# Ku-Band Quadri-SSPA for Stentor Satellite Transmit Active Antenna

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***Abstract* — This paper presents the architecture and the performances of a Ku-band Quadri-SSPA (4 RF amplifying channels) developed in the frame of Stentor French technological satellite for a transmit active antenna application. Major technical advances in terms of technological features and RF performances (output power capabilities, DC power consumption and linearity) over a 13 unit lot (52 single SSPA) are highlighted.**

## I. INTRODUCTION

The explosion of the telecommunication market is also impacting the space segment and the satellite payloads. All over the world the industry is making strong efforts to reduce cost and delivering time for commercial programs while decreasing hardware mass and increasing overall performances. French agencies (CNES, FRANCE TELECOM and DGA) have joined their efforts to promote new and competitive technologies by implementing a technological satellite program : STENTOR.

This ambitious project aims at flying several advanced concepts [1]. One of the challenge of this technological satellite was to develop a Ku-band transmit active antenna including 48 SSPA (or 12 Quadri-SSPA) able to deliver substantial output power with limited on-board resources. In single carrier condition, the specified output power is higher than 34.6 dBm per channel with a DC consumption lower than 58.3 W for the equipment (for 4 channels and including DC/DC efficiency) over the 12.5-12.75 GHz frequency bandwidth and the –15°C/+50°C temperature range. For two-tone mode the goal is to reach 31.6 dBm output power with less than 56.8 W DC consumption and C/I3 higher than 22 dBc over the same temperature range. To overcome this challenge and to achieve the best trade-off between antagonist parameters as high output power, low DC consumption and high linearity, the p-HEMT technology appeared to be the best candidate for the output stages. Every RF chain includes a self compensation for absolute gain and insertion phase variations over temperature range. For low performance dispersion over the 48 RF chains, an all-MMIC approach has been adopted. For calibration antenna purpose, a compact passive combiner 4 towards 1 using multilayer technology (stripline propagation) made on TPFE substrate with resistive layer has been implemented into the equipment.

## II. QUADRI-SSPA DESCRIPTION

For cost and mass reduction purpose on one side and for mechanical and electrical antenna architecture constraints on the other side, the 48 SSPA have been grouped by packs of 4 leading to 12 Quadri-SSPA. A trade-off performed on active antenna DC power supply was concluded by the selection of a distributed network made of 12 DC/DC converters, one per Quadri-SSPA. To insure the antenna calibration and its performances monitoring over the satellite lifetime, additional functionalities have been implemented in the SSPAs for each RF chain: sampling by weak coupling of RF output signal for calibration purpose, and output power detection and digital conversion of associated analog voltage.

