KA-BAND TRANSMITTER MODULE FOR LOW EARTH ORBIT SATELLITES

VIPER RF: J. Mayock, T. Le Toux, S. Chan, F. Eshghabadi, P. Deshpande
Surrey Satellite Technology Ltd: K. Mason, D. Sanderson, K. Maynard
ESA: I. Davies

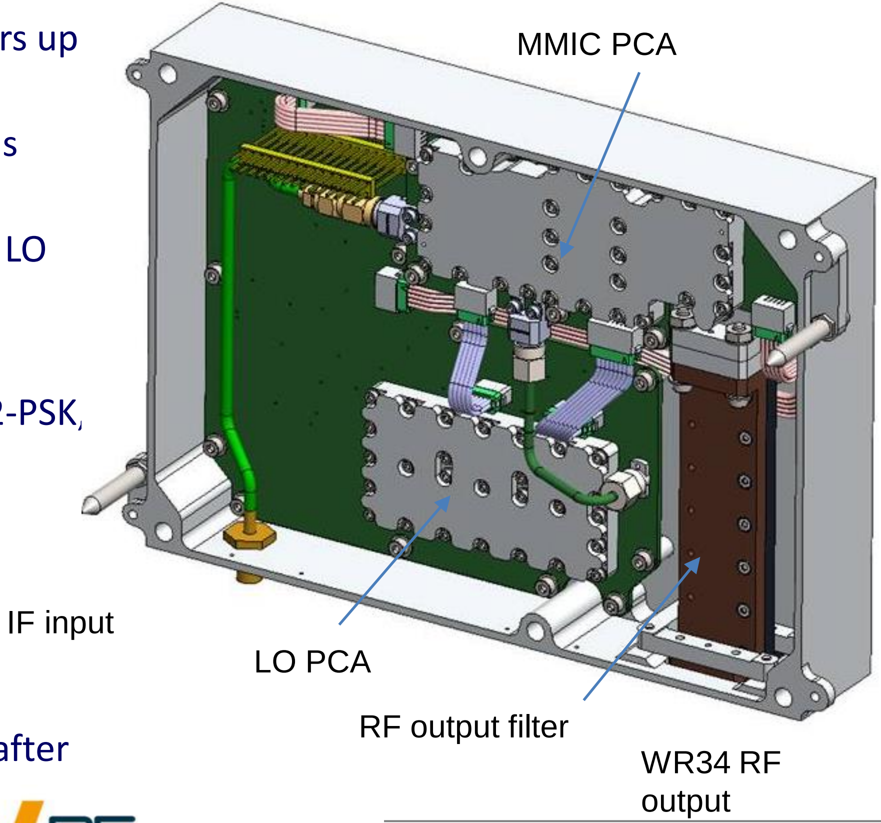
advanced radio frequency solutions

Introduction

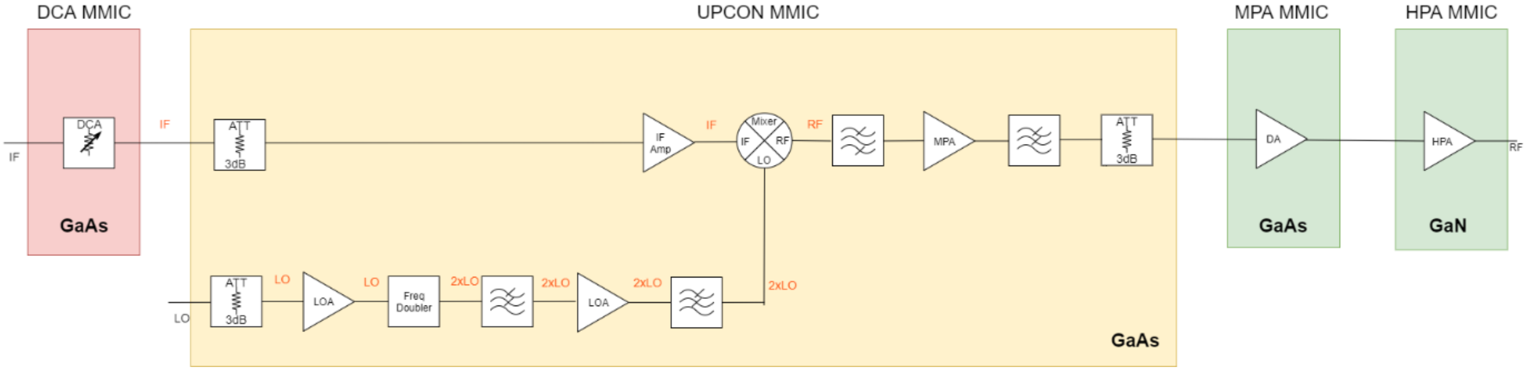
- This presentation covers work carried out under the ESA Contract 'Compact K-Band Up-converter / Solid State Power Amplifier for LEO Missions' (4000123872/18/NL/HK)
- The aim of the project is to develop an elegant breadboard of a Ka-Band transmitter for high data rate downlinks based on a set of customised GaAs and GaN MMICs
- This work is a collaborative project between VIPER RF Ltd and Surrey Satellite Technology Ltd
  - SSTL is responsible for the design of the Ka-Band modules and VIPER RF is developing the set of customised MMICs
- In this paper, the main focus is on the MMIC development/RF components and first test of the full module
- The module consist of LO PCA, Power supply board, MMIC PCA, output waveguide filter/transition
- The chipset comprises of four parts:
  - Digital controlled attenuator (DCA) – PPH15X GaAs technology
  - Up-converter (UP-CON) – PPH15X GaAs technology
  - Medium power amplifier (MPA) – GH15 GaN technology
  - High power amplifier (HPA) – GH15 GaN technology

