



Inter-Planetary Small Satellite Conference - 1-2/05/2023

CubeSAT Deep Space X-Band TT&C Transponder (C-DST)

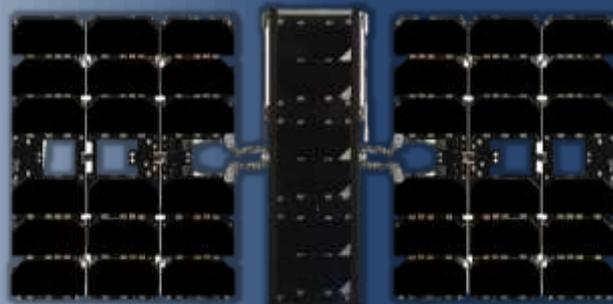
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G. Piscopiello, A. Gabriele, C. Attanasio, E. Bruschini (Sitael SpA)

Prof. P. Tortora, Prof. E. Paolini (University of Bologna - CIRI AERO)

Giovanni Cucinella - IMT srl

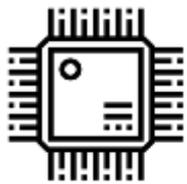


IMT at glance - Mission

IMT Srl is an Italian private company (SME), founded in 1991 and active on three main activities:



System Engineering: Design and Development of Nano/Microsatellites and relevant On-board units for space commercial, scientific and defence applications.



Parts Engineering: Characterization and Testing of Electrical, Electronic and Electro-Mechanical components.



IoT solutions: Development of IoT Solutions for Smart Cities, Environmental Monitoring and Agriculture.



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1-2 May 2023

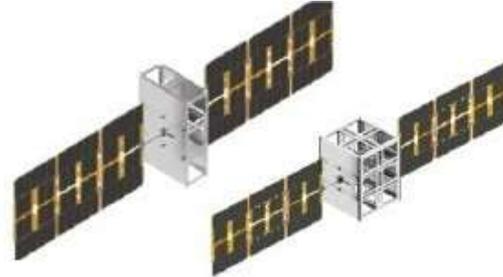
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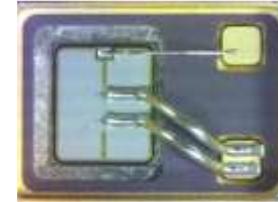
IMT at glance - Ongoing main Projects



C-DST
 μ Sada and C-DST will be embarked on LUMIO and M-ARGO ESA Missions



μ SADA



Qualification of rad-hard power MOS-FET N-Channel



BISS (BI-directional IoT Satellite Service)



Advisoring to ASI on EEE Space Parts



Italian Public Funding



EOSS
 (Earth Observation Small Satellite)



HORTA
 (Remote Sensing by GNSS-R Passive Reflectometry)



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C-DST Overview

ESA Project (GSTP Contract N.: 4000128163/19/NL/FE)

C-DST is the first European Cubesat Deep Space X-Band TT&C Transponder, designed by IMT srl, Thales Alenia Space Italia, SITAEL and University of Bologna.

This subsystem can be used to perform TT&C and Ranging functions.

C-DST is compliant to the ESTRACK Stations.

IMT Srl is the Prime Contractor of this project with the ESA (European Space Agency).

Thales Alenia Space Italia SpA, Sitael SpA and University of Bologna - (CIRI AERO) are Subco's/Partners



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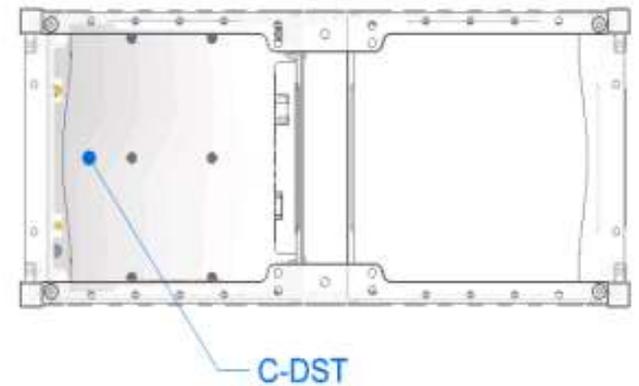
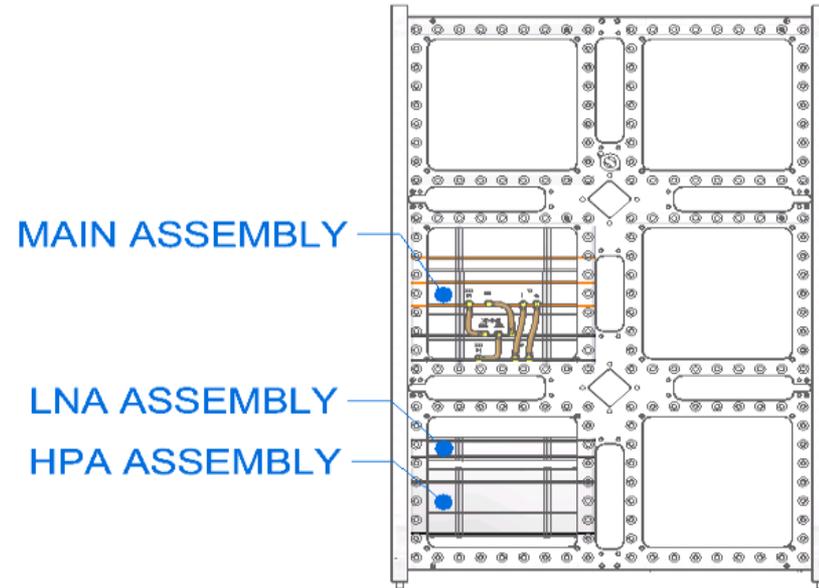
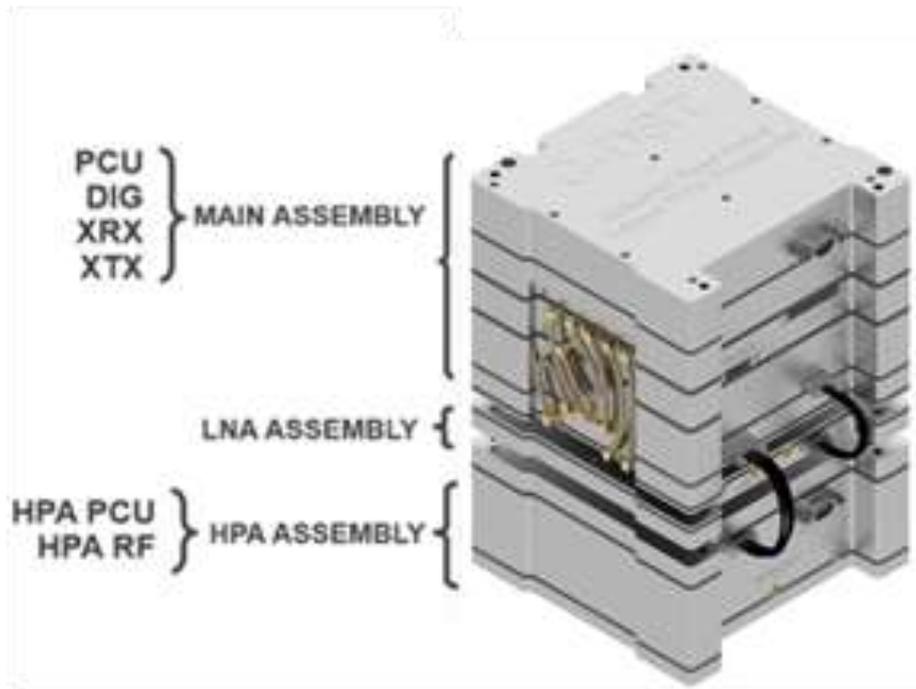
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C- DST Layout and I/F



