NanoCom Link S, X and SX

Communication Products

Datasheet

GomSpace A/S | Langagervej 6 | DK-9220 Aalborg East | Denmark
gomspace.com | sales@gomspace.com | T: +45 71 741 741

NanoCom Link S, X and SX Communication Products

Document reference: DS 1076242
Source reference: doc-nanocom-link-sx-datasheet
Date: January 22, 2026
Revision: 12.0

GomSpace A/S
Langagervej 6, 9220 Aalborg East
Denmark
Phone: +45 71 741 741
www.gomspace.com

Contents

List of Figures

List of Tables

List of Abbreviations

16APSK 16-ary amplitude and phase shift keying.

32APSK 32-ary amplitude and phase shift keying.

8PSK 8-ary phase shift keying.

AES Advanced Encryption Standard.

BER bit error rate.

BPSK binary phase-shift keying.

BW bandwidth.

CAN Controller Area Network.

CCM constant coding and modulation.

CCSDS Consultative Committee for Space Data Systems.

CSP Cubesat Space Protocol.

DC direct current.

DSN Deep Space Network.

EMI electromagnetic interference.

eMMC embedded multi-media controller.

ESD electrostatic discharge.

EVM error vector magnitude.

GCM Galois/Counter Mode.

GSSE GomSpace Stream Encapsulation.

GSUFTP GomSpace Unidirectional File Transfer Protocol.

HBM human-body model.

I2C Inter-Integrated Circuit.

ICD interface control document.

IF intermediate frequency.

IP Internet Protocol.

IPv4 Internet Protocol version 4.

ITU International Telecommunication Union.

JTAG Joint Test Action Group.

LPM lumped parameter model.

LVDS low-voltage differential signal.

MODCOD modulation and coding.

MTU maximum transmission unit.

OOB out-of-band.

PA power amplifier.

PC personal computer.

PFD power flux density.

PL programmable logic.

PPS pulse-per-second.

QPSK quadrature phase-shift keying.

RF radio frequency.

RHCP right hand circular polarization.

RMS root mean square.

RSSI received signal strength indicator.

RX receive.

SDR software-defined radio.

TCP Transmission Control Protocol.

TCP/IP Transmission Control Protocol/Internet Protocol.

TRL technology readiness level.

TVAC thermal vacuum.

TX transmit.

UART universal asynchronous receiver/transmitter.

UDP User Datagram Protocol.

USB universal serial bus.

VCM variable coding and modulation.

1 Overview

NanoCom Link is a product family designed to provide seamless space to ground segment communication links in S- and X-Band.

This datasheet summarizes the key performance characteristics as well as selected parameters relevant for integration and interfacing with the NanoCom Link product in a satellite. Further details are available in the datasheets for the individual products as well as the NanoCom Link S, X, SX User Manual [1].

Depending on the purchased configuration, NanoCom Link consists of the following GomSpace devices:

NanoCom Link S:

- SDR: NanoCom SDR MK3, equipped with one TR600
- ANT: NanoCom ANT2150-DUP, S-Band frontend, full duplex receive (RX) and TX.
- Space Link: S-band CCSDS 131.0-B-3 standard [2] up to 7.5 Mbit/s.

NanoCom Link X:

- SDR: NanoCom SDR MK3, equipped with one TR600
- ANT: NanoCom ANT8250, X-Band frontend, TX only.
- Space Link: X-band DVB-S2 standard [3] up to 50 Mbit/s, 150 Mbit/s, 225 Mbit/s.

NanoCom Link SX:

- SDR: NanoCom SDR MK3, equipped with two TR600s.
- ANT1: NanoCom ANT2150-DUP, S-Band frontend, full duplex RX and TX.
- ANT2: NanoCom ANT8250, X-Band frontend, TX only.
- Space Link1: S-band CCSDS 131.0-B-3 standard [2] up to 7.5 Mbit/s.
- Space Link2: X-band DVB-S2 standard [3] up to 50 Mbit/s, 150 Mbit/s, 225 Mbit/s.

The NanoCom Link SX variant supports only one active data downlink at a time. When a link is enabled, it continuously transmits idle pattern or data, allowing ground stations to synchronize with the signal at any moment. Switching between S-band and X-band downlinks for data can be done quickly, without the need for additional synchronization procedures.

To ease integration and development, each product variant is delivered preloaded with modem software and includes all necessary cables to interconnect the software-defined radio (SDR) and antennas.