Ka-Band Module Overview

- Evolve SSTL’s X-Band solution (500MBps) to by using Ka-Band frequencies (>1GBps)
- Capable of transmitting a range of modulated output powers up to 37.2dBm (39.1dBm at HPA output)
- The module has in IF input range between 7.8-8.6GHz and is upconverted to 25.5-27GHz
- The RF band is split into two bands (675MHz) by selectable LO frequency of 17.0375GHz and 17.4125GHz
- LO generated through an internal phase locked loop
- Several modulation schemes from QPSK and 8-PSK up to 32-PSK, output symbol rate up to 500MBd
- In-band spurs <45dBc
- PAE>14%
- The system interfaces with SSTL bias control
- Dimensions of 135x206x35mm (<1Kg)
- SMA connector on IF input and a WR34 waveguide output after internal waveguide filtering



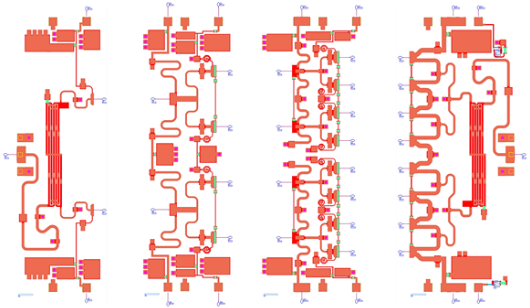
MMIC Line-Up

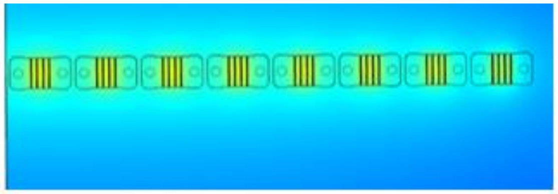


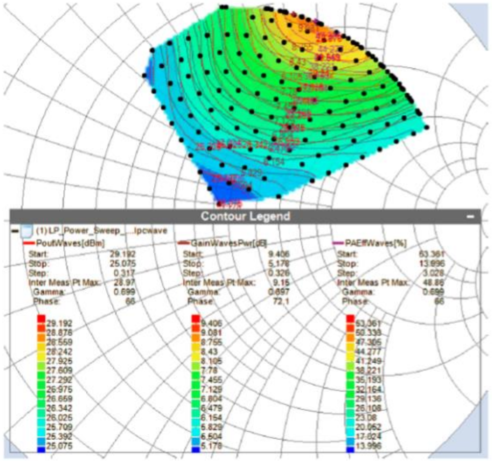
- The MMIC line-up comprises of a four packaged part solution (Kyocera open-tool package SGMR-A2416-B)
- Higher levels of integration were avoided due to potential excessive levels of gain on a single-chip
- Line-up analysis was carried out to ensure the system would work over a range of conditions (temperature, process spread, antenna VSWR)
- The DCA provides the required gain control to provide constant output power over temperature etc
- The up-converter is designed to provide spurious-free up-conversion of the IF signal to the RF band
- The MPA and HPA provide efficient power amplification up to the required level of TX output power

MMIC Design and Analysis

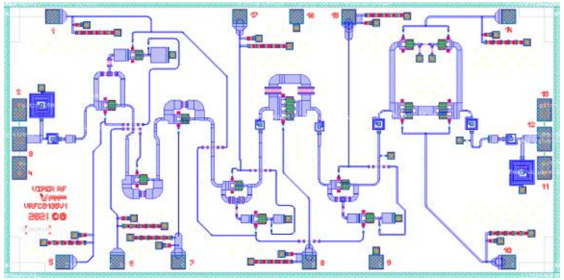
- Load-pull and small-signal measurements were was carried out on samples of active devices from PPH15X and GH15 to validate models prior to manufacture
- 3D EM modelling of the package
- Thermal analysis of active devices to understand peak channel temperature/MTTF was carried out using COMSOL Multiphysics
- A full range of small-signal, large-signal, EM analysis, process, package simulations were carried out prior to manufacture



