# Ripple+slope performance of satellite channel amplifiers related to GaAs MMIC technology

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### Abstract

This paper reports on the development[1] of two generic satellite transponder channel amplifier subsystems for the 5.35–5.65 GHz band, respectively the 10.70–12.75 GHz band, both to be based on full application of GaAs MMIC technology. A novel Slope Compensation MMIC is introduced as a curative counter-measure to minimize residual inband gain ripple and slope. Furthermore, a control loop algorithm is used to account for all principal control characteristics, all interdependencies between them and all temperature effects. Measurements show competitive inband ripple+slope values for all gain settings over the complete temperature range.

### Introduction

This development is aimed to demonstrate that the introduction of today's standard GaAs MMIC technology yields channel amplifiers which are able to compete with or even surpass the microwave performance (in particular inband ripple+slope) of conventional MIC-based designs, while taking full benefit from ultimate miniaturisation and reduced parts count and mass. The ultimate objective is to pave the way for real exploitation of this technology within channel amplifiers for near-future space missions (ARTEMIS, DRS, EUTELSAT-III).

### Topology

For both channel amplifiers, a distributed fixed-gain/variable-attenuator topology has been synthesized for the RF Module, see Fig. 1, based on requirements for maximum and minimum gain, maximum power levels, maximum noise figure and the available MMIC technology (0.5 μm MESFET).

The major engineering challenge is to meet the inband forward gain ripple requirement (≤ +/–0.1 dB over a 150 MHz critical subband and ≤ +/–0.3 dB over the full 5.35–5.65 GHz band, respectively ≤ +/-1.0 dB over 10.70–12.75 GHz) over the full gain range from –7 dB respectively +30 dB up to 51 dB respectively 61 dB (gross gains as high as 70 dB). This is especially challenging when considering output/input stray feedback associated with the amplifier's longitudinal size reduction, and interstage-mismatch ripple accumulation due to reflection coefficient consistency of the stages within the chain.

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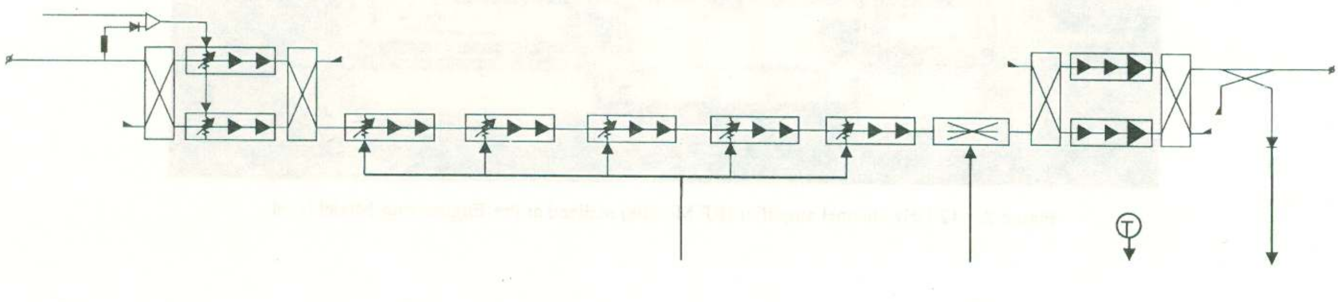

Figure 1. Topology of the RF Module of the 12 GHz channel amplifier (5.5 GHz channel amplifier comparable).

## Ripple+slope counter-measures

Due to the inherent properties of GaAs MMIC technology, the following counter-measures have been implemented.

As a preventive measure to suppress output/input stray feedback, the small chip size has allowed considerable narrowing of the metal corridor containing the cascaded MMICs (only 3 mm lateral dimension) such as to achieve maximum suppression of waveguide propagation over the fixed operating frequency ranges.

As a preventive measure to minimise interstage-mismatch ripple, the MMICs' input and output reflection coefficients have been specified to meet an inband *phase variation* limit and *magnitude variation* limit, in addition to the usual magnitude upper limit alone. The basically lumped nature of the electrical entities with which MMICs are constituted by itself already prevents too frivolous behaviour of the complex input and output impedances within the Smith-chart, so that, when using MMIC technology, the extra reflection coefficients variation restrictions are not unattainable beforehand.

As a curative measure, a novel voltage controlled Slope Compensation Circuit has been introduced, see the MMIC just in front of the balanced output stage in Fig. 1. Due to its lumped nature and multi-feedforward paths, this circuit has proved to be well suited for GaAs MMIC implementation.

Fig. 2 shows the RF Module implementation of the 12 GHz channel amplifier realised at Pre-Engineering-Model level.