User selectable configurations like different antenna back plates, X-band bitrates, and optional filters for Deep Space Network (DSN) compliance are chosen when ordering the product based on an option sheet. The option sheet can be found on the GomSpace web page.

Refer to product control- and radio frequency (RF) interface control documents for CCSDS 131.0-B-3[2] related implementation limitations and details.

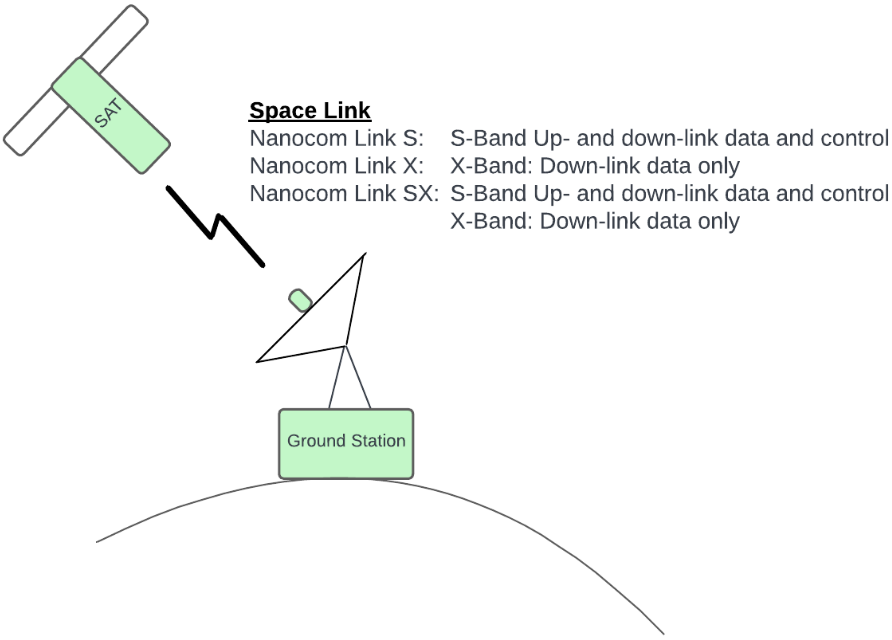


Figure 1.1: Supported Space Link Configurations.

1.1 Highlighted Features

General

- Based on TRL9 proven hardware modules.
- Qualified for more than 5 years operation in space according to the GomSpace qualification program.
- Controller Area Network (CAN) bus interface for Cubesat Space Protocol (CSP) based control and telemetry.
- RS-422 full duplex interface for low-speed payload data transfer.
- 3x SpaceWire low-voltage differential signal (LVDS) interfaces for high-speed payload data transfer.
- Authenticated encryption aligned with CCSDS 355.0-B-2 [4] for secure RF communications.
- Cryptographic key management aligned with CCSDS 354.0-M-1 [5].

S-Band

- Full duplex continuous mode RX and TX based on the CCSDS 131.0-B-3 standard [2] with:
  - GomSpace Stream Encapsulation (GSSE).
  - Idle byte insertion.
  - Binary phase-shift keying (BPSK) and quadrature phase-shift keying (QPSK) modulation support.
  - Symbol rates 0.5 MBd/s to 7.5 MBd/s.
  - Concatenated Code: Rate ½ Convolutional code with Reed Solomon (255, 223).
  - Reed Solomon interleaving of 1, 2, 3, 4, 5 or 8 blocks.
- Transmit frequency range: 2200 MHz to 2290 MHz in steps of 1 Hz.
- Receiver frequency range: 2025 MHz to 2110 MHz in steps of 1 Hz.
- Adjustable output power up to 32 dBm.
- Different back plates available for antenna mounting on nadir facing satellite side.

X-Band

- Based on the ETSI DVB-S2 standard[3].
- DVB-S2 modulation and coding, modulation and coding (MODCOD) 1 to 28.
- DVB-S2 baseband filtering roll-off of 0.2.
- Symbol rates 2 MBd/s to 50 MBd/s in standard configuration.
- Variable coding and modulation (VCM) and constant coding and modulation (CCM) modes of operation.
- DVB-S2 dummy frames inserted on idle link.
- DVB-S2 pilot frames included.
- DVB-S2 physical layer scrambler signature of 0.
- Store and Forward with GomSpace Unidirectional File Transfer Protocol (GSUFTP).
- Standard configuration:
  - Transmit frequency: 8000 MHz to 8400 MHz in steps of 10 MHz.
  - Adjustable output power up to 33 dBm.
- With optional ‘DSN Filter Kit’:
  - Transmit frequency: 8020 MHz to 8280 MHz in steps of 10 MHz.
  - Adjustable output power up to 31 dBm.
- Designed for minimum 20 minutes of continuous TX operation.
- Different back plates available for antenna mounting on nadir facing satellite side.