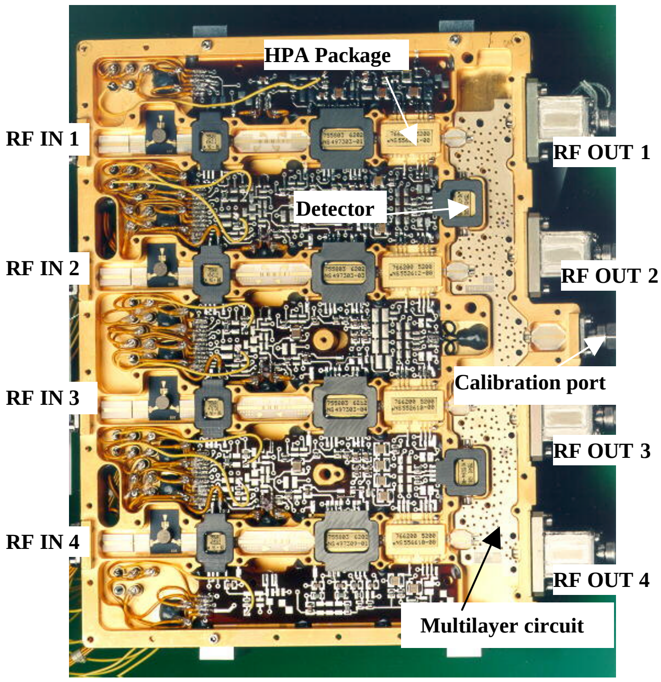


Fig. 1. Photograph of RF portion of Quadri-SSPA

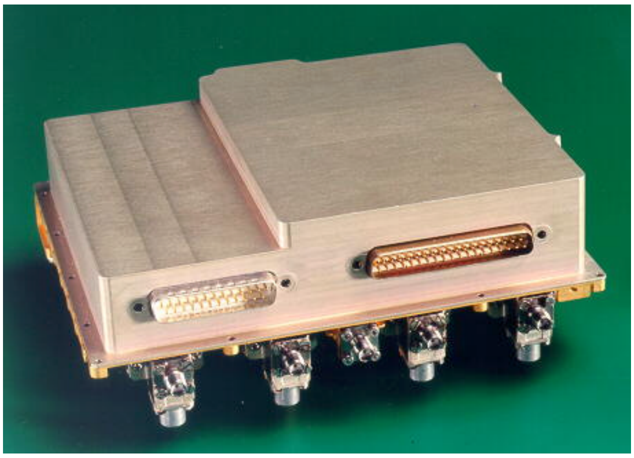

Fig. 2. Photograph of Quadri-SSPA (RF outputs and calibration port)

*A. RF chain description*

To reach the 62 dB specified gain over the –15°C/+50°C temperature range, 12 amplification stages were required partly due to passive elements losses. Three different MMIC amplifiers were used to form the amplifying chain : a front-end 3-stage low level amplifier (Triquint HAV process / Alcatel design) used twice, a 3-stage medium power amplifier (Triquint 0.5µm HFET process / Alcatel design) and a 3-stage high power amplifier (Triquint 0.25µm p-HEMT process / Triquint design) able to deliver typically 36 dBm output power with 36% P.A.E. in single carrier mode. In bi-carrier mode, it delivers 34.9 dBm with 32% P.A.E. and 22 dB C/I3 [2].

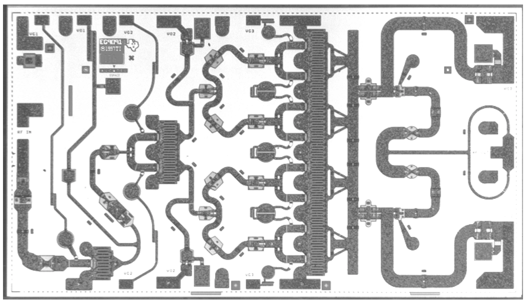

Fig. 3. Photograph of 4 W MMIC HPA (0.25 µm p-HEMT)

For gain and insertion phase compensation over the temperature range, analog MMIC attenuator (dynamic range higher than 20 dB) and phase-shifter (more than 100° dynamic range) have been inserted into the RF chain at appropriate locations to avoid any pre-distortion (Triquint HAV process / Alcatel design). A digital attenuator (5 bits/0.5 dB step) made on alumina substrate operates as gain leveler to reduce dispersion over the 48 SSPA.

*B. Calibration combiner*

A calibration system able to compensate active and passive antenna element drifts over lifetime has been implemented on the active antenna. The calibration signal is injected at one of the input of the antenna and sampled by a weak coupling at the SSPA RF outputs. The 48 calibration outputs are added through several cascaded 4 to 1 combiners. To reduce size, mass and complexity of combiners network, the first combiner step (4/1) is performed inside the Quadri-SSPA. To separate power signals from combined calibration ones at SSPA outputs, a RF multilayer circuit made on TPFE substrate and composed of 5 conductive levels ( 2 superimposed stripline circuits) has been designed. This state-of-the- art technology operating at Ku-band integrates resistive layers and multiple non-sequential vias to perform RF complex routings. To implement the passive dividers/combiners of the Beam Forming Network of the same active antenna up to 13 conductive layers circuit has been successfully realized and space qualified in the frame of STENTOR program

*C. Power detection*

To monitor and control the SSPA outputs level within the lifetime, analog power detectors based on Schottky diodes are located at RF outputs. The power signal is sampled by the same couplers used for calibration. A part of the coupled signal is routed towards the detectors. The detected voltage is filtered and its DC component digitized by an ADC located on the telemetry board.

*D. TM/TC boards and Power supply*

A telemetry/telecommand board is implemented into the equipment to interface with the active antenna controller for telemetry purpose and to manage the internal DC power supply switches of the Quadri-SSPA. It interfaces also with the satellite payload for secondary voltages and temperature telemetry and primary ON/OFF equipment switch telecommand. Three regulated voltages (+ 8 V, +5 V, -5V) are delivered by an internal DC/DC converter located on top of Quadri-SSPA RF chains.

## III. Quadri-SSPA Performances

A 13 units lot of Quadri-SSPA (12 flight models and one spare) have been manufactured and fully characterized in linear conditions, in single carrier mode and in bi-carrier mode. The main performances are presented hereafter.

