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SIMPLE SLOPE COMPENSATOR FOR KU-BAND APPLICATIONS.

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1. ABSTRACT.

The present paper describes a simple circuital solution for a slope compensation function to be used in an amplification chain when it is necessary to recover for both fast ripple and slope variation occurred within the whole bandwidth. The circuit has been studied and developed mainly for Ku-Band Applications and has been implemented in MMIC form using a standard Low Noise MESFET process. The performed tests have shown the effectiveness and the versatility of the MMIC which has been successfully inserted in several satellite on board equipment.

1. INTRODUCTION.

In the last years the use of GaAs MMIC technology in Satellite on board equipment is becoming increasingly effective because of its advantages in reducing size, weight and cost of microwave dedicated units. Size and weight reduction result more useful for equipment in which a large number of subsystems equal to each other must be implemented to build a complex function. Moreover, relatively complex circuits implementation, allows to reuse the same MMIC for more than one application thus increasing also the yield at equipment level by means of optimized modularity [1]. In satellite applications there are many units in which the advantages offered by this technology results evident. The drawback of this technology is that due to the poor gain per MMIC usually obtained at higher frequencies when dealing with large bandwidth circuits, sometime it becomes necessary to cascade several MMICs on the same unit to keep the overall gain/bandwidth performances. For particular applications such as Channel Amplifiers this means that, because of fast ripples due to the MMICs interconnections , the overall amplifier performances in terms of flatness could be extremely unsatisfactory also in the single channel bandwidth [2]. Here is proposed a circuit that has been designed in order to compensate for the ripple due to a MMICs long chain assembly at each point in the operation bandwidth.

2. CONCEPTUAL AND ELECTRICAL DESIGN.

Examples of "slope compensators" for microwave applications have already been reported in literature [3], [4] but they are able to control the overall bandwidth slope. The proposed circuit is conceptually quite simple and allows to obtain both a positive and a negative slope control also into a small variable portion of its operating bandwidth. Moreover it has been conceived as a modular elements and can be used alone or together with another MMIC on the same carrier or package. Our basic idea, is to use , along the signal path, a "notch" filter in which it's possible to control both the "Q" and the position of the resonant frequency. We analyzed several solution which can perform this operation making a continuous trade off between simplicity and effectiveness. The simplest circuit for the expected purpose resulted to be a parallel resonant RLC implemented with variable resistor and capacitor and buffered between two lange couplers.

Choosing L and C for the right operation bandwidth, it is possible to obtain either a negative or a positive slope by simply varying the notch position adjusting the capacitor's value. The slope value can be adjusted by varying the resistor from Rmin. to Rmax. The insertion of two such a resonant circuits between two lange couplers allows to keep constant return losses over all the bandwidth thus improving the modularity.

In this way, as mentioned before, this circuit can be used together with other MMICs (mainly Amplifiers) in order to implement more efficient building blocks for different applications.

3. TECHNOLOGY DESCRIPTION and PHYSICAL IMPLEMENTATION.

The technology used for the MMIC implementation is a self aligned gate medium power low noise MESFET process with a gate length of 0.5 μm. The entire wafers are implanted and annealed. MESA etching is used to create the active areas. Typical process parameters are Idss = 350 mA/mm, Vp = -3.2 V. and Gm 165 mS/mm.

The cold mesfet approach has been used to implement both variable capacitor and variable resistor and a small microstrip line serves as tuning inductor. The mesfet dimension for the capacitor has been calculated using the Cgs variation model in order to get the expected value In order to reduce the corresponding series resistor, a large gate width has been used for the implementation of this component. Similarly the variable resistor has been dimensioned considering the linear part of the I-V curves and a large gate width allowed to reduce the insertion losses in the "zero" slope condition.

MIM capacitors have been used for all DC block and bypass where needed. The lange coupler has been implemented using a folded structure in order to keep the overall MMIC dimension inside the required one. Accurate models, based on quite a lot measurements, have been used both for active and passive components in order to get a simulation as much real as possible. A very accurate sensitivity analysis has been done to individuate and compensate for process variations.

4. RESULTS.

All measurements have been done on a Wiltron Type test fixture using an HP 8510 Network analyzer. The circuit requires both negative and positive voltage for complete slope control. Fig. 1 shows the realized MMIC. Figures 2, 3 and 4 show the simulated performances for different variable capacitor and variable resistor voltages. Due to the lange couplers the Input and output return losses are quite stable in all operative conditions.