Ground Segment

- Verified against commercial off-the-self modulator/demodulators:
  - S-Band: Kratos quantumRadio.
  - X-Band: Newtech MDM9000.
- Ground Segment integration shall follow the NanoCom Link S, X, SX RF Interface[6] interface control document (ICD) for compatible front-end processing for streaming and file handling.
- Optionally, the Ground Segment integration can be aided with the GomSpace NanoGround and NanoGround Link Connect software product from GomSpace (sold separately) which supports GSSE and GSUFTP front-end processing for Transmission Control Protocol/Internet Protocol (TCP/IP) streaming connection and file downlink handling.

2 System Overview

Figure 2.1 provides a high-level system overview of the NanoCom Link SX product. Refer to the NanoCom Link S, X, SX User Manual[1] for detailed description on how to configure and control the system.

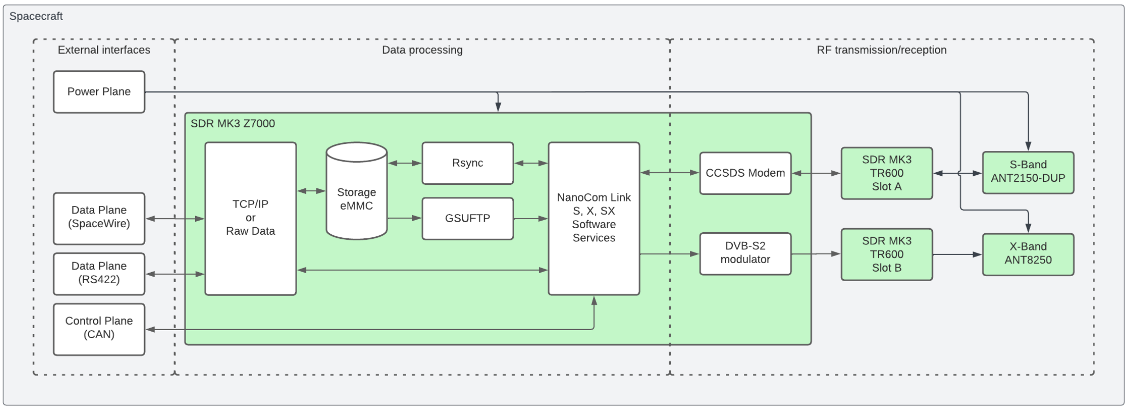


Figure 2.1: High-level system overview.

Power Plane

Power supply for the NanoCom SDR MK3, NanoCom ANT2150-DUP and NanoCom ANT8250.

Control Plane

The system is configured and controlled using CSP over the CAN interface. Telemetry can be obtained using that interface as well.

Data Plane

The product is equipped with three SpaceWire and one RS422 interface that can be used for data transfer.

The SpaceWire interfaces and the RS422 Interface supports TCP/IP or User Datagram Protocol (UDP)/Internet Protocol version 4 (IPv4) which is realized as a Linux IP tunnel interface for ease of integration allowing the use of standard linux tool to transfer or access the data storage. In addition to Internet Protocol (IP) traffic, the SpaceWire has file mode allowing raw SpaceWire Link Layer (N-char) ingress frames to be written to the file storage.

When data is stored for future transmission, it is put into files and stored on the file system. These files can either be downlinked via TCP/IP over the S-band CCSDS Modem link. with the Linux rsync[7] application. When X-band is available files can also be forwarded to ground using the embedded GSUFTP application can transmit and re-transmit files to ground.

3 Absolute Maximum Ratings

Stresses above those listed under Table 3.1 may cause permanent damage to the product.

