.

Fig. 1 shows the 2nd harmonic output power through the whole operational frequency band. With +16dBm input power, the output power is close to +16dBm that means a conversion loss of some 0dBm.

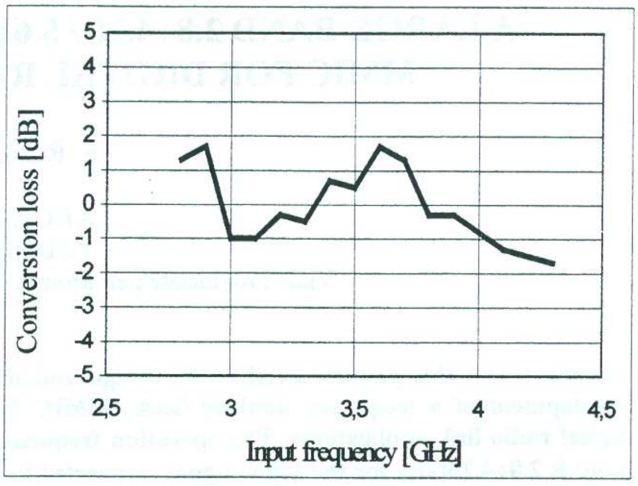

Fig. 1

Fig. 2 shows, for the output signal, the suppressions of fundamental, 3rd and 4th harmonics related to the 2nd harmonic level when the RF input signal sweeps over its operational frequency band. The spurious fundamental is 15dB lower than the 2nd harmonic output signal, and far lower are the spurious 3rd and 4th harmonics. Higher harmonics are rejected due to the filtering action of the matching nets and the limited active device frequency band.

Fig. 3 shows the power saturation level for the 2nd harmonic output signal at the lower, central and upper frequencies, when the input RF signal power sweeps from small level to the saturation. At small power level the 2nd harmonic rises at 2:1 dB ratio, due to the square effect of the non-linear device, then there is gain compression up to the saturation, whose minimum level is at 18dBm.

In Fig. 4 is shown a picture of the designed chip that allows having a look of its any single part.

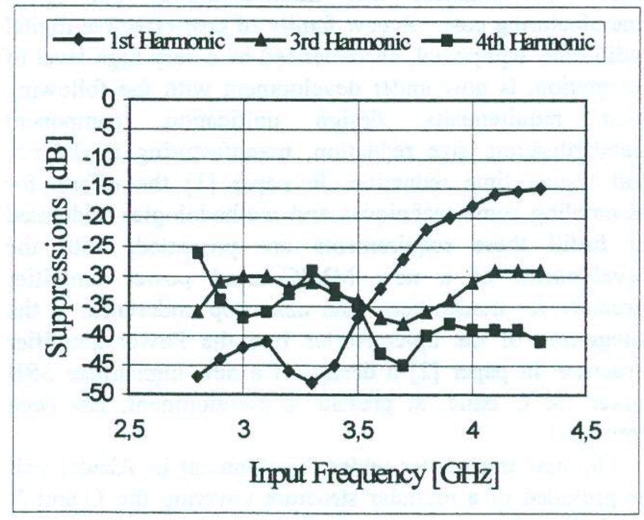

Fig.2

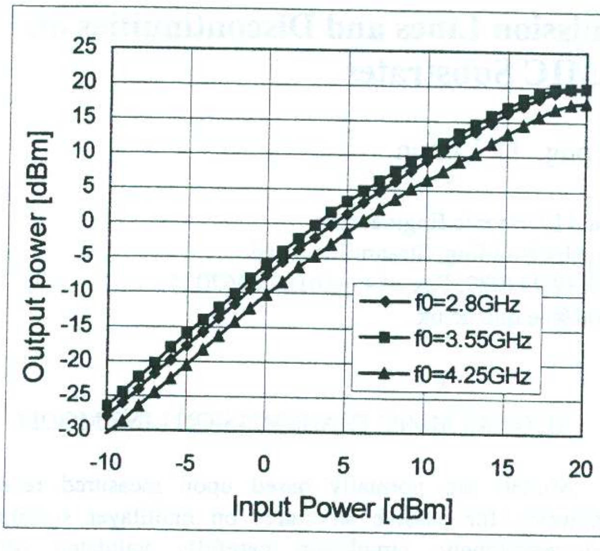

Fig.3

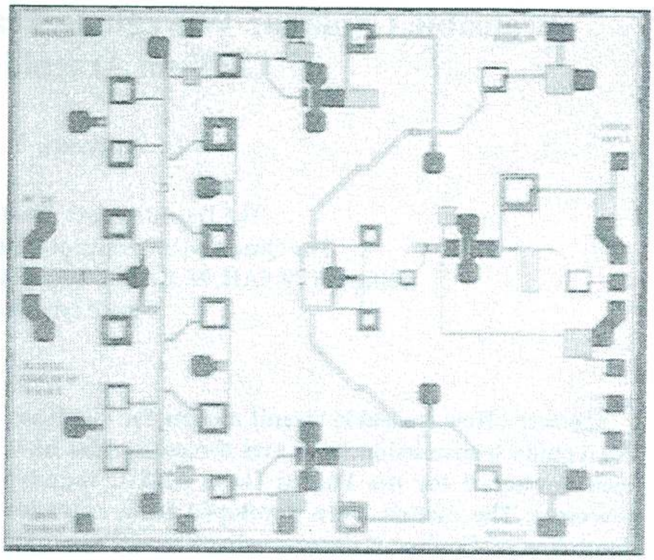

Fig.4

V. CONCLUSION

A MMIC frequency doubler with a large operation band for the C band digital radio links use has been designed and developed. The chip dimension is suitable for relative small package use. The measured performances well satisfy the design requirements that are suitable for radio link applications. The new MMIC permits the reduction of the LO assortment for the new generation of SDH radio links next produced for the C and X band range and the integration of a new up/down conversion function into a relative small micro-module next developed in ALCATEL with the new MMIC mixers presently under development.

VI. REFERENCES

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