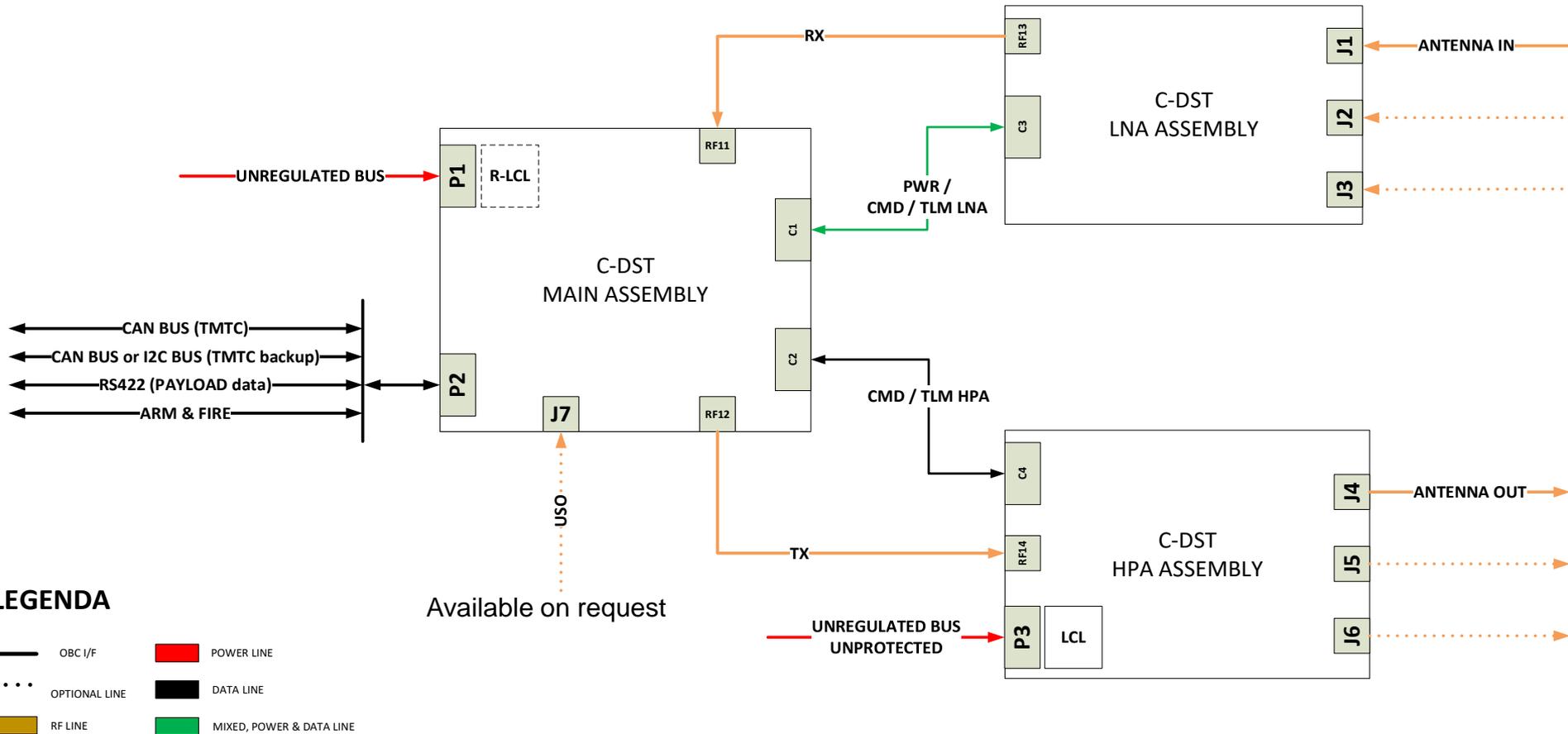
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C- DST Block Diagram



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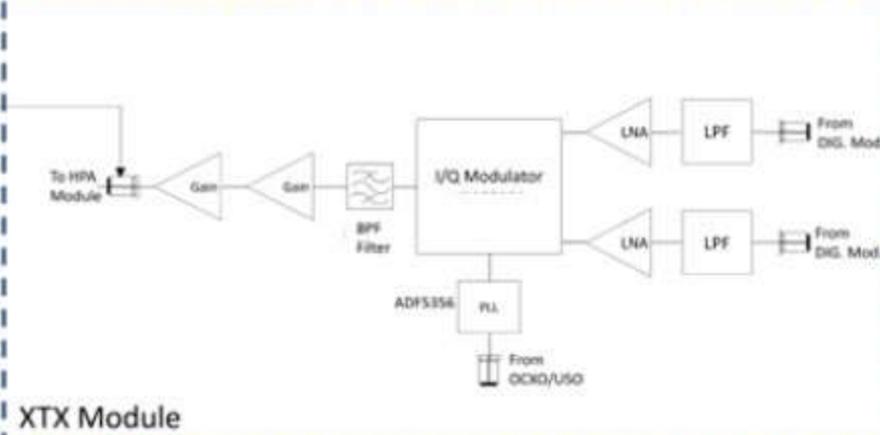
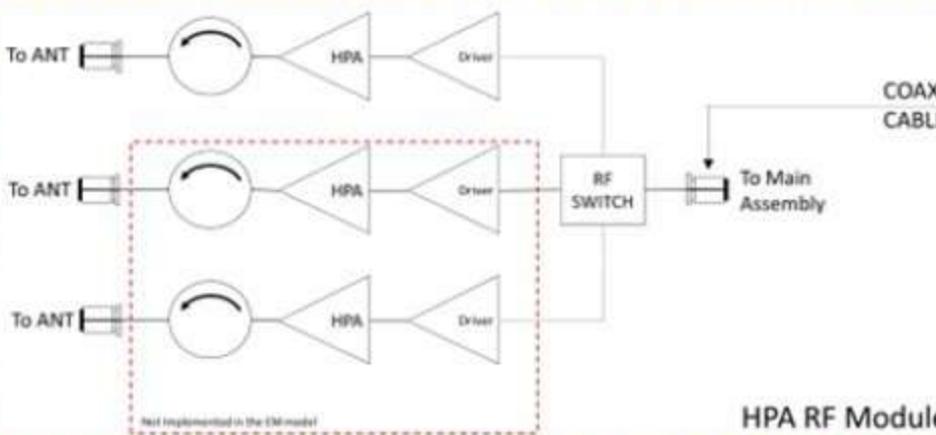
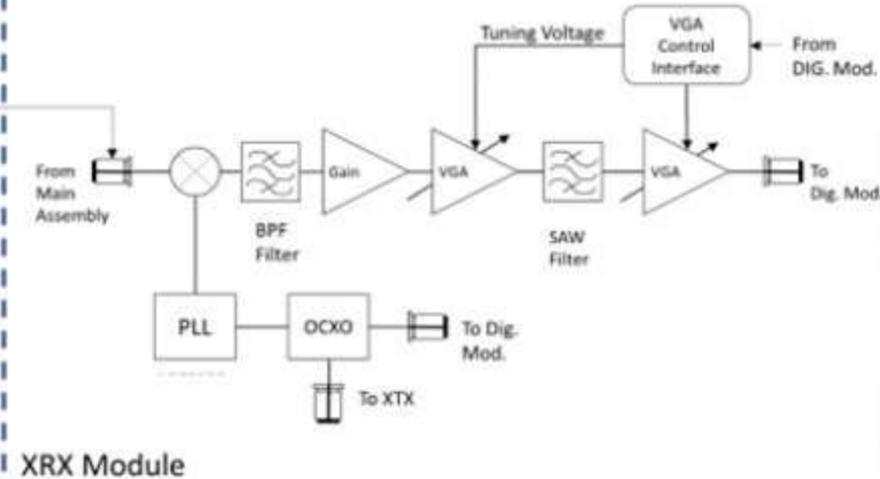
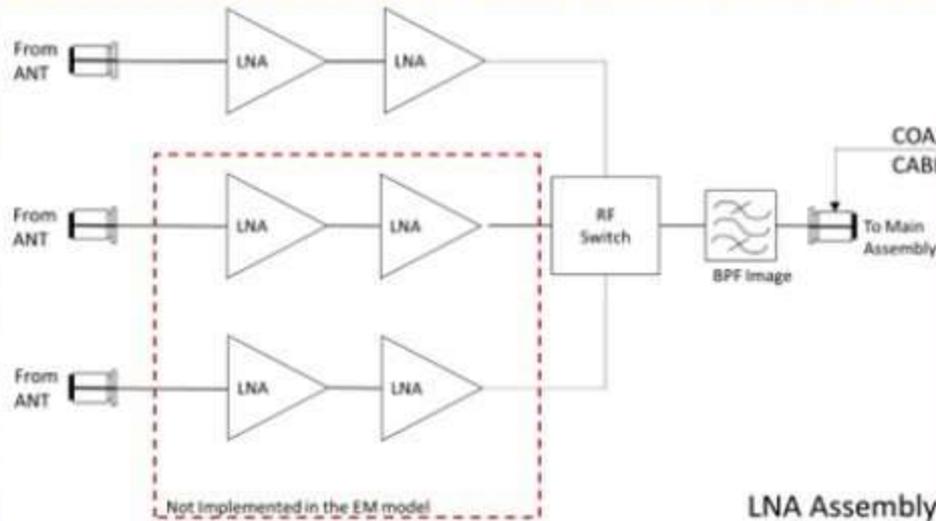
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C- DST RF - Sections