## Control Module algorithm

In addition to the mentioned counter-measures in the RF Module, a digital Control Module is used, working as interface, and which contains RF Module calibration data and a sophisticated control loop algorithm. This control loop algorithm transforms values for gain or output power level setting and slope setting into a set of optimum control voltages, compensated in real-time and in a self-iterative manner for the Variable Attenuator's transfer function, the Slope Compensation MMIC's transfer function, gain⇔slope control interdependency, the RF Power Detector's transfer function and for temperature dependency of all transfer functions, see Fig. 3. The control loop algorithm is implemented fully in software.

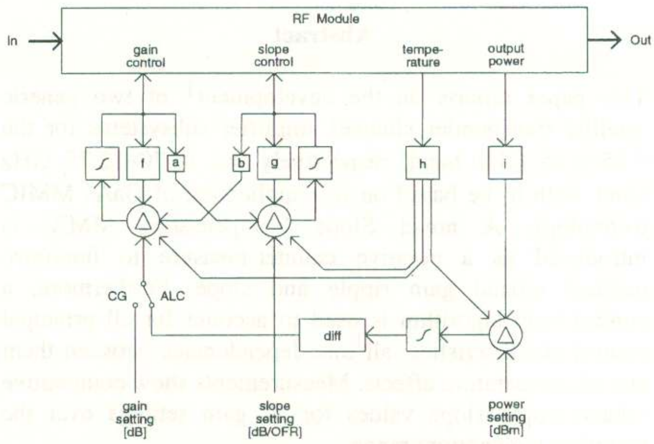


Figure 3. Control loop algorithm.

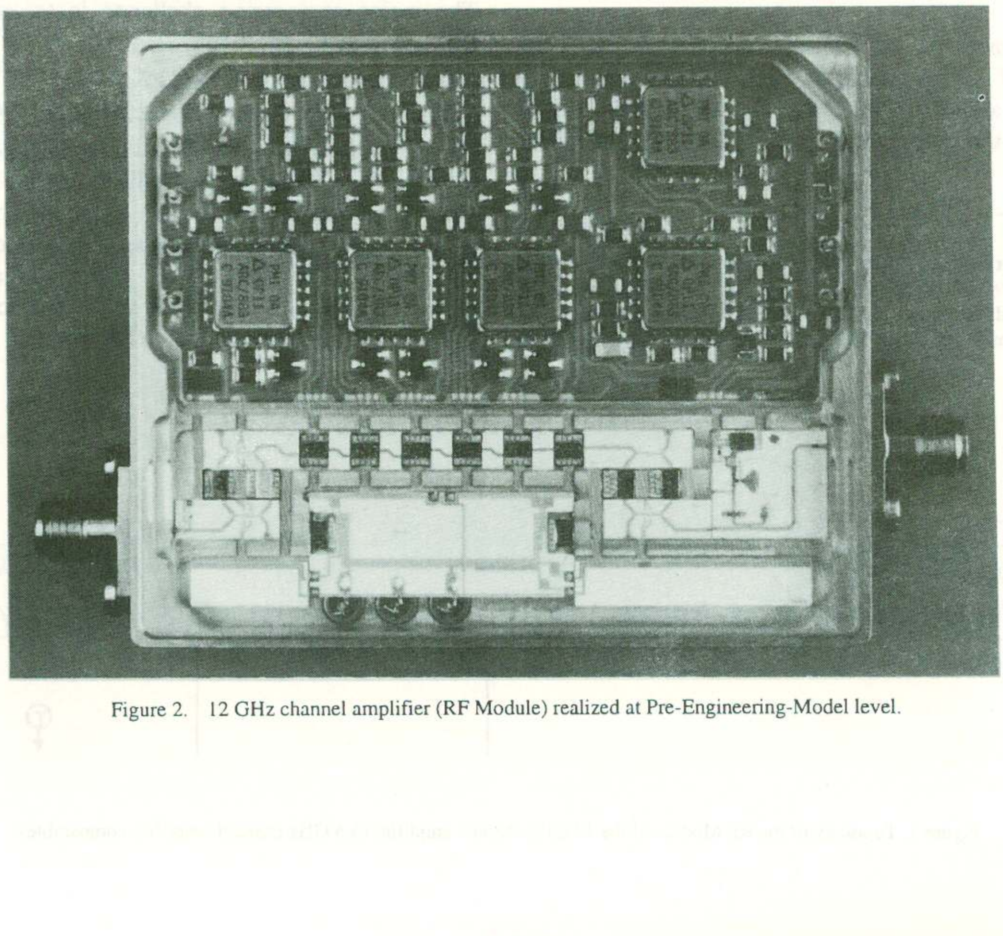

Figure 2. 12 GHz channel amplifier (RF Module) realized at Pre-Engineering-Model level.