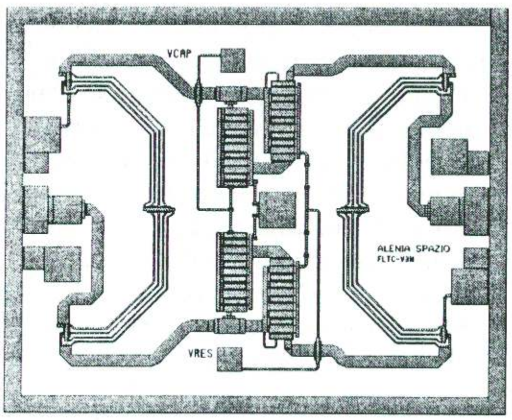

Fig. 1 Realized Chip

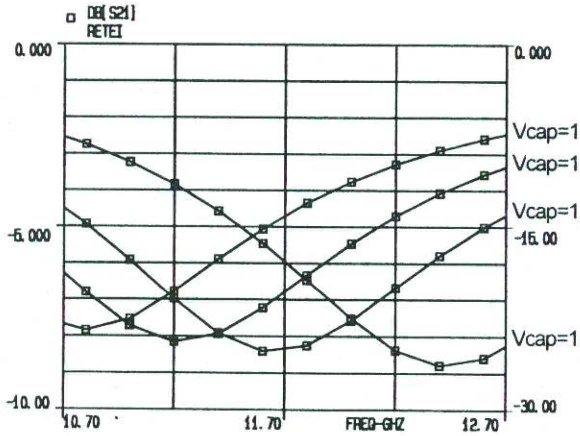

Fig.2. Simulated S21 at various Control Voltages

Fig. 5 shows the measured performances. As can be seen, the measurement are in accordance with the simulations and, although not shown, slope values up to 2.7 dB/500MHz have been measured with a control voltage up to 5 V. Of course the circuit response is not linear, but, at module level, this problem can be overcome using a digital circuit like a PROM to drive both Vcap and Vres of the MMIC.

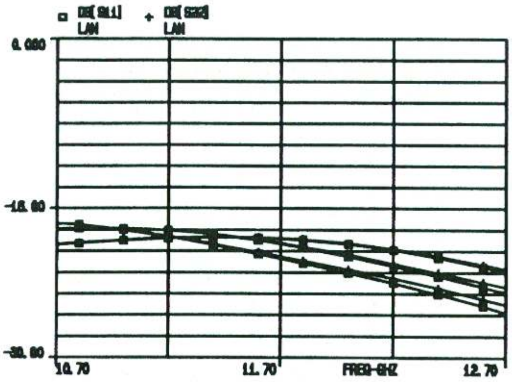

Fig.3. Simulated S11 and S22

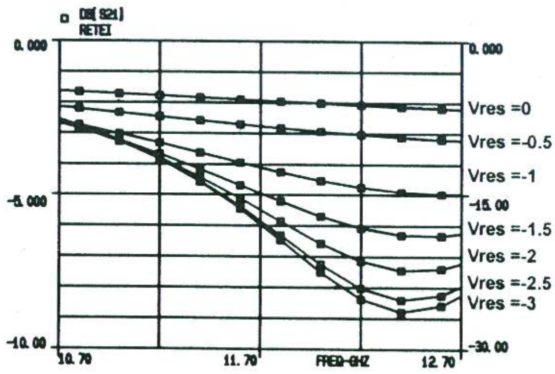

Fig.4. Simulated S21 at various Slope Control Voltages

5. APPLICATIONS.

We have used this slope compensator together with a Variable Gain Amplifier as building block for different applications. As Variable Gain Amplifiers normally change their flatness slope while decreasing gain, this type of arrangement allows to keep a constant flatness overall the gain dynamic range. Two MMICs have been mounted on a carrier to form a module. A small alumina substrate can be also inserted for the interconnection giving the possibility to perform some "off-chip" tuning to improve the overall module performances if necessary. Fig. 6 shows the performances obtained at equipment level when the realized circuit is inserted within a very long chain of MMIC amplifiers. Is quite clear the improvement obtained with flatness control "on". From figure 7 it results evident the possibility to have both negative and positive slopes. Fig.8 shows how the slope compensator has been integrated with the Amplifier.

Both the slope compensator and the Variable Gain Amplifier have been developed on the same "Wafer". The Variable Gain Amplifier is a three stages circuit which has a good linearity and an attenuation Dynamic range of 40 dB reached using an internally implemented "T" type attenuator. Self biasing configuration has been used for all the stages in order to use a single voltage supply and reduce the gain variation vs. temperature.