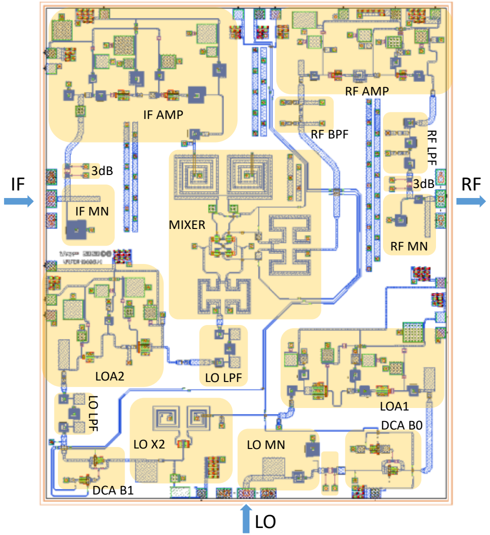




Attenuator and Up-Con Design & Simulation (PPH15X)

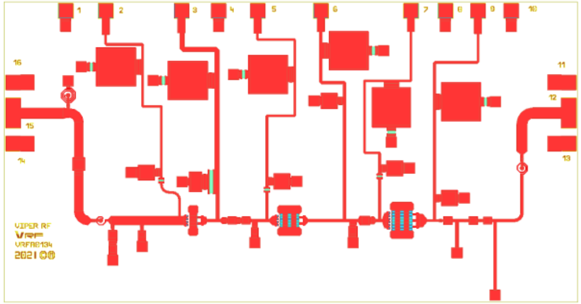


- The attenuator is a 6-bit design based on switch FETs
- Minimum insertion loss – 8dB
- Control 0/-3V
- 31.5dB range
- Higher size steps based on PI/T attenuators embedded in SPDT switches

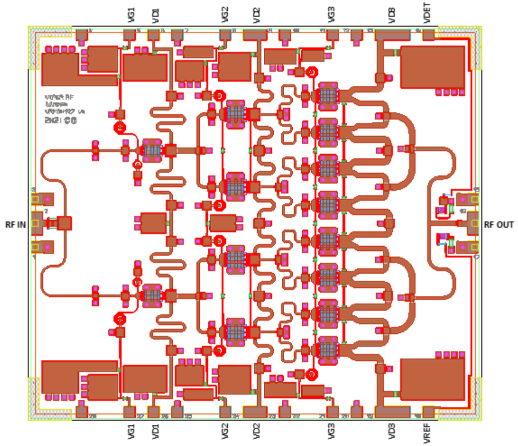


- The LO uses a high-LO configuration due to inherent improved spurious response
- The LO circuit comprises of diode-based doubler, Ku and Ka-Band two-stage LO amplifiers and filtering networks
- The IF stage consists of an input attenuator and two-stage amplifier
- The RF section consists of a two-stage amplifier, filtering and output attenuator
- The Mixer is based on a double-balanced ring mixer approach
- >25dB conversion gain with in-band spurs >45dBc

MPA and HPA Design and Simulation (GH15)

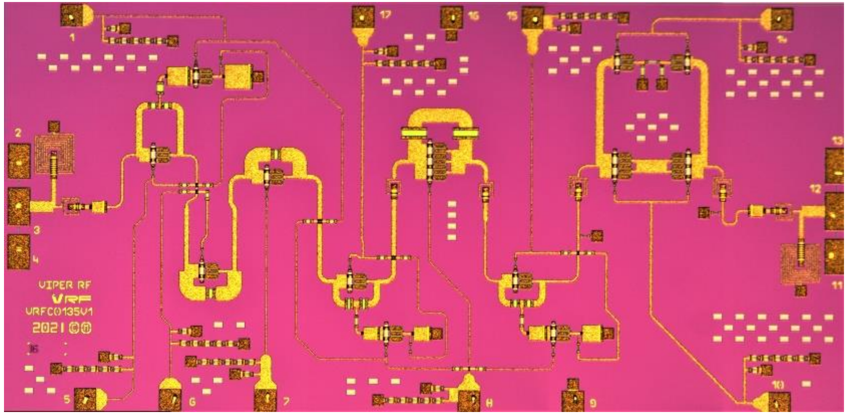


- The MPA is a three-stage single-ended design
- Designed to provide the required drive power from the UP-CON to the HPA
- The output stage is based on a 6x135um cell, the driver is based on a 4x125um and the input stage uses a 4x50um cell
- >25dB gain with P1dB>26dBm