## *A. Linear performances*

The small signal gain of 52 RF chains (13 Quadri-SSPA) at 25°C and over 12.5 -12.75 GHz is presented on Fig. 4. The mean gain is higher than 63 dB with about 0.5 dBrms associated standard deviation . The mean flatness over frequency bandwidth is 0.5 dB and standard deviation 0.26 dBrms.

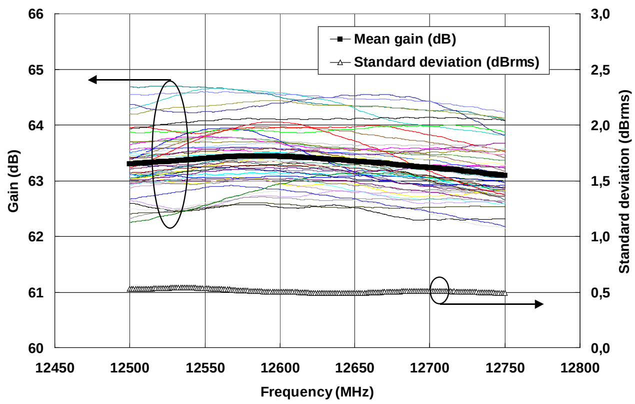


Fig. 4. Linear gain dispersion over 52 RF chains

## *B. Single carrier mode performances*

Power characterizations in terms of AM/AM, AM/PM and DC consumption have been performed in single carrier mode on the 13 Quadri-SSPA. The corresponding performances are respectively presented on figures 5, 6 and 7.

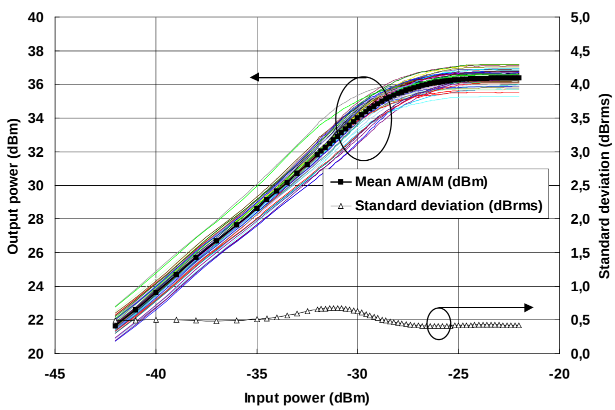


Fig. 5. AM/AM dispersion over 52 RF chains at 25°C and at 12.665 GHz

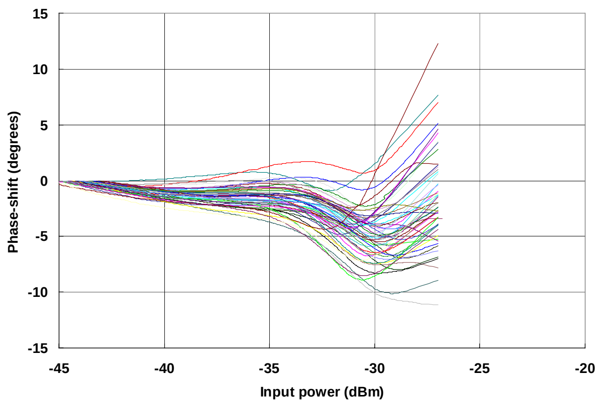


Fig. 6. AM/PM dispersion over 52 RF chains at 25°C and at 12.665 GHz

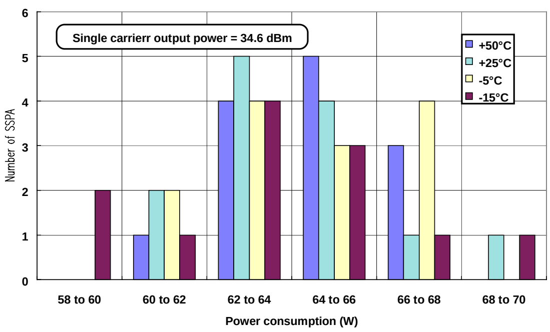


Fig. 7. DC consumption dispersion over 13 Quadri-SSPA and at 12.665 GHz for 34.6 dBm output power

## *C. Bi-carrier mode performances*

The 13 Quadri-SSPA have been measured in bi-carrier mode. The AM/AM curves, DC consumption and C/I3 are respectively presented on figures 8, 9 and 10.