Symbol	Parameter	Min	Max	Unit
$T_{Storage}$	Storage temperature	−40	85	°C
$T_{IF\text{-}SDR}$	SDR Thermal Interface temperature	−35	53	°C
$T_{IF\text{-}ANT8250}$	ANT8250 Thermal Interface temperature	−35	57	°C
$T_{IF\text{-}ANT2150}$	ANT2150 Thermal Interface temperature	−35	57	°C
V_{SDR}	SDR MK3 supply voltage	−0.3	36	V
$V_{MAIN\text{-}8250}$	ANT8250 main supply voltage	10	36	V
$V_{COM\text{-}8250}$	ANTT8250 interface supply voltage	−0.3	5.5	V
$V_{MAIN\text{-}2150}$	ANT2150-DUP main supply voltage	8	18	V
V_{SPW}	SpaceWire / LVDS voltage levels	−0.4	2.6	V
V_{RS422}	RS422 input voltage levels	0	4	V
V_{CAN}	CAN voltage levels	−60	60	V
$P_{IN\text{-}2150}$	Maximum input power at ANT2150-DUP, 2025 MHz to 2110 MHz		−40	dBm

Table 3.1: Absolute Maximum Ratings of the NanoCom Link.

4 External Interfaces

Figure 4.1 shows a high-level overview of the NanoCom Link SX system solution. The following external interfaces are available for integration with the spacecraft/satellite bus:

Power:
Power supply for NanoCom SDR MK3, NanoCom ANT2150-DUP and NanoCom ANT8250 (depending on the purchased configuration).

Control:
The system is configured and controlled using CSP over a CAN interface. Telemetry can be obtained using that interface as well.

Data:
1x RS422 and 3x SpaceWire interfaces are available for TCP/IP or raw data transfer of payload data.

Debug:
On ground debug and firmware upgrades are possible using the debug interface. Not intended to be used for flight or to be integrated with the satellite bus. Included for optional debug and test purposes.

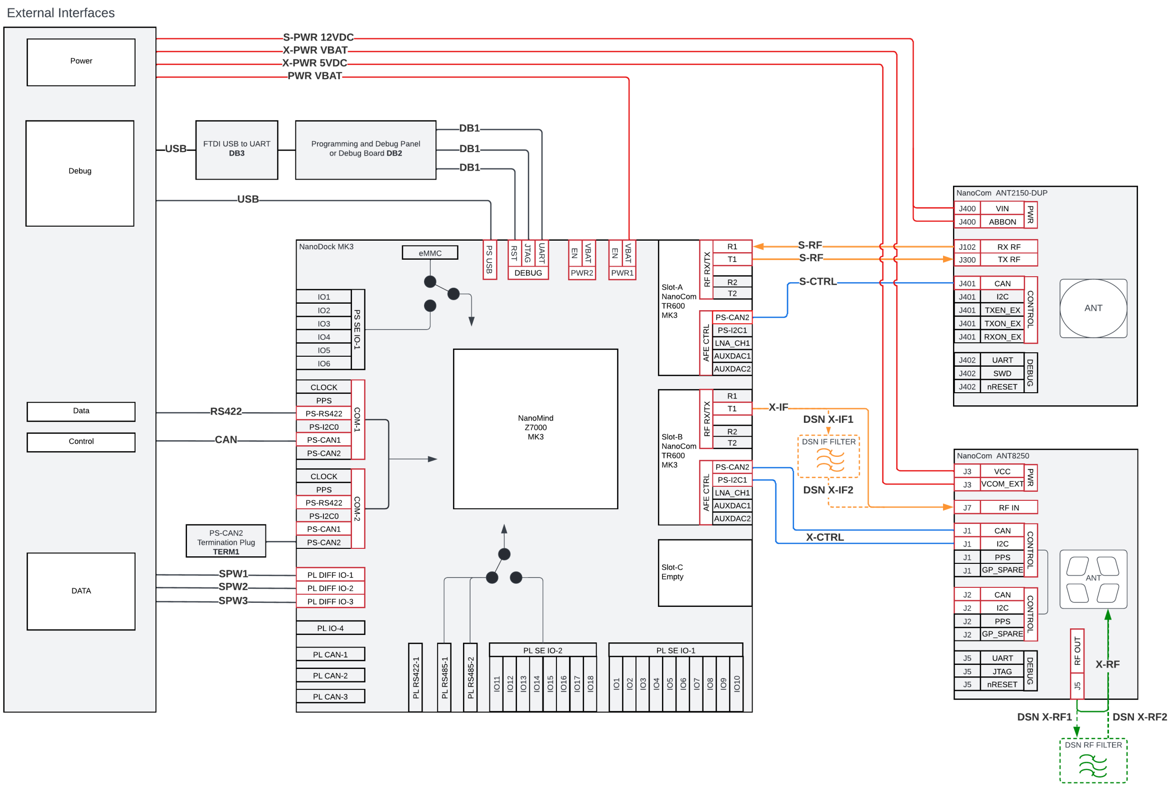


Figure 4.1: NanoCom Link SX system overview
SDR MK3, ANT2150-DUP and ANT8250 are equipped with different interfaces. It is only a subset of those which are used/supported within the NanoCom Link family. Unused or unsupported connections are greyed out and does not carry any external signals in the block diagram.