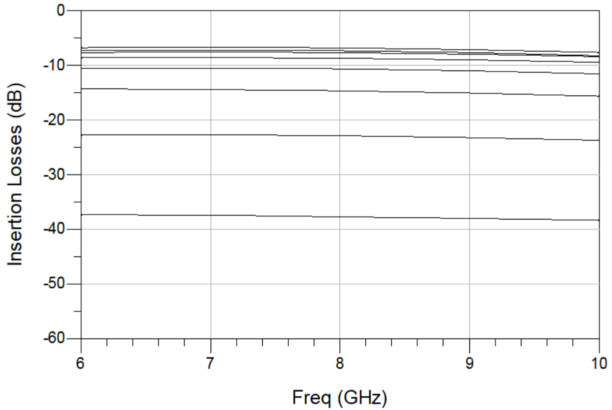
- The HPA is a three-stage design with integrated output power detector
- The output stage consists of a periphery of 8x6x125um, the driver is based on 4x6x125um and input stage based on 2x4x125um
- >40.8dBm Psat, >25dB small-signal gain

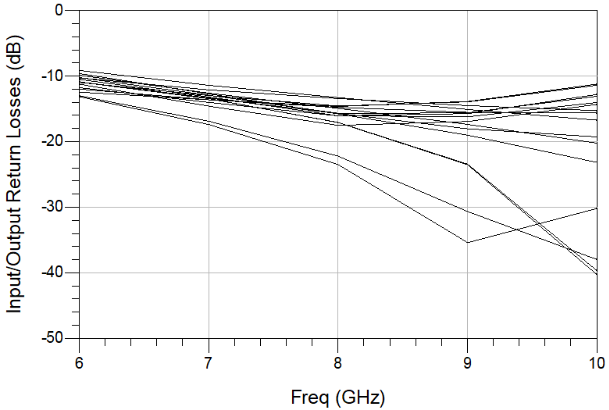
Attenuator MMIC Measured Results

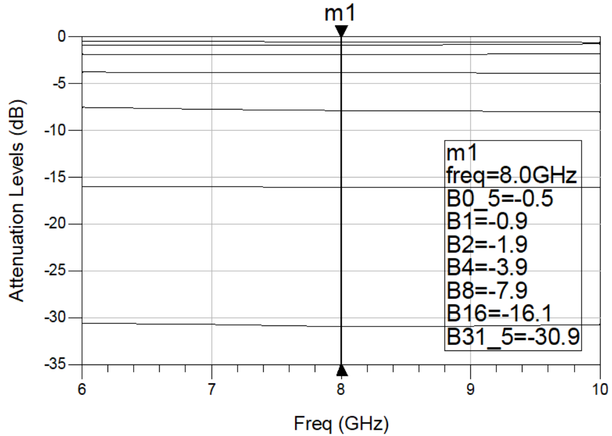


	Freq = 7.8 GHz		Freq = 8.2 GHz		Freq = 8.6 GHz	
	Sim.	Meas.	Sim.	Meas.	Sim.	Meas.
Attn = 0.5 dB	0.54	0.53	0.52	0.53	0.51	0.55
Attn = 1 dB	0.96	0.89	1.01	0.89	1.05	0.88
Attn = 2 dB	2.06	1.90	2.07	1.89	2.06	1.89
Attn = 4 dB	4.04	3.84	4.06	3.86	4.07	3.87
Attn = 8 dB	8.02	7.85	8.04	7.89	8.06	7.92
Attn = 16 dB	15.94	16.07	15.98	16.09	15.99	16.11
Attn = 31.5 dB	31.41	30.91	31.46	30.91	31.49	30.94