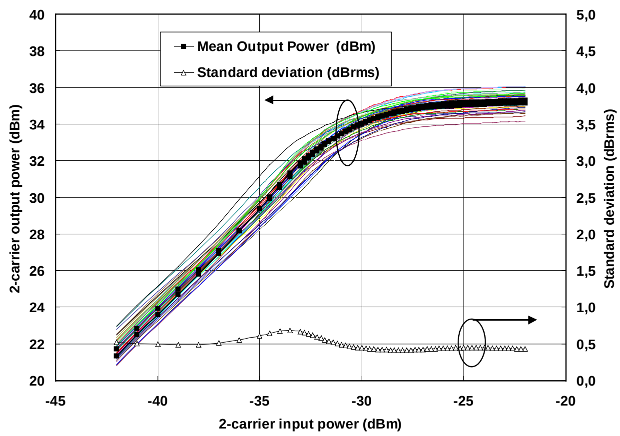


Fig. 8. AM/AM dispersion over 52 RF chains at 25°C and at 12.665 GHz in bi-carrier mode (2-carrier power)

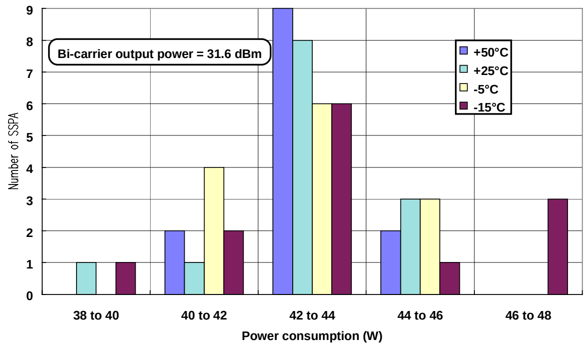


Fig. 9. DC consumption dispersion over 13 Quadri-SSPA at 12.665 GHz for 31.6 dBm 2-carrier output power

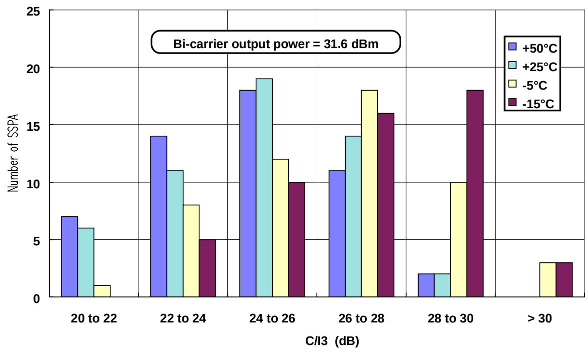


Fig. 10. C/I3 dispersion over 52 RF chains at 12.665 GHz for 31.6 dBm 2-carrier output power

We observe that for 31.6 dBm output power (2 carriers) mean DC consumption is 42.7 W (< 56.8 W specified) and mean C/I3 equals 25 dBc (< 22 dBc specified).

*D. Mechanical parameters*

The mass of the 13 equipments has been evaluated (see fig. 11) : mean mass is 1403 g with less than 7 g standard deviation.

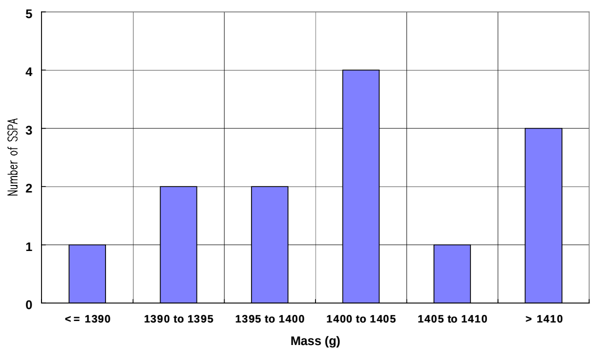


Fig. 11. Mass dispersion over 13 Quadri-SSPA

## V. Conclusion

The architecture and performances of a Ku-band Quadri-SSPA for active antenna application have been presented. Several advanced technologies as p-HEMT process for output stages and multilayer circuit for calibration combiner have been space qualified for integration in the flight units. A good trade-off between antagonist parameters as high output power, low DC consumption and high linearity has been reached thanks to p-HEMT technology. The characteristic dispersions of the critical parameters (gain, output power, DC consumption and linearity) are very low and compatible with the reproducibility level required by active antenna specification. The active antenna has been integrated and tested in near field environment and exhibits very satisfactory results. The final test on STENTOR satellite payloads are in progress in ALCATEL SPACE facilities. The launch is planned for mid 2001.

## Acknowledgement

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## References

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