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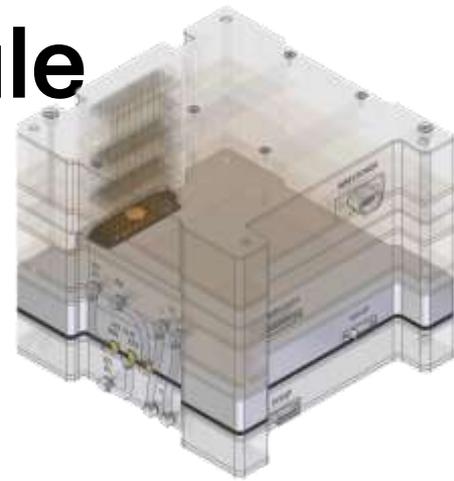
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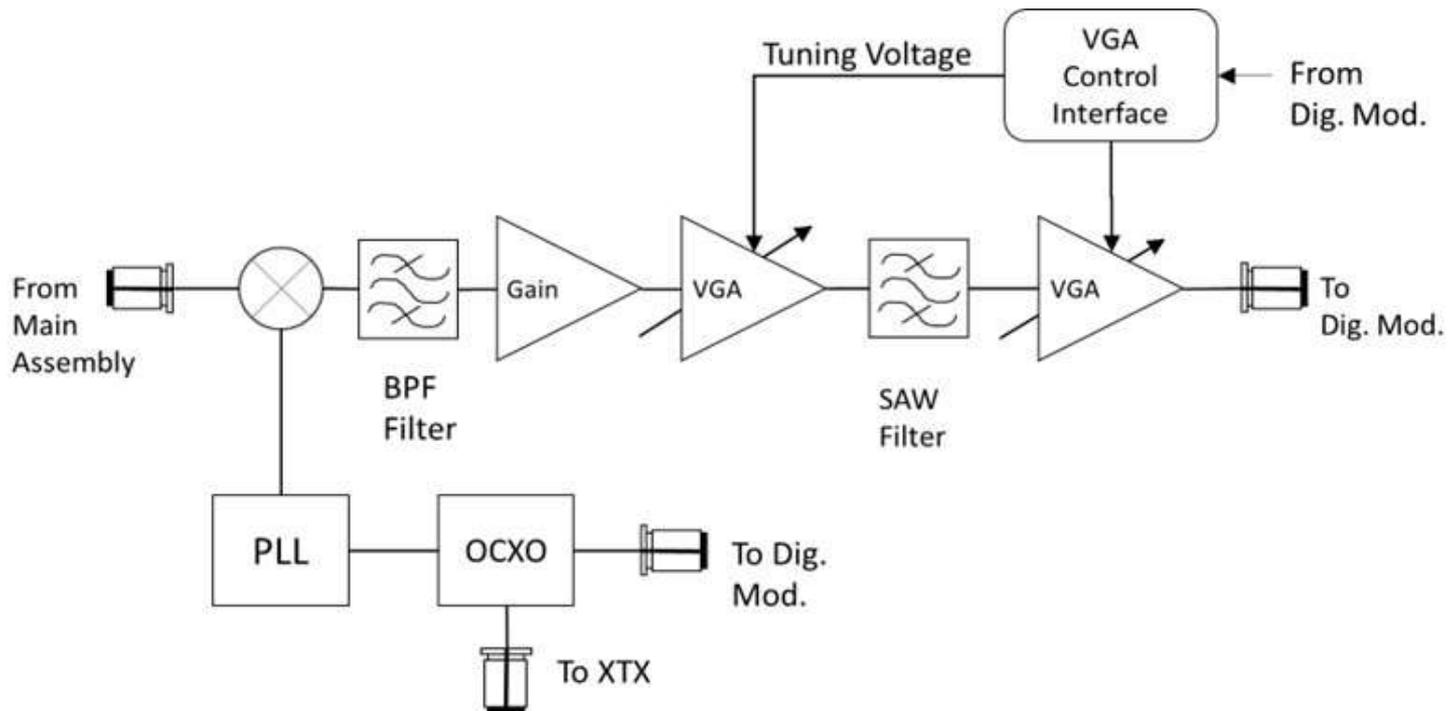
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C- DST RF - XRX Module



The architecture of XRX is based on a single Down-Conversion heterodyne architecture. The local Oscillator is a fully integrated PLL, phase locked to an OCXO stable oscillator, physically placed on the RX Board.