## Measurement results

Measurement results on the 5.5 GHz channel amplifier show an inband forward gain ripple+slope (@ 51 dB net gain) as small as +/–0.01 dB over the critical 150 MHz subband and +/–0.15 dB over the full 5.35–5.65 GHz band, see Fig. 4. This ripple+slope is maintained within +/–0.05 dB and +/–0.1 dB respectively, for all required gain settings and over the temperature range ($T_{amb}$:–15°C ... +55°C).

The 12 GHz channel amplifier show +/–0.5 dB ripple+slope over 10.70–12.75 GHz (@ 61 dB net gain), see Fig. 5. This ripple+slope is maintained within +/–0.2 dB for all required gain settings and over the temperature range.

The Slope Compensation MMICs feature a measured continuous control range of +1.5 to –0.8 dB slope over 5.35–5.65 GHz, respectively +3.0 to –1.5 dB slope over 10.70–12.75 GHz. Fig. 6 show the measured control range of the 12 GHz Slope Compensation MMIC (limited positive slope setting).

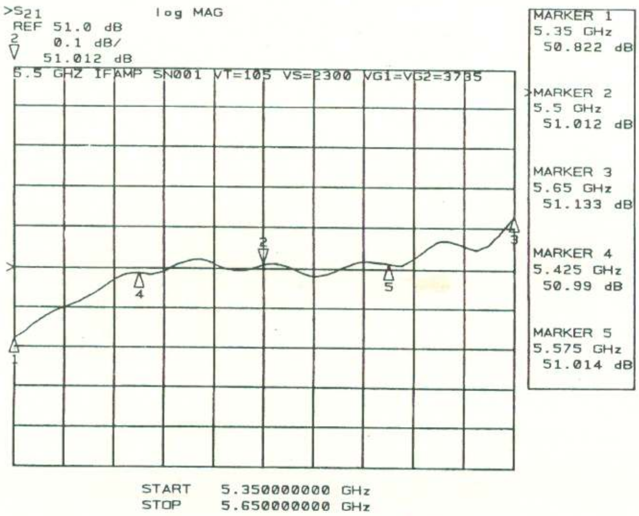

Figure 4. Inband $S_{21}$ ripple performance 5.5 GHz channel amplifier.

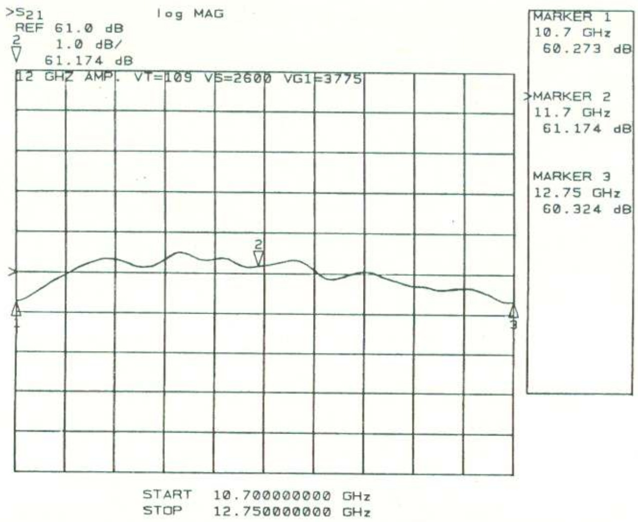

Figure 5. Inband $S_{21}$ ripple performance 12 GHz channel amplifier.

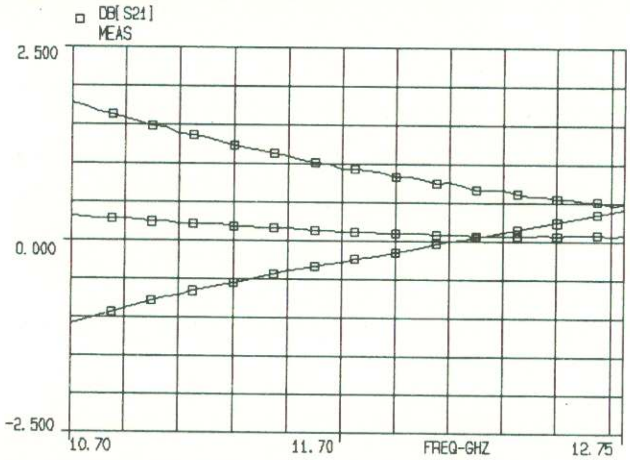

Figure 6. Measured control range 12 GHz Slope Compensation MMIC.

## Conclusion

This work has demonstrated that the introduction of GaAs MMIC technology yields the achievement of superb satellite channel amplifier transfer characteristics. Furthermore, a novel Slope Compensation Circuit has been introduced which effectively minimises residual ripple+slope at subsystem level.