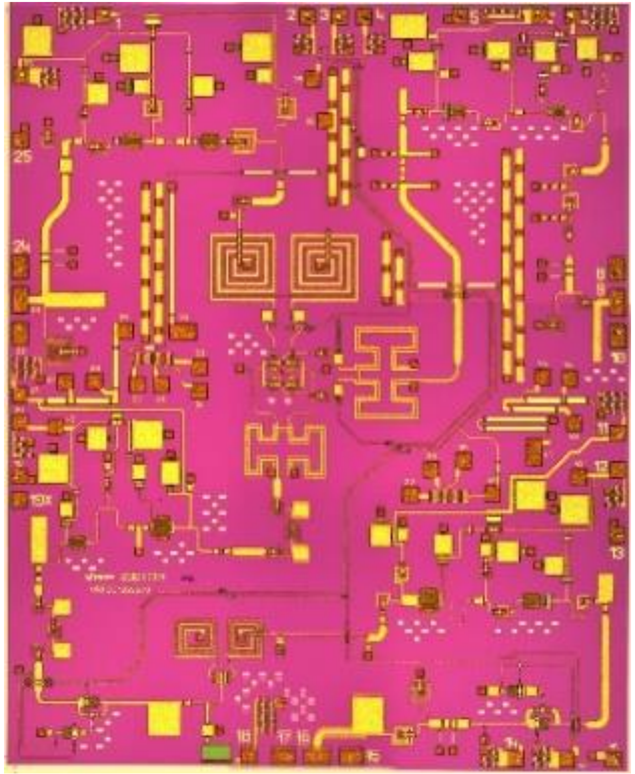
All attenuation values are in dB

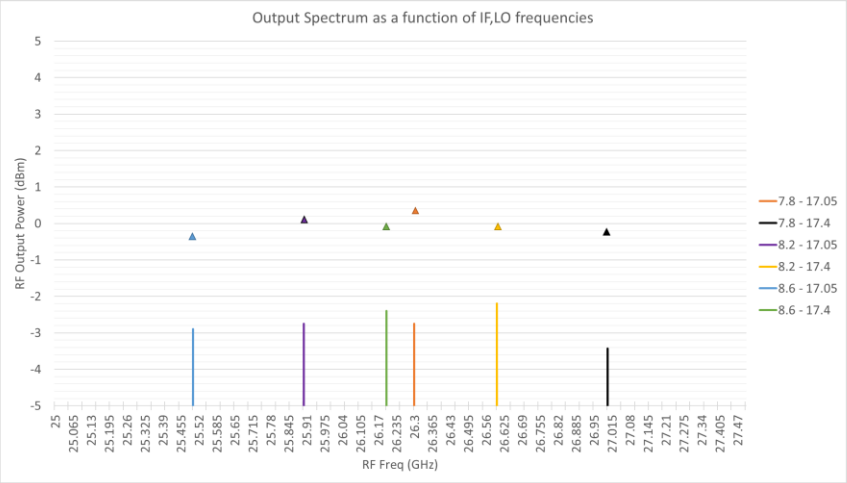






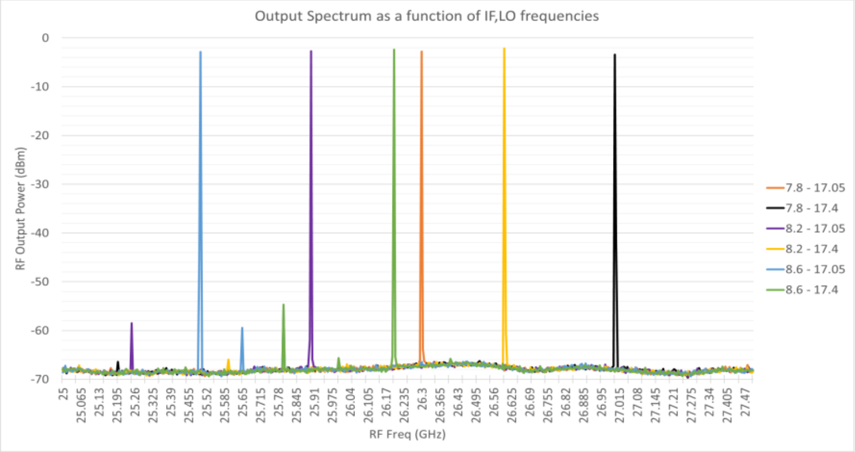
Up-Converter MMIC Measured Results





Simulation

Measurement



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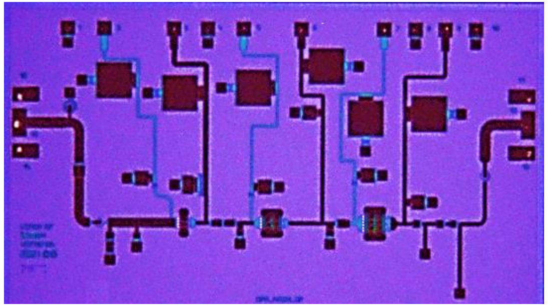