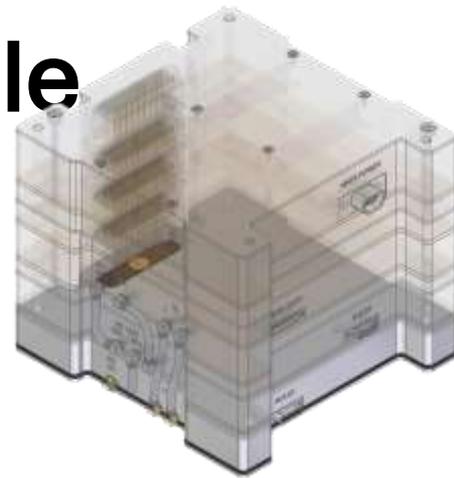
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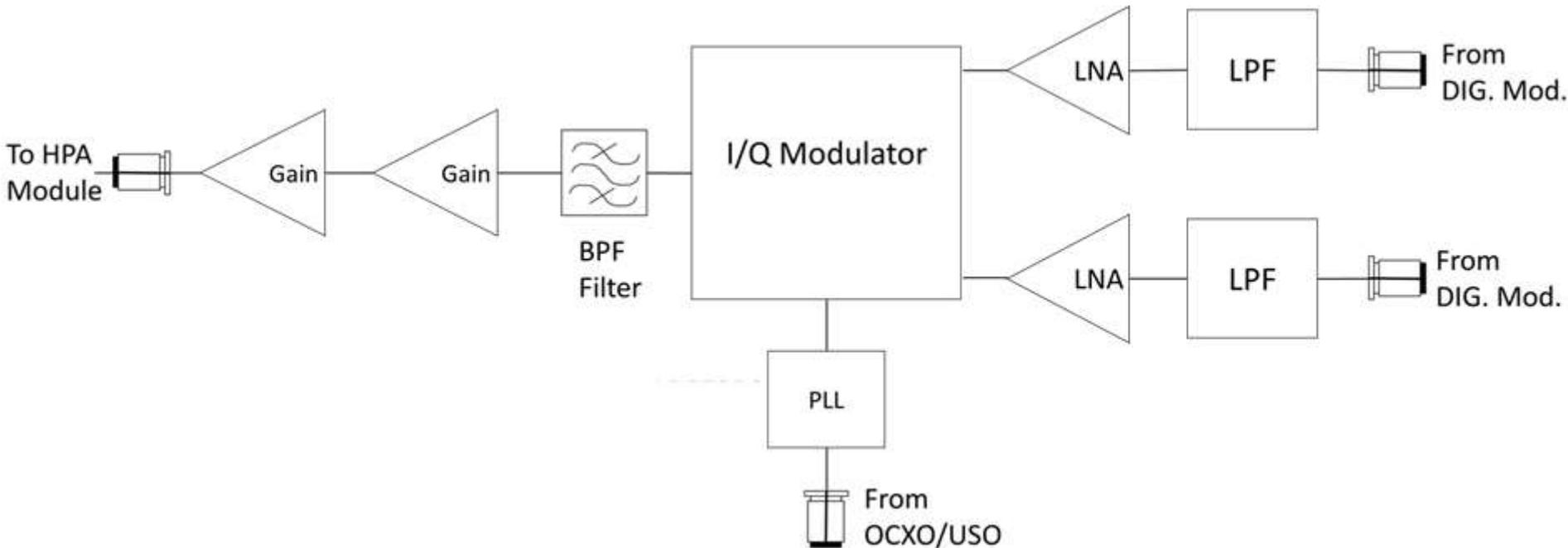
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C- DST RF - XTX Module



The Tx architecture is based on a X-band Vector modulator, driven by I/Q data signals provided by DACs in the Digital section.



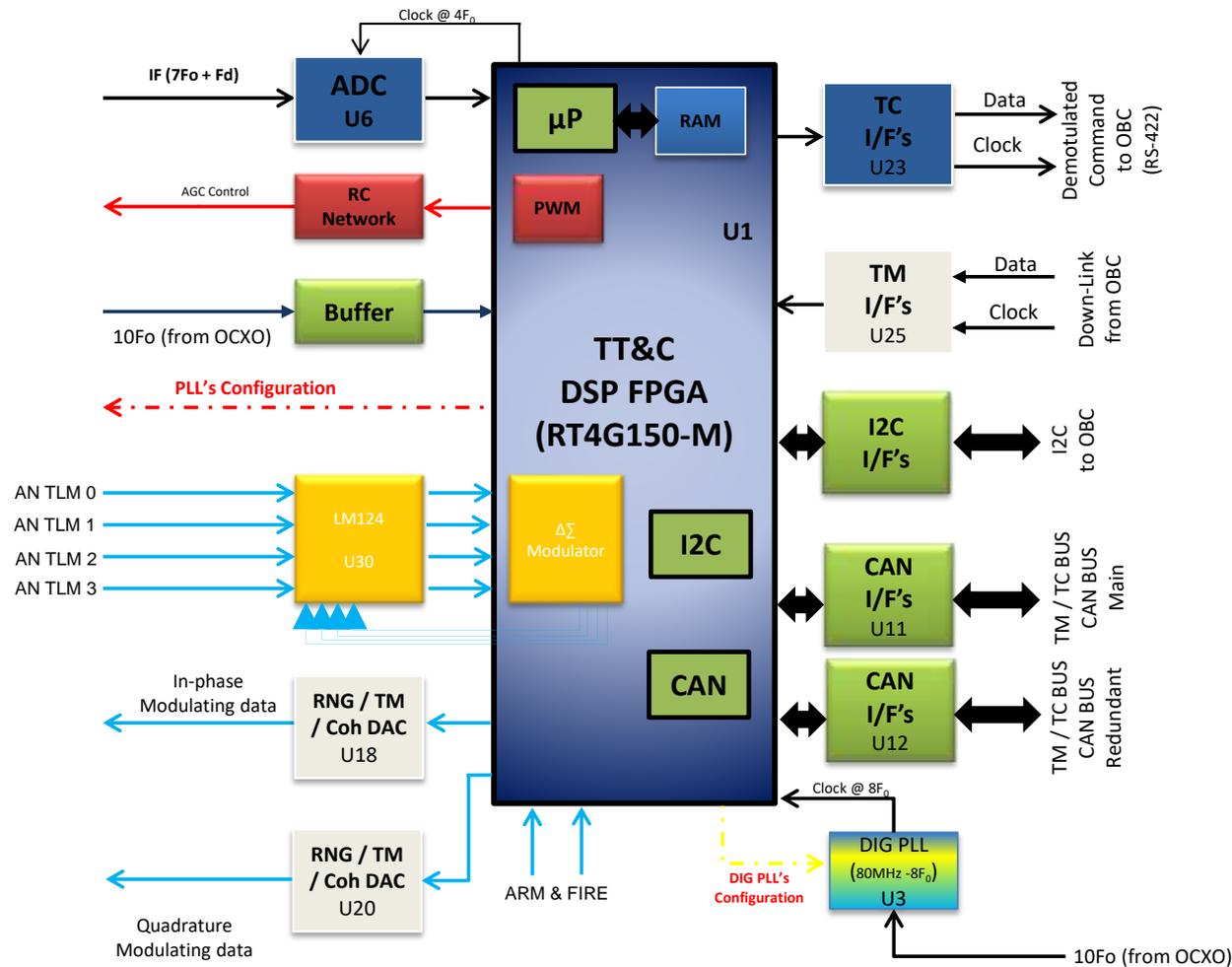
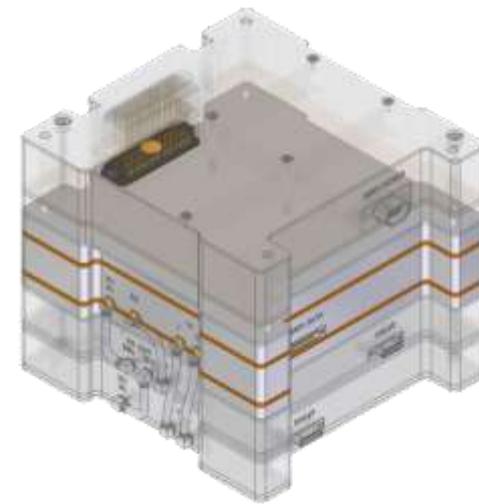
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C- DST - DIGITAL MODULE