Cables necessary for interfacing between the SDR MK3 and NanoCom ANT2150-DUP and NanoCom ANT8250 are included with the product. This includes power cables as well.

Table 4.1 shows an overview of cables included with the product depending on the purchased configuration of NanoCom Link:

ID	S	X	SX	Length	Description
PWR	✓	✓	✓	50 cm	SDR MK3 power to flying leads
S-PWR	✓	N/A	✓	50 cm	ANT2150 power to flying leads
X-PWR	N/A	✓	✓	50 cm	ANT8250 power to flying leads
DB1	✓	✓	✓	3.5 cm	SDR MK3 debug harness[1]
DB2	✓	✓	✓	N/A	SDR MK3 debug breakout PCB[1]
DB3	✓	✓	✓	N/A	FTDI USB-TTL serial cable[1]
USB	✓	✓	✓	100 cm	SDR MK3 USB Cable[1]
S-RF	✓	N/A	✓	50 cm	RG-178 Coax cable, SSMCX to SMPM[2]
X-IF	N/A	✓	✓	50 cm	RG-178 Coax cable, SMPM to SMPM3[2]
X-RF	N/A	✓	✓	5.5 cm	SMPM to SMP 0.085” semi rigid coax cable
S-CTRL	✓	N/A	✓	50 cm	TR600 MK3 to ANT2150 control harness
X-CTRL	N/A	✓	✓	50 cm	TR600 MK3 to ANT8250 control harness
TERM1	✓	✓	N/A	N/A	SDR MK3 Mainbus CAN2 120 Ω termination[3]

Table 4.1: Product cable kit content.

The location of the required individual connectors is documented in Section 5, followed by a detailed connector pinout for the Power, Control and Data along with the RF interface. These are the only electrical interfaces to be integrated with the spacecraft/satellite bus.

[1] Included for debug / test purpose only.

[2] Minimum bend radius is 10 mm.

[3] For the NanoCom Link S and X variants a CAN termination resistor is needed on the SDR DOCK. The plug is included in the cable kit and can be inserted into either COM-1 or COM-2 on the SDR MK3 DOCK for proper termination of PS-CAN2.

4.1 X-Band DSN Filter Kit

For the NanoCom Link X and SX it is possible to select an optional 'DSN Filter Kit' when ordering the product. The kit adds an intermediate frequency (IF) filter, RF filter, and necessary coax cables for wiring to comply with International Telecommunication Union (ITU) regulations when running X-band. Table 4.2 shows the content of the 'DSN Filter Kit'. Limitations on usage when used in proximity of the DSN stations with and without the 'DSN Filter Kit' is further detailed in Section 6.4.

The X-Band 'DSN Filter Kit' is an add-on to the standard configuration. It is therefore possible to revert to the standard configuration simply by omitting the filters and use the standard wiring.

ID	Length	Description	Interconnection
DSN X-IF1	5.5 cm	SMA to SMPM RG 178 coax cable[1] [3]	T1 TR600 Slot B to IF filter
DSN X-IF2	50 cm	SMA to SMPM RG 178 coax cable[1] [3]	IF filter to ANT8250 RF input
DSN X-RF1	22 cm	SMA to SMPM 0.085" semi rigid coax cable[2] [3]	ANT8250 RF output to RF filter
DSN X-RF2	22 cm	SMA to SMP 0.085" semi rigid coax cable[2] [3]	RF filter to AM8250 RF input
DSN X-IF Filter	N/A	1150 MHz band pass filter, 60 MHz BW - attached to SDR MK3 Slot-C cover shield.	
DSN X-RF Filter	N/A	8150 MHz band pass filter, 300 MHz BW - with mounting bracket.	

Table 4.2: DSN Filter Kit content.