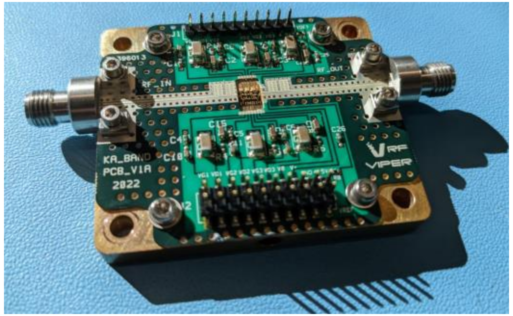
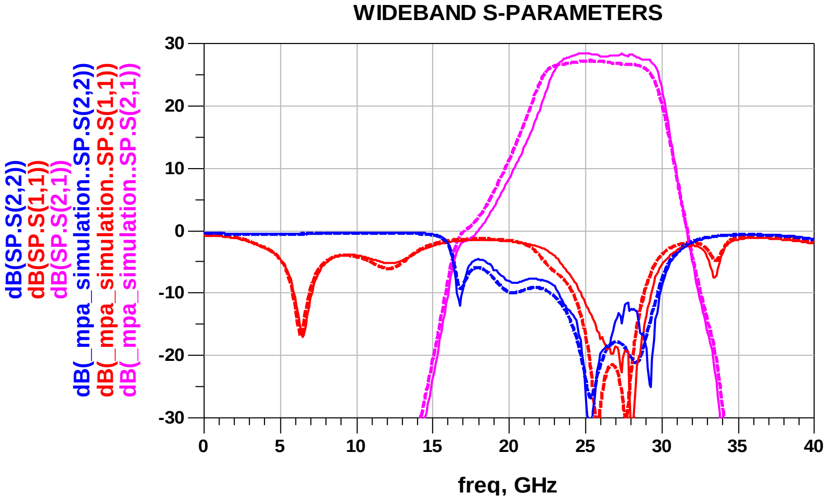
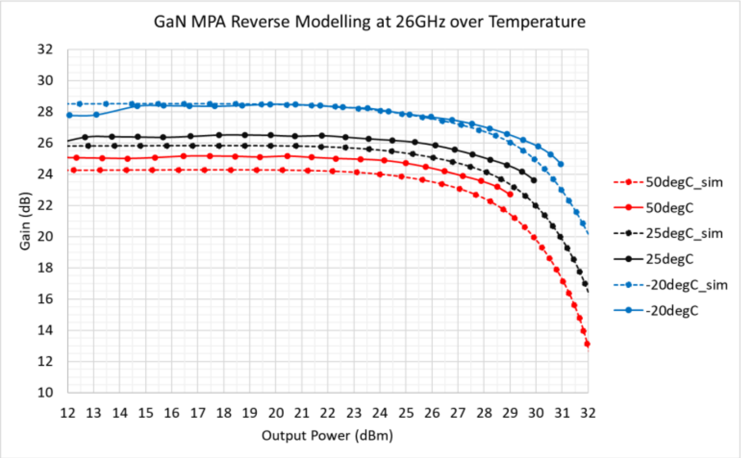
GaN MPA MMIC Measured Results





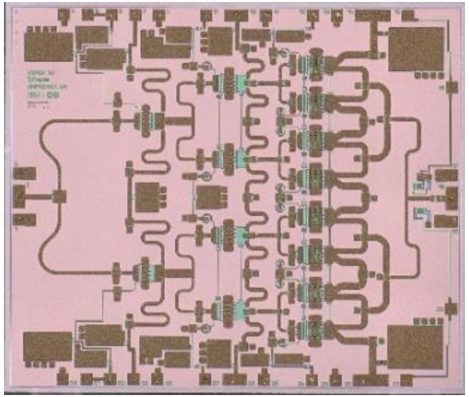


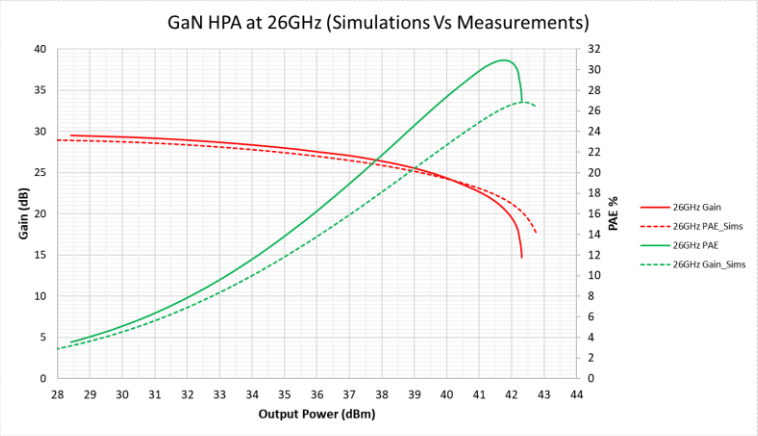


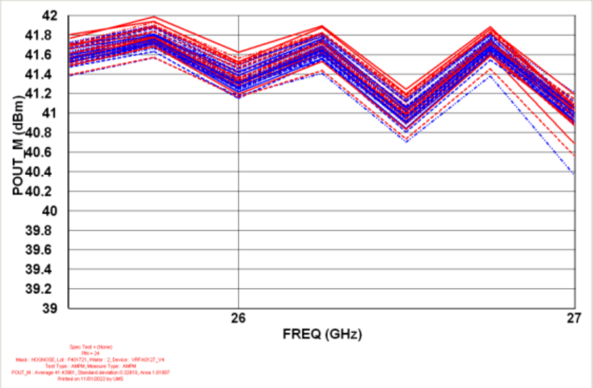
Simulation (dash)