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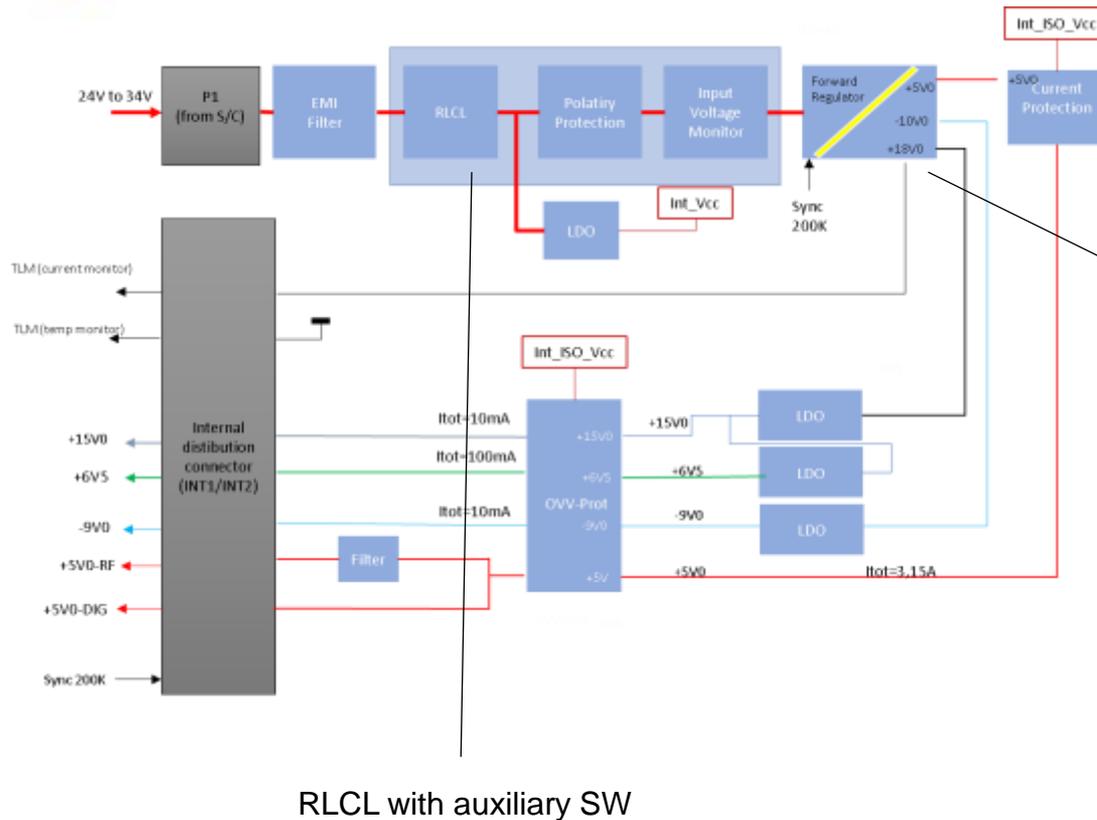
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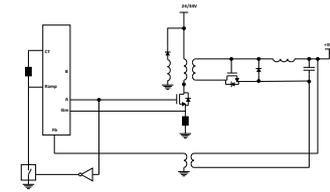
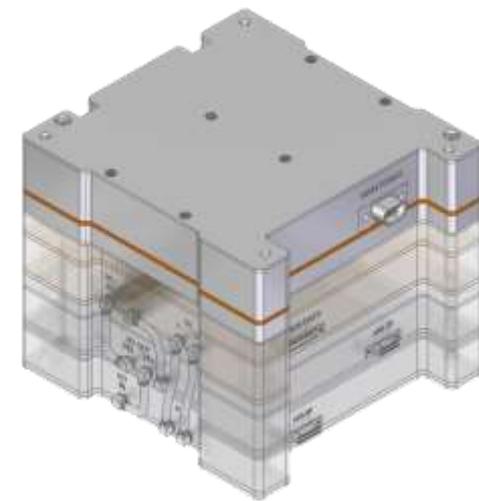
C- DST - PCU MODULE



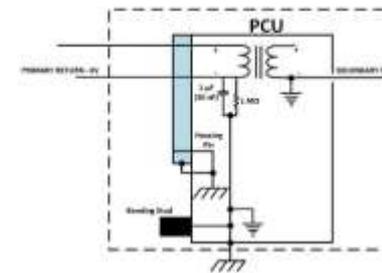
Power section overview



RLCL with auxiliary SW



- Forward isolated converter
- Magnetic feedback to improve reliability



Single point grounding scheme



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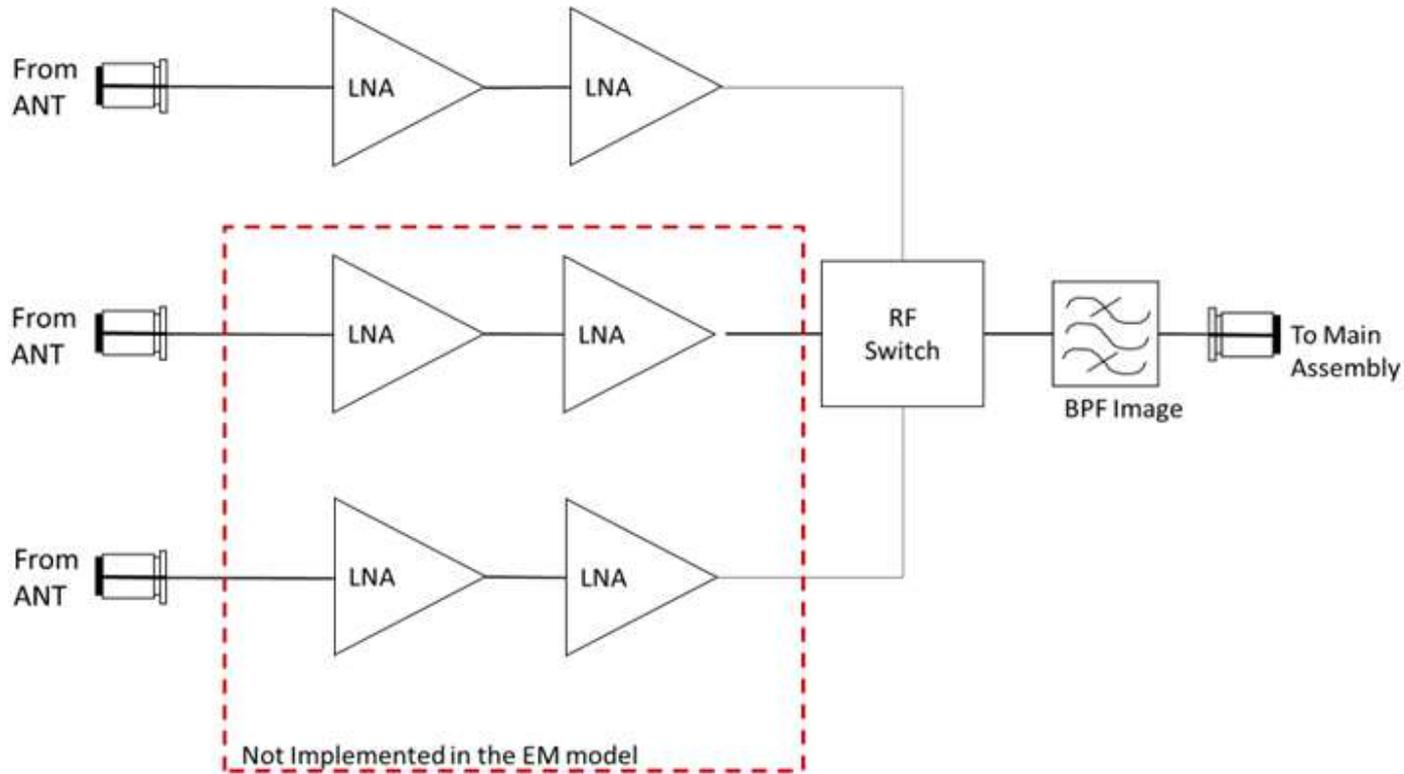
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C- DST RF - LNA ASSEMBLY