4.2 Interface Connectors

Interface connectors used by NanoCom Link on NanoCom Link SDR MK3, ANT2150-DUP and ANT8250. Connector placement is shown in Figures 4.3, 4.4 and 4.5.

4.2.1 NanoCom SDR MK3

The SDR MK3 is equipped with one or two TR-600 depending on the purchased configuration. Perspective views of the different configurations are shown in Figure 4.2.

All external connectors reside on the dock except for the interface for the active frontends ANT2150-DUP and ANT8250, which are located on the allocated TR600s. The individual connector placement is illustrated for the NanoCom Link SX variant can be seen in Figure 4.3.

[1] Minimum bend radius is 10 mm.

[2] Minimum bend radius is 3.2 mm.

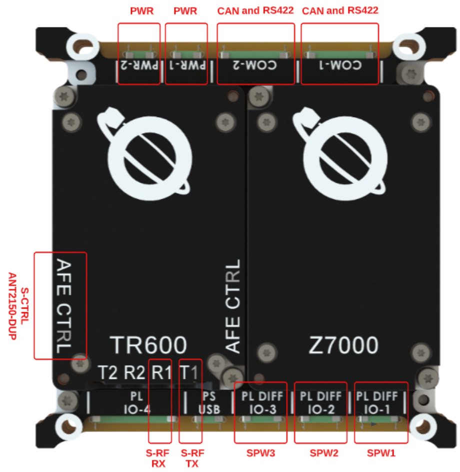
[3] Coax cables are mounted on to the IF and RF filters on the SMA connector side using a mounting torque of 0.8 nm to 1.0 nm. For the end-user to be able to modify the orientation of the SMA plugs, the product is delivered without any kind of thread lock applied to fixate the SMA plugs.

(a) SDR MK3 NanoCom Link S
TR600 Slot A ↔ ANT2150-DUP
Slot B and C Empty

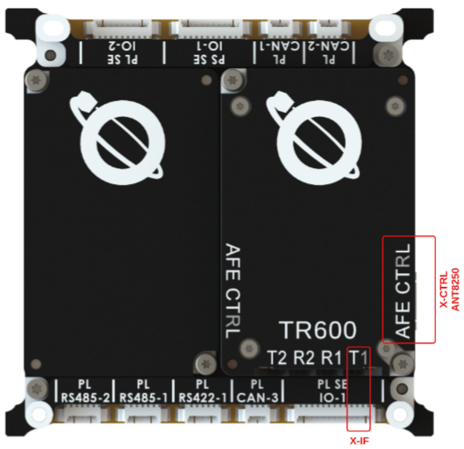
(b) SDR MK3 NanoCom Link X
TR600 Slot B ↔ ANT8250
Slot A and C Empty

(c) SDR MK3 NanoCom Link SX
TR600 Slot A ↔ ANT2150-DUP
TR600 Slot B ↔ ANT8250
Slot C Empty

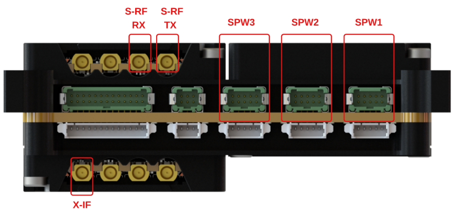
Figure 4.2: Perspective views of SDR MK3 NanoCom Link S, X and SX.



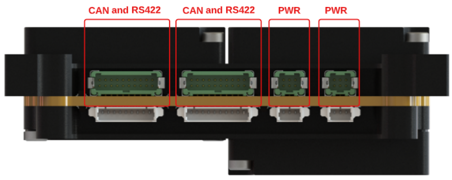
(a) SDR MK3 NanoCom Link SX top view.



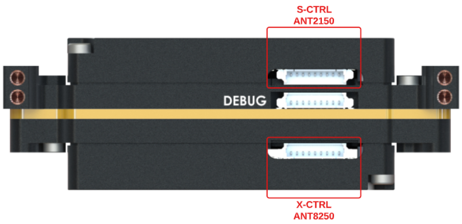
(b) SDR MK3 NanoCom Link SX bottom view.



(c) SDR MK3 NanoCom Link SX front side view.



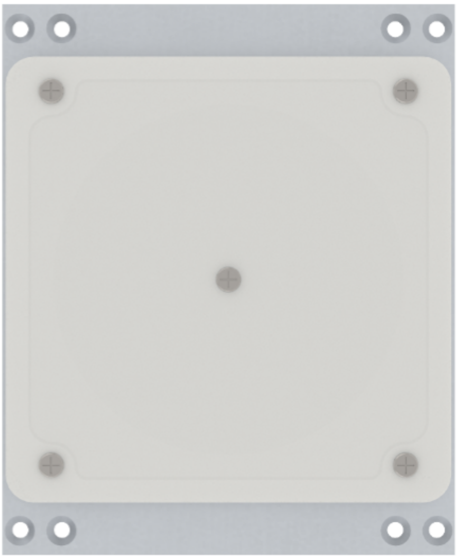
(d) SDR MK3 NanoCom Link SX back side view.



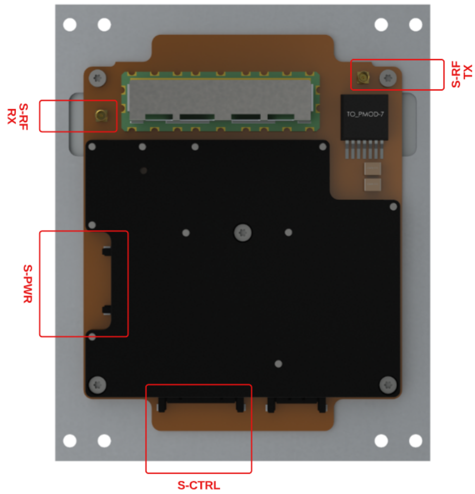
(e) SDR MK3 NanoCom Link SX left side view.

Figure 4.3: Individual connector placements of the NanoCom Link SX variant.

4.2.2 NanoCom ANT2150



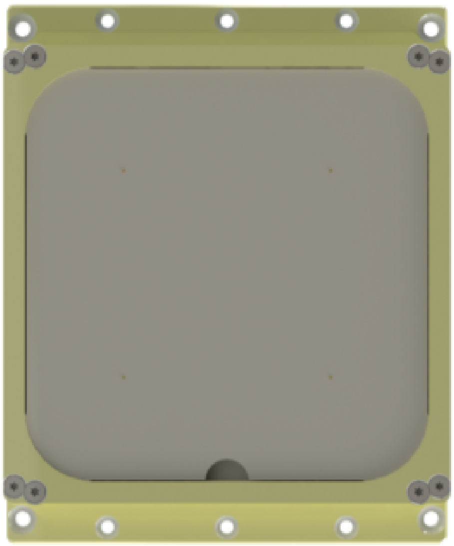
(a) NanoCom ANT2150-DUP top view.



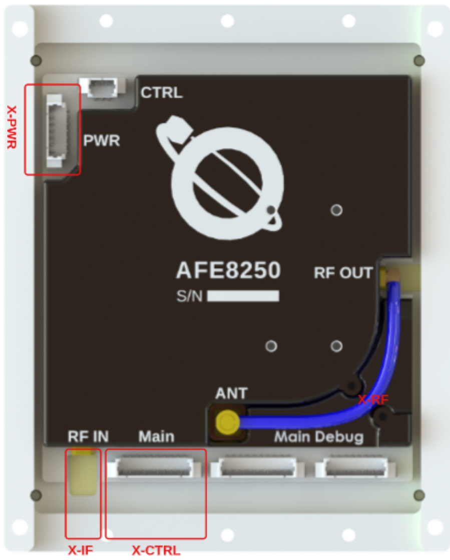
(b) NanoCom ANT2150-DUP bottom view.

Figure 4.4: Connector placement of ANT2150

4.2.3 NanoCom ANT8250



(a) NanoCom ANT8250 top view.



(b) NanoCom ANT8250 bottom view.

Figure 4.5: Connector placement of ANT8250

4.3 Power Interfaces

4.3.1 SDR MK3 PWR-1 and PWR-2

SDR MK3 is equipped with two Gecko G125-MH10605L1R 1.25 mm pitch high-reliability connectors with latches from Harwin for external power supply. The connector pinout is shown in Figure 4.7 and Table 4.3.

The board can be supplied through either connector, PWR-1 or PWR-2, using a single power supply or by connecting two independent power supplies for redundancy. A supply balancing circuit automatically selects whichever of the two power connectors that carries the highest VIN voltage as supply source. The load will be shared between the two power connectors if the external supply voltages VIN1 and VIN2 are of equal levels.