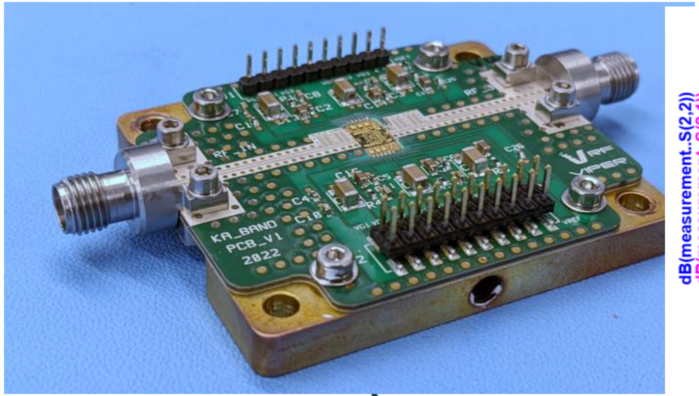
Measurement (solid)

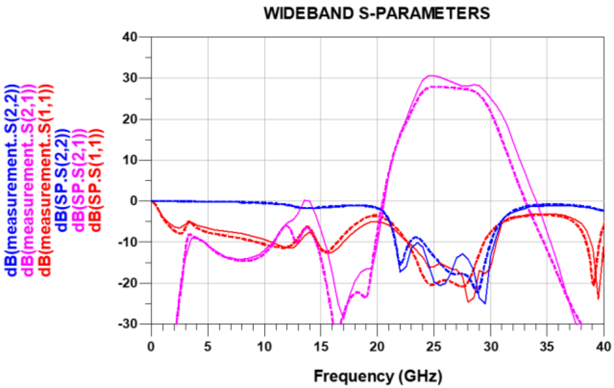
HPA MMIC Measured Results



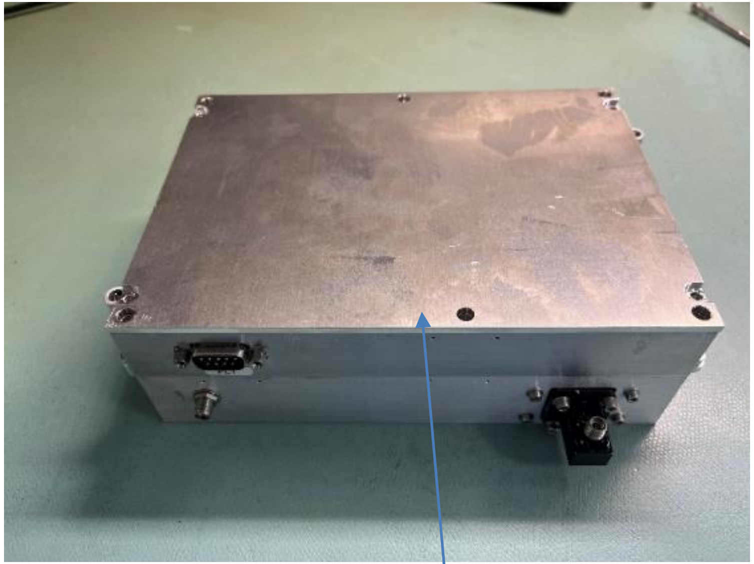




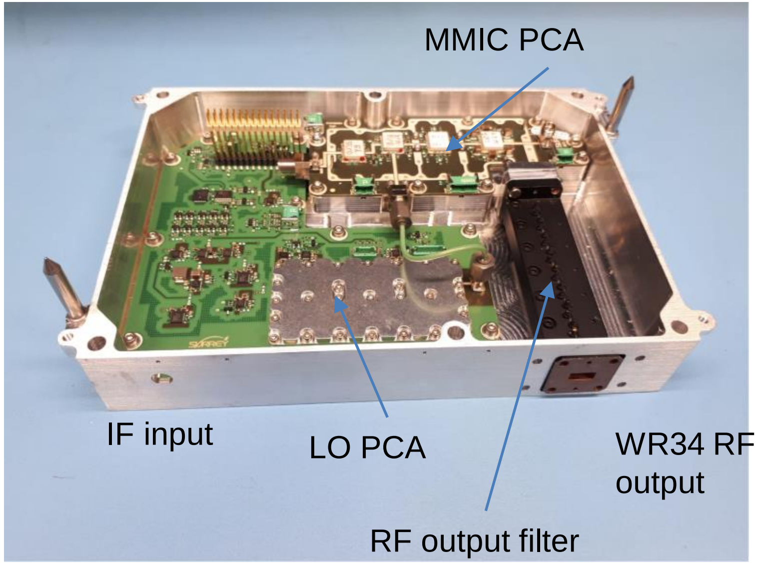




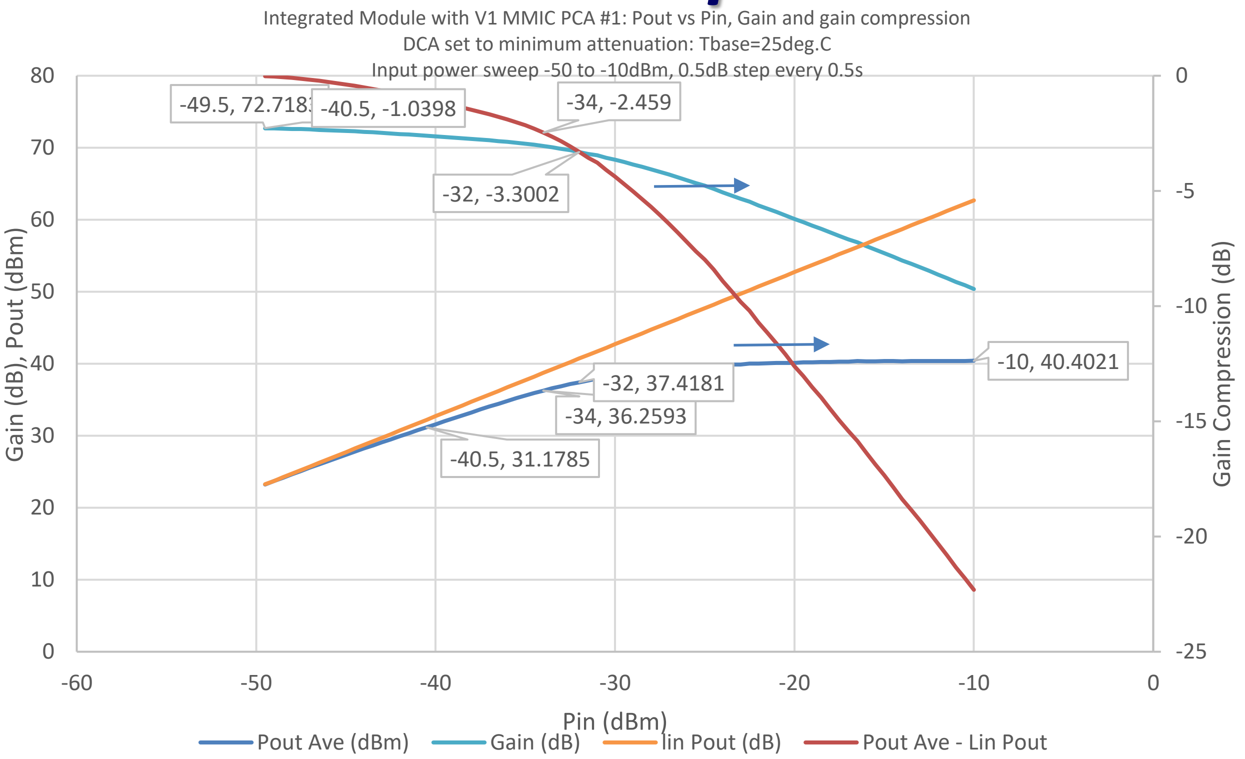
Ka-Band Up-Converter Prototype Module



Power supply board



Full-Module Module Compression Characteristic



- Maximum module power for 37.5dBm is 55.4W, less than 57.7W predicted. At 36.2dBm the max is 47.9W which exceeds the max of 45.5W
- Output power is 40.4dBm which is close to predicted based on filter losses

BER Measurements

- SSTL have carried out a set of BER measurements over a range of modulation schemes from QPSK up to 32-APSK up to 400MBd
- Good performance is achieved up to 16-APSK and lower ACMs
- Marginal performance with 400MBd 32-PSK to meet the link budget requirements
  - 32-APSK @ 500MBd is key to a viable throughput/link margin trade-off
  - Some trade-off analysis between throughput (coding rate used), link margin and back-off is required to see if an optimum solution exists
  - Potential linearizer/HPA bias solution is ongoing

Summary

- A Ka-Band transmitter module has been developed based on a set of customized MMICs
- The Ka-Band chipset offers good RF performance including gain control, up-conversion with required spur performance and the required output power levels
- Other components in the module have been designed including an LO PCA and RF output filter
- An existing power supply board is employed in the modules
- The module is compliant with output power requirements and the required efficiency levels at the highest output power levels
- Compliant spur performance with adequate gain control
- First BER measurements have been carried out and the performance is presently being optimised for up to 32-PSK@500MBd