The preselecting filter is included in the BPF image filter in order to guarantee a noise figure less than 2dB (TTC-10).



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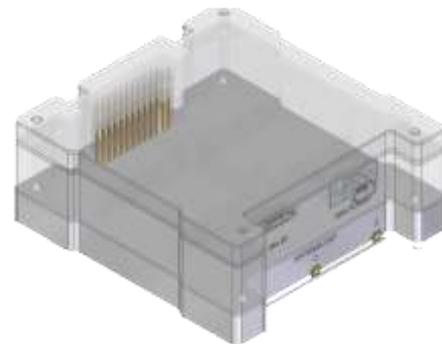
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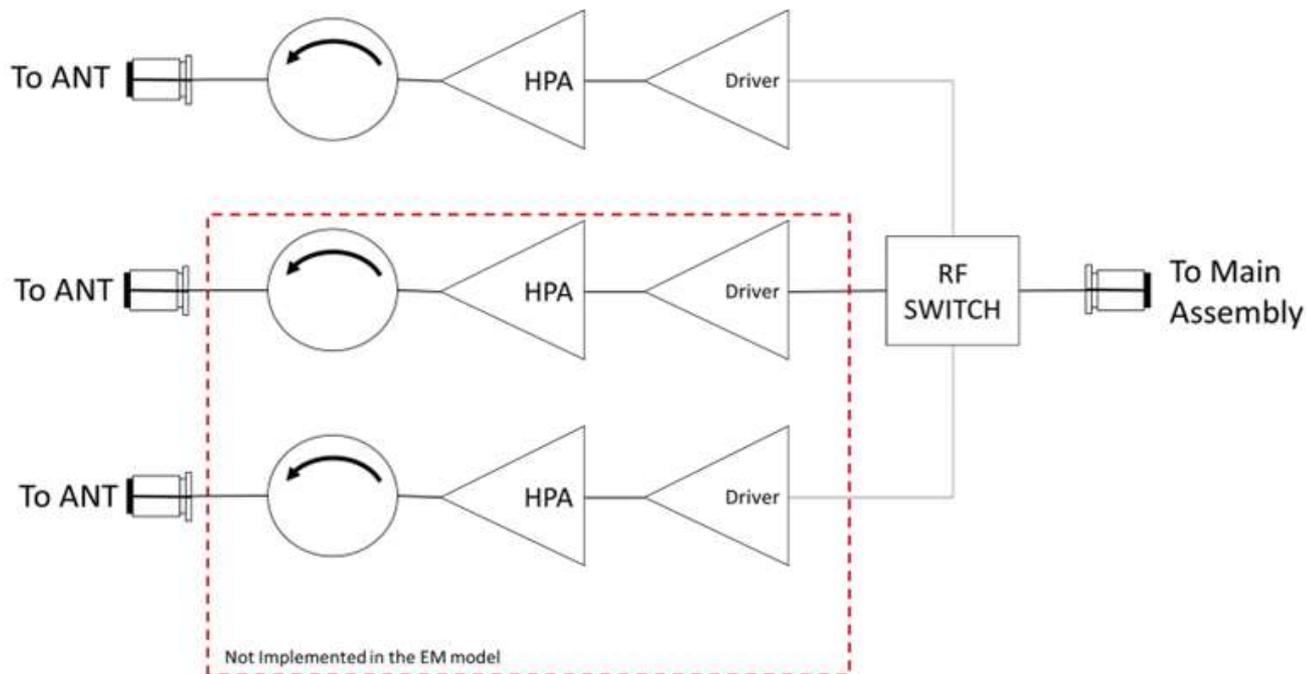
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C- DST - HPA RF MODULE



The several amplifier stages drive the HPA card with capability to provide up to 15 Watt of RF power (2W and 5W on demand)



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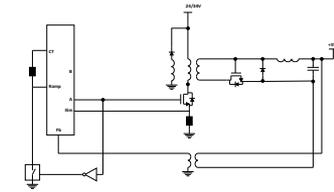
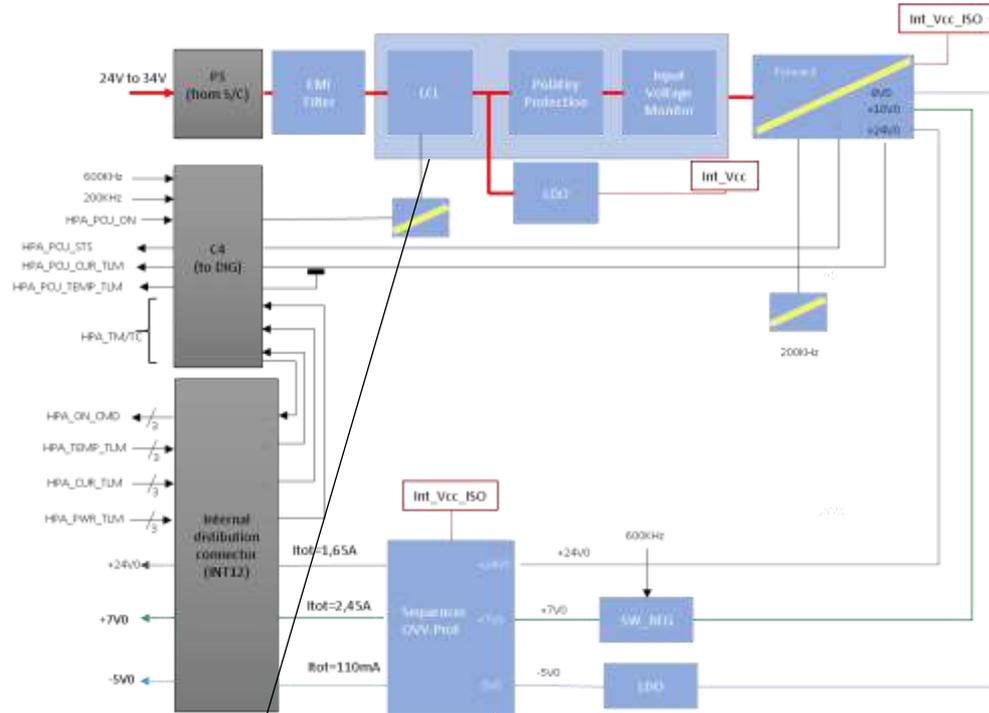
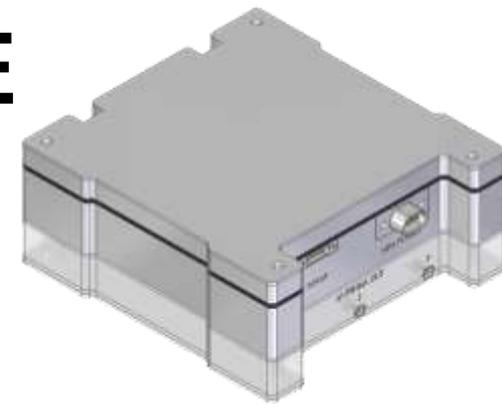
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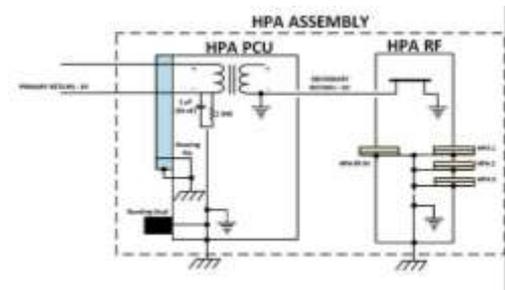
C- DST - HPA PCU MODULE