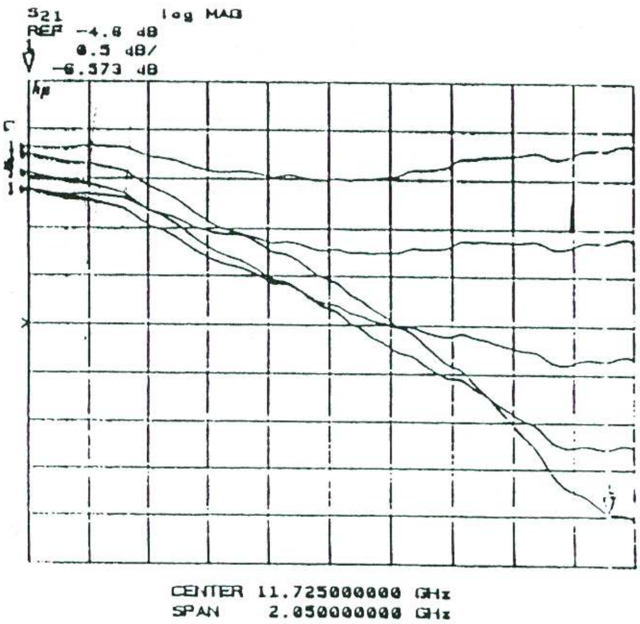

Fig. 5. Measured MMIC Performances.

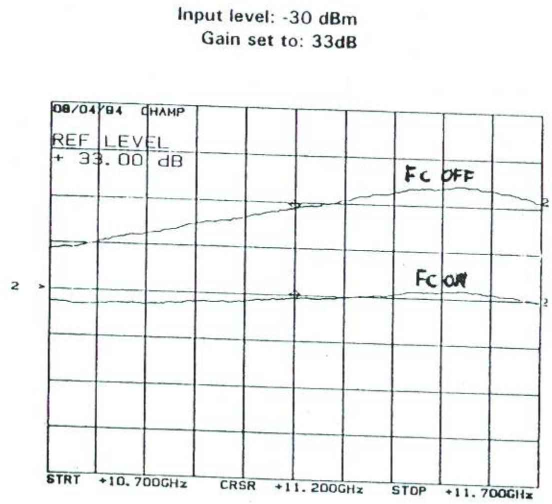

Fig.6. Measured Module Performances

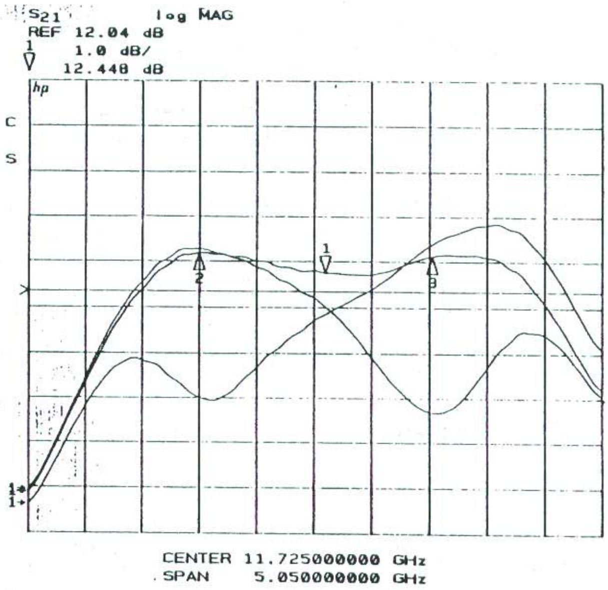

Fig.7. Example of negative and positive slope at module level.

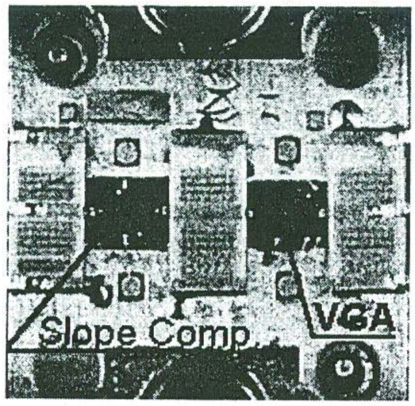

Fig.7. Integration of the Slope Compensator with the Amplifier.

5. CONCLUSIONS.

A very simple approach has been presented for the realization of a "Slope compensator" with low expensive Mesfet MMIC technology. The circuit results very suitable not only for Satellite Channel Amplifiers but also in all the equipment in which the use of several cascaded MMICs can introduce both very fast ripples and very high slope variations inside the large bandwidth. The combination of a slope compensator an a Variable Gain Amplifier has been also used in a number of different equipment showing very effective results. The reported results are quite good and show the effectiveness of the circuit and the accordance with the simulation.

6.REFERENCES.

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