ABSTRACT

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

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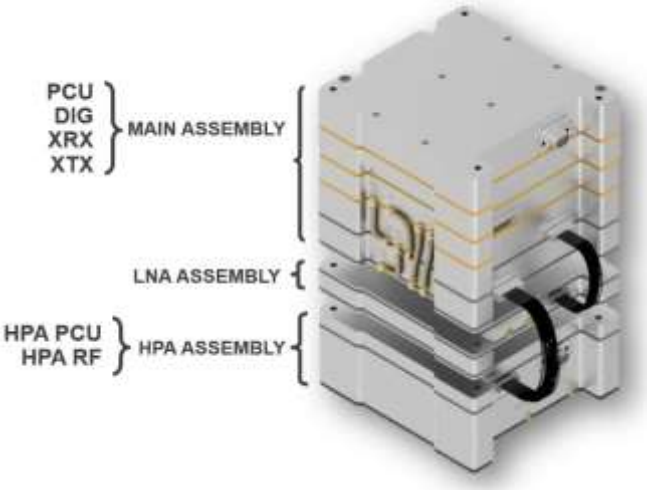
In recent years, there has been a clear trend of space mission projects to include planetary small spacecraft (e.g., CubeSats) that fly as secondary payloads, and are deployed at destinations to perform missions and communicate via the main spacecraft or direct to Earth. The added value for planetary science and exploration is twofold: (a) enhance primary science objectives; (b) enable new science and exploration in new, potentially dangerous environments. Furthermore, these small companion missions can be an excellent platform for testing novel technology demonstrators.
In addition, science investigators are usually more inclined to accept higher risk by exploring dangerous/unknown environments using relatively low-cost platforms. A recent example of this paradigm are the Mars Cube One (MarCO, launched on May 5th, 2018 (with the Insight mission to Mars). This was the first ever interplanetary CubeSats flown in deep space, and these twin communications-relay CubeSats were built by NASA's Jet Propulsion Laboratory, Pasadena, California. Another example is ESA's proposed Miniaturised – Asteroid Remote Geophysical Observer', or M–ARGO, a nano-spacecraft based on the CubeSat design employing a 12-unit CubeSat, that would hitch a ride on the launch of a larger space mission, to study a little-known class of asteroid: small in size and rapidly spinning.
A key element of all these missions is the communication system, which needs to be DSN/ESTRACK compatible, small, light, and not power-hungry. Such a unit does not exist in Europe, at the moment. Bearing in mind JPL's IRIS unit as a benchmark, we preliminarily proposed to ESA, in mid- 2019, our technical solution prepared by a consortium (**IMT srl**, **Thales Alenia Space Italy**, **Sitael** and **CIRI Aerospace of University of Bologna**) which brings together all necessary know-how and expertise in the field of CubeSat and SmallSat technologies, digital and analog RF TT&C systems, power systems, radio science experiments.
The Project name, chosen by the consortium, is **C-DST**: "**CubeSAT Deep Space X-Band TT&C Transponder**".
The Contract with ESA was signed by IMT, as Prime Contractor, on sept. 2019.

This paper describes the results gained so far in the design and development of the Model to be validated/qualified in view of two main ESA missions, LUMIO and M-ARGO.
In summary, the C-DST includes three assemblies:

- **Main Assembly**: it allocates the main functions of the unit, both DIGITAL and RF. It is composed of four modules, each one with a dedicated function (RX, TX, DIGITAL, Power). The Main assembly is powered by the unregulated satellite bus (protected or unprotected lines), and it is connected to the OBC through the digital interfaces (discrete lines, CAN bus for TM/TC data, and RS422 for Payload data). In addition, internal interfaces ensure the power and data connections with the LNA assembly and HPA assembly.
- **LNA Assembly**: it provides the LNA chains. The assembly can accommodate up to 3 antenna input ports, and it can be located close to the antenna (to improve the RF performances) or in-stack with the Main Assembly. The LNA chains are selected by the CAN BUS command through the Main Assembly.
- **HPA Assembly**: it is composed of the power conditioning and the SSPA modules. The SSPA module could accommodate up to 3 SSPA chains with 3 different antenna ports (in the same way as LNA, the HPA chains are selectable by the CAN Bus through the Main Assembly)

The transponder is designed for CubeSAT 12U (as for M-ARGO platform) as well as for CubeSAT 6U. This modularity gives high opportunities for the CubeSAT and NanoSAT markets. Moreover, using the CubeSAT standard digital interfaces, such as CAN BUS (for Telemetry and Commands) and RS422 (for Payload data), as well as the possibility to accept a large range of power supply voltage (24V-34V as a minimum), the transponder is suitable for MicroSAT deep space missions, too. In addition, the LNA and HPA Assemblies can accommodate several configurations with the minimum re-design phase. The system can allow up to 3 antenna ports, depending on the satellite's architectural design.
Thanks to the design flexibility (based on the Plug-and-Play philosophy), the transponder can cover several applications (in addition to the TT&C for Deep Space missions), maximizing the reuse of the C-DST design. C-DST is compliant for CAT A (7190MHz-7235MHz / 8450MHz-8500MHz) and CAT B missions (7145MHz-7190MHz / 8400MHz-8450MHz). In addition, the USO (Ultra Stable Oscillator) input option allows performing radio occultation experiments for future deep space missions, and different Signal Power Output values can be implemented with a re-design focused on the HPA Assembly, only.
Additional characteristics of C-DST are:
Mass: 1.2 Kg
Volume: <1.5U
Design Lifetime: 3 years
Power consumption: STBY 7W
RX mode 13W
TX+RX mode 80W
Op Temp: -20°c to +50°C
Carrier tracking signal range -60dBm to -150dBm
Output Power: 15W


PCU
DIG
XRX
XTX
MAIN ASSEMBLY
LNA ASSEMBLY
HPA PCU
HPA RF
HPA ASSEMBLY