Power section overview



- Forward isolated converter
- Magnetic feedback to improve reliability



LCL with auxiliary SW

Output sequencer and protection

Single point grounding scheme



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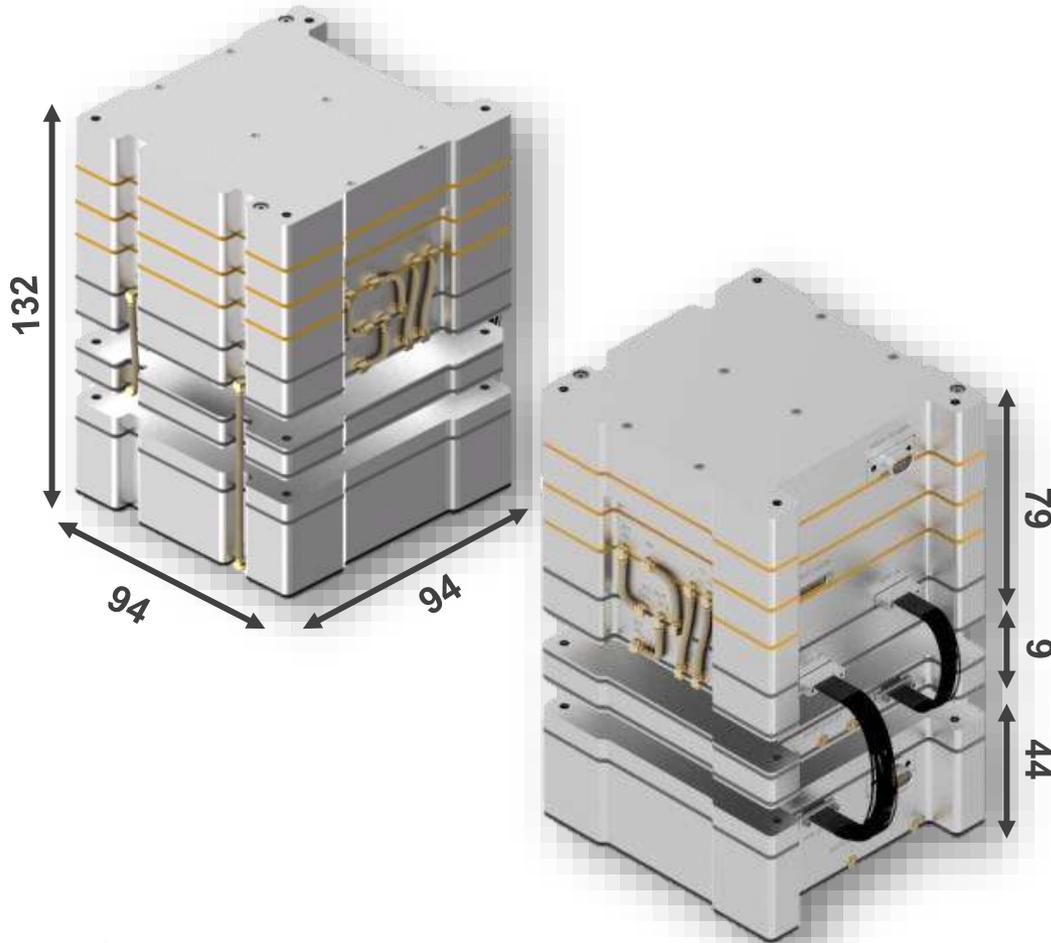
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C- DST - Dimensions and Mass



MASS BUDGET

Assembly	Module	Mass (g)	Contin. (%)	Mass (g)
MAIN	PCU	191	5%	201
	DIG	182	5%	191
	XRX	149	5%	156
	XTX	89	5%	93
	Miscel.	15	5%	16
	TOT	626	5%	657
LNA		109	5%	114
	TOT	109	5%	114
HPA	HPA_PCU	192	5%	202
	HPA_RF	198	5%	208
	Miscel.	5	5%	5
	TOT	395	5%	415
Harness		10	5%	11
	TOT	1140	5%	1197



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C- DST - PERFORMANCES

MAIN PERFORMANCES	
Network Compatibility	ESTRACK
Design Lifetime	3 years
Frequency Bands (Uplink)	7145 MHz -7190 MHz (Cat. B missions) 7145 MHz - 7235 MHz (Cat. A missions)
Frequency Bands (Downlink)	8400 MHz -8450 MHz (Cat. B missions) 8400 MHz -8500 MHz (Cat. A missions)
Coherency	Coherent operations supported
Turn-around ratios	749 / 880
Ranging	ESA STD ranging PN regenerative ranging
Navigation Support	2-way Doppler Ranging Delta-DOR
Volume	< 1,5U (94 mm x 94 mm x 131,5 mm)
Mass	1200 g
Form Factor	CubeSat compliant. 3 separate assemblies: <ul style="list-style-type: none"> • Main Assembly • LNA Assembly • HPA Assembly
Oscillator	Internal OCXO External USO – Ultra Stable Oscillator (100 MHz)
OCXO / USO selection*	Through HPC command using the Main DATA I/F
External USO Interface*	Radial SMPM connector
OCXO Allan Deviation	< 1E ⁻¹⁰ at 1 sec
TM/TC Interface	Redundant CAN bus CAN Bus or I2C as backup HPC Command (ARM & Fire)
Payload Data Interface	RS422



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C- DST - PERFORMANCES

MAIN PERFORMANCES (cont.d)		
Operation Modes	<ul style="list-style-type: none"> • STBY • RX – Signal Detection, Carrier Acquisition, Carrier Tracking and TC Tracking • RX & TX 	
Granularity (Accuracy)	23 mHz	
Stability (worst case and EOL)	± 2 ppm	
Power Consumption	Operative Mode	POWER
	STBY	7.7W
	RX RX & TX	12.8W 94.4W @ 15W Output Power
Operative Temperature	-20°C + 50°C	
Non-Operative Temperature	-30°C + 60°C	