The power supply interface is shown in Figure 4.6.

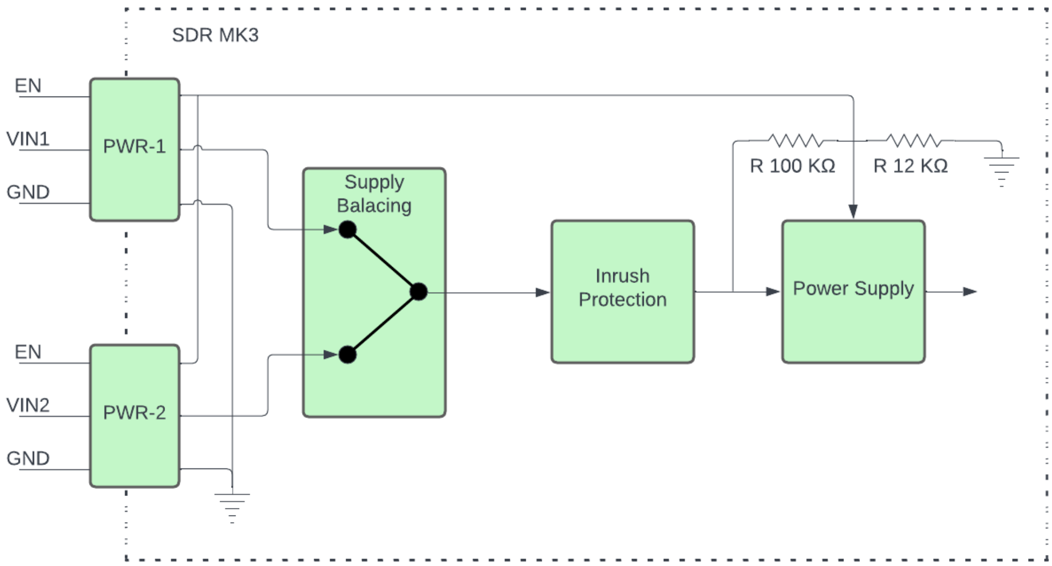


Figure 4.6: SDR MK3 power supply interface.

The EN pin makes it possible to turn ON or OFF the SDR MK3 independent of supply voltage. The feature can be omitted by leaving the EN pin not connected. When the EN pin is left floating/not connected, the SDR MK3 will automatically turn ON when the supply voltage raises above 10 V and turn OFF below at supply voltages below 8.5 V.

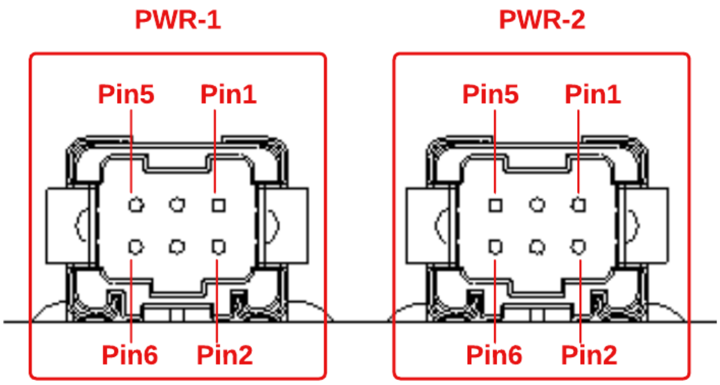


Figure 4.7: PWR-1 and PWR-2 connector pinout.

Pin	PWR-1 Signal	PWR-2 Signal	Description
1	VIN1	VIN2	Supply voltage 12 V to 32 V
2	EN	EN	Optional enable signal, tied to VIN through a 100 kΩ / 12 kΩ divider locally on the SDR MK3. **EN = 0 V to 0.8 V:** SDR MK3 is OFF **EN = 1.2 V to 24 V:** SDR MK3 is ON **EN = Not connected:** Automatic supply switching, SDR MK3 is ON when supply voltage is >10 V and OFF when supply voltage is <8.5 V.
3	VIN1	VIN2	Supply voltage 12 V to 32 V
4	GND	GND	
5	VIN1	VIN2	Supply voltage 12 V to 32 V
6	GND	GND	

Table 4.3: PWR Signal Table.

4.3.2 ANT2150-DUP Power

ANT2150-DUP is powered via a PicoLock, 504050-0791, 1.50 mm pitch Molex connector. The connector pinout is