National Aeronautics and Space Administration

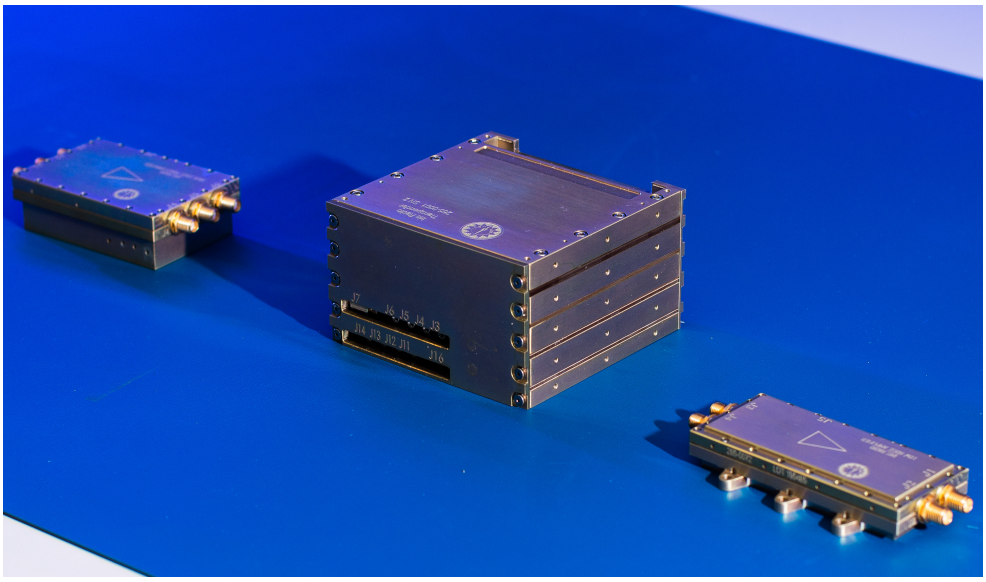
Iris V2.2 SmallSat Deep Space Transponder

X-, Ka-, S-Band, and UHF

Deep Space Telecommunications and Navigation

Features

- NASA Deep Space Network (DSN) and Near Earth Network (NEN) Compatible at X-Band Frequencies for Command, Telemetry, and Navigation
- Over-the-air (OTA)-reprogrammable, software-defined coherent transponder with Software fall-back boot safety feature.
- Low Volume, Mass, and Cost
- Configurable Software Defined Coherent Transponder
- 0.5 U Volume and 1.1 kg Mass
- 35 W DC Power Consumption at 3.8 W Radio Frequency Output, Full-Transpond
- Ka-Band, S-Band, UHF Options with additional NRE
- Turbo and LDPC encoding Capability.
- Radiation Tolerant Parts for Extended Deep Space Missions.
- Targeted for NPR 7120.8 technology demonstrations, Class-D space flight projects.
- SPI or SpaceWire (SpW) Interface
- Advanced Ranging Modes
- Programmable Spectral Mask Filtering
- AES-256 Command Decryption
- Beacon Modes Transmit Capability
- Multiple Uplinks Per Antenna Receive Capability.
- Conductive Thermal Dissipation.



Iris Radio Components, left to right: SSPA, Transponder, and LNA

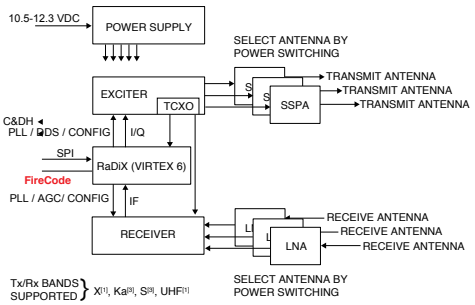
Iris Version 2.2 is a CubeSat/SmallSat compatible transponder developed by the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Laboratory (JPL) as a low volume and mass, lower power and cost, software/firmware defined telecommunications subsystem for deep space. Iris is a deep-space transponder targeted for NPR 7120.8 technology demonstrations and Class-D space flight projects, utilizing COTS-grade components. Iris V2.2's features include 0.5 U volume, 1.1 kg mass (including the LNA and SSPA), 34 W DC power consumption when fully transponding at 3.8 W radio frequency output (10.3 W DC input for receive only), and interoperability with NASA's Deep Space Network (DSN) at X-Band frequencies (7.2 GHz uplink, 8.4 GHz downlink) for command, telemetry, and navigation.

Iris V2.2 is designed with an environmentally robust architecture including radiation tolerant parts needed for deep space missions with durations of a few years and thermal management needed for navigation tracking sessions of several hours.

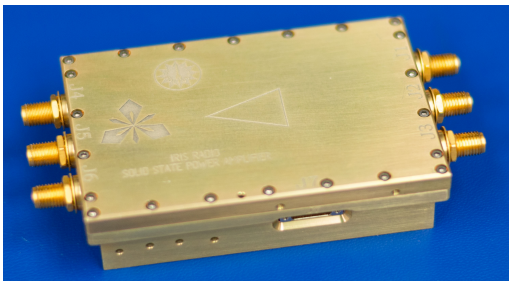
Iris uses a hardware slice architecture and reconfigurable software and firmware enabling extension and adaptation to new capabilities. Among those now planned are: Radio Science support (atmospheric and media measurements and occultations, gravity fields, radars, and radiometers); additional frequency bands (Ka-, S-, UHF); Disruption/Delay Tolerant Networking (DTN); proximity operations (at other planets such as Mars); Near Earth Network (NEN) compat-ibility; and Space Network (SN) compatibility.

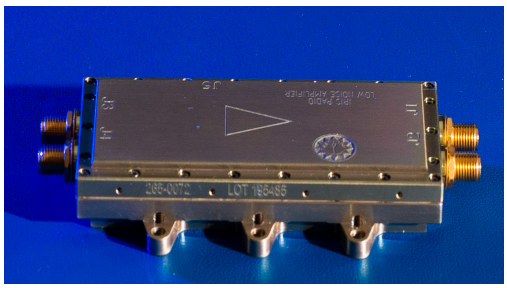
Iris V2.2

General Specifications	
Network Compatibility	DSN, NEN, SN[1]
Design Lifetime	3 years
Frequency Bands	X-band, UHF receive, Ka-[1], S-[1], UHF transmit[1]
Transponder Envelope	100.5 x 101.0 x 56.0 mm
LNA Envelope	114.3 x 46.0 x 15.5 mm
SSPA Envelope	102.9 x 55.7 x 24.4 mm
Flight Operating Temperature	–20 to +50°C
Solid State Power Amplifier	3 RF paths, dedicated to 3 antennas, path selectable via power switching
Low Noise Receive Amplifier	2 RF paths, dedicated to 2 antennas, path selectable via power switching
VCO	Internal TCXO, external 10 MHz
TCXO Allan Deviation	10^{-9} at 1 sec (non-coherent operation)
Ranging Delay Variation	< ±30 nsec
Telemetry Symbol Rates (downlink)	62.5 sps - 12.5 Msps Other arbitrary rates[1]
Subcarriers, Downlink	25 kHz Arbitrary subcarriers to 10 MHz[1] Direct carrier modulation
FPGA	Virtex 6
CPU	Gaisler LEON3-FT softcore (on Virtex 6)
Memory	32 Mbit non-volatile NOR-Flash (radiation tolerant) 16 Mbit volatile SRAM (radiation tolerant) 4 Mbit volatile EDAC SRAM (radiation tolerant)
Interface	Point-to-point SPI or SpaceWire (SpW)
Launch Capability	Non-operational at launch
Radiation, SEE Levels (100 mil (Al))	LET >37 MeV–cm²/mg (Virtex 6), 23 krad TID (ELDRS to 5 krad)
Telemetry Encoder	Firmware encoder
Command Detector	Firmware decode with FireCode (spacecraft reset direct command)
Mounting	CubeSat stack in chassis with separate SSPA and LNA modules
Carrier Loop BW	Configurable (100 Hz typical)
Command uplink rates (bps)	PCM/PSK/PM: 62.5 bps - 8000 bps PCM/PM: 8000 bps - 3.125 Mbps Other arbitrary rates[1]
Command uplink subcarriers	16 kHz Arbitrary subcarriers[1] Direct Carrier modulation
Command/Telemetry Interface	Command and Telemetry Dictionary, configurable[1] Uplink: TC Space Data Link Protocol CCSDS 232.0-B-3 Downlink: AOS Space Data Link Protocol CCSDS 732.0-B-3
Ranging Modes	Delta Diff 1-way Ranging (DDOR) (coh w/DL carrier) PN DDOR Coherent Sequential Ranging Coherent PN Regenerative Ranging
Beacon Modes	Capability to transmit tones at programmable frequencies to convey to Ground different Spacecraft State conditions.
Command Decryption	AES256 Command Decryption Capability.
Spectral Mask Filtering	Programmable pulse shape filtering to meet NTIA masks
Multiple Uplinks Per Antenna	On-baord Carrier Sweep and Doppler Compensation Capability.



Iris V2 Block Diagram





Iris V2 3-Ch SSPA (a) and 2-Ch LNA (b) are mounted separately for thermal reasons.

[1]Capability supportable due to software/firmware reconfigurability with additional NRE.

Iris V2.2

Mass and Power	
Stack Mass	875 g including thermal enclosure (no UHF) not including cables
SSPA Mass	150 g
LNA Mass	80 g
Input Supply Voltage	9–28 VDC
Input Supply Power	0.5–35 W @ 28V (see power states)

Iris Mode	DC Input (W) @12V
Battery Connect	0<.05
X-Receive Only	9.1
X-Transmit Only	25.0
X-Transmit/Receive	29.0

Transponder Specifications	
X-Band Uplink Frequency Range	7.145 – 7.190 GHz (channel assignment programmed in firmware) 7.190 – 7.235 (near Earth supported)
X-Band Downlink Frequency Range	8.400 – 8.450 GHz (channel assignment programmed in firmware)) 8.450 – 8.500 (near Earth supported)
Other Bands	S-Band: Deep Space[1]/near Earth[1] Ka-Band: 32/34 GHz Deep Space[1]; 26 GHz near Earth[1] UHF: 390–450 MHz receive; transmit[1]
Coherant Turnaround Ratio	880/749, standard S- and Ka-Band ratios[1], arbitrary ratios[1]

Receiver Specifications	
Noise Figure	2.5 dB for X-Band and 3.5 dB for UHF
Carrier Tracking Signal Range	–70 to –147 dBm
Tracking Range	100 MHz
Ranging Filter Type	Digital
Ranging Filter	1500 kHz, 6000 kHz

Exciter (X-Band)	
8.4 GHz Output Power (SSPA)	4.0 W BOL (–15 dBm drive from exciter)
X-Band Phase Noise (1 Hz offset) (100 Hz – 100 kHz offset)	TBM (–20 dBc/Hz) TBM (–60 dBc/Hz)
X-Band Spurious & Harmonic Outputs	< –40 dBc (–60 dBc at SSPA)
TLM Encoding	Convolutional (CC): 7-1/2 Manchester, Bi-Phase, and bypass (NRZ) Reed Solomon: RS (255,223) Turbo coding rates 1/2, 1/3, 1/6 Turbo block sizes 1784 or 8920 bits LDPC coding rates 1/2, 2/3, 4/5, 7/8 LDPC block sizes 1024, 4096, or 7136 bits
TLM Bit Rates (tested at DSN Testing Facility - DTF-21	• 12.5 Msym/s (coded symbol rate) when in QPSK with CC (1/2) + RS (255,223) - (10.93 Mbps info bit rate). • 6.25 Msym/s (coded symbol rate) when in QPSK with LDPC 4/5 - (5 Mbps info bit rate). • 12.5 Msym/s (coded symbol rate) when in NRZ-L with Turbo 1/3 - (4.167 Mbps info bit rate).
TLM Phase Deviation	0 to 180 degrees
TLM Modulation	NRZ-L and Manchester (Bi-phase-L) BPSK, QPSK, OQPSK, GMSK Additional Schemes[1]
Spectral Mask Filtering	Programmable pulse shape filtering to meet NTIA[2]/SFCG[3] masks.

[1] Capability supportable due to software/firmware reconfigurability with additional NRE.
[2] NTIA: The National Telecommunications and Information Administration.
[3] SFCG: The Space Frequency Coordination Group.

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