CubeSAT Deep Space X-Band TT&C Transponder (CDST)

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C- DST - PERFORMANCES

RECEIVER PERFORMANCES	
Uplink symbol rate	Up to 4000 sps
Uplink modulation	PCM / PSK / PM (sine sub-carrier)
Uplink encoding	BCH LPDC (128, 64)
Carrier Tracking Signal Range	-60 dBm to -150 dBm
Carrier acquisition threshold	-145 dBm
Carrier tracking threshold	-150 dBm
RX Noise Figure	< 2 dB
Doppler Deviation	+/- 280 kHz
Doppler Rate	Different doppler rates are supported vs uplink power: 1000 Hz/s up to -133 dBm 80 Hz/s up to -143 dBm 30 Hz/s up to -148 dBm
Implementation Loss	< 1.0 dB (TBC) (carrier recovery) < 1.0 dB (TBC) (STD ranging) < 2.0 dB (TBC) (PN regenerative ranging) < 2.0 dB @BER<10 ⁻⁵ (TBC) (TC recovery)



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C- DST - PERFORMANCES

TRANSMITTER PERFORMANCES	
Downlink symbol rate	Up to 60 ksps Up to 1 Msps 8 Symbol rate selectable
Downlink modulation	PCM / PSK / PM (sine and square sub-carrier) SP-L
Downlink encoding	Concatenated RS (255,223) and convolutional code rate $\frac{1}{2}$ LDPC (2048,1024) Turbo rate $\frac{1}{4}$
Output power	15W @ antenna port (other options 5W and 2W)

LNA ASSEMBLY PERFORMANCES	
Power Supply Voltage	Provided by the MAIN Assembly
LNA Assembly	1 RF input (standard version) Up to 3 RF inputs * (RF input selectable via Main Assembly - CAN Bus)
LNA Assembly Dimensions	94 mm x 94 mm x 8,6 mm
LNA Assembly Power Supply Voltage	Provided by MAIN ASSEMBLY
Electrical Interfaces	Power and Data IF/: Harness provided with the unit
RF Interfaces	Radiall SMPM connectors Coaxial cable suggested: RG405
Mass	115 g (including 3 antenna ports)
Maximum distance from/to MAIN ASS.	75 cm



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C- DST - PERFORMANCES

HPA ASSEMBLY PERFORMANCES	
Power Supply Voltage	24V ÷ 34V (internal LCL circuit)
HPA Assembly	1 RF output - 15W @ antenna port (standard version) Up to 3 RF outputs (15W eachone) (RF input selectable via Main Assembly - CAN Bus)
Electrical Interfaces	Power I/F: OMNETICS MICRO-D FEMALE 9 pin Data IF/: Harness provided with the unit
RF Interfaces	Radiall SMPM connectors Coaxial cable suggested: RG405
HPA Assembly Dimensions	94 mm x 94 mm x 44,4 mm
Mass	420 g (including 3 antenna ports)
Maximum distance from/to MAIN ASS.	75 cm

MAIN ASSEMBLY PERFORMANCES	
Power Supply Voltage	24V ÷ 34V RLCL circuit
Electrical Interfaces	Power I/F: OMNETICS MICRO-D FEMALE 9 pin Data IF/: OMNETICS NANO-D FEMALE 31 pin
RF Interfaces	Radiall SMPM connectors Coaxial cable suggested: RG405
Main Assembly Dimensions	94 mm x 94 mm x 78,5 mm
Mass	660 g



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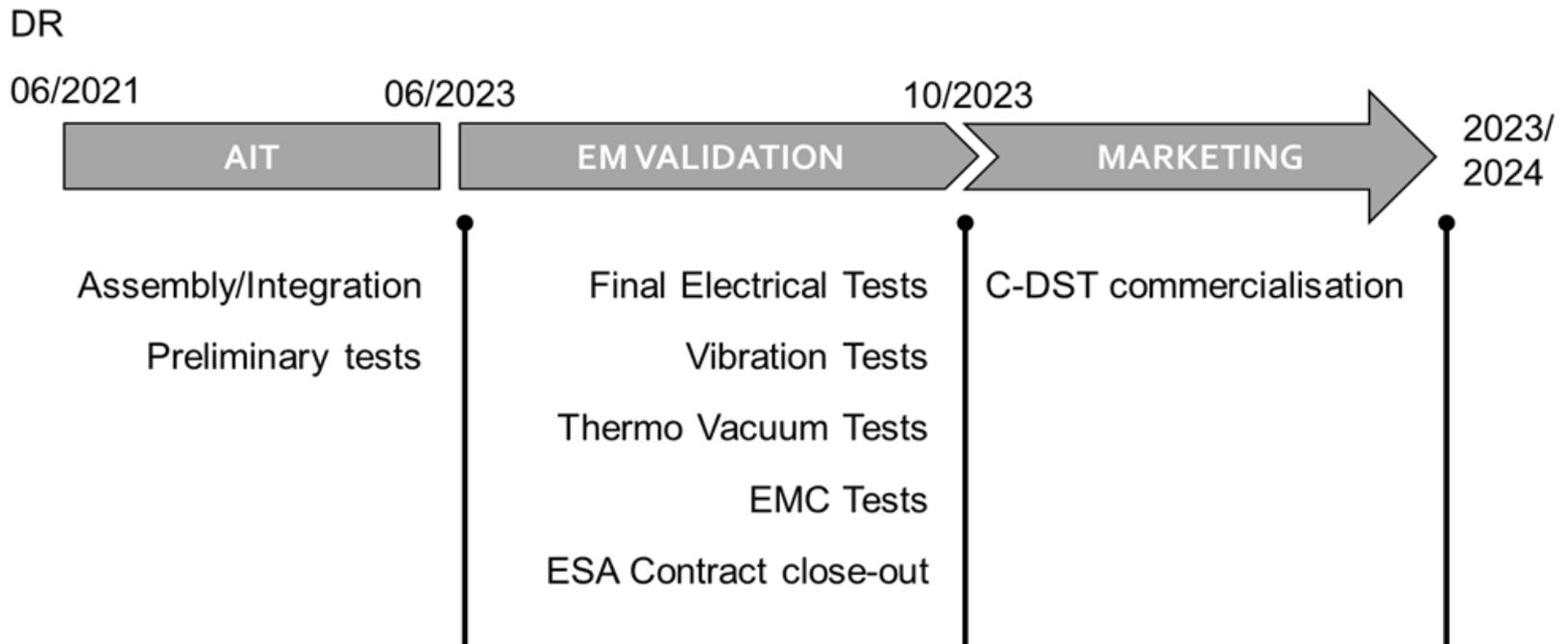
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Conclusion

The main objective to design and X-Band Transponder compatible with Cubesat 6U and 12U for Deep Space mission has been reached with the C-DST design and development that appear very promising for several low-cost space missions already established in the ESA programs (LUMIO/ M-ARGO).

The following roadmap is planned for the for the C-DST follow-on activities.



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Thank You for your attention



C-DST Nanosat X-Band TT&C Transponder EM

(ESA Contract No .: 4000128163/19/NL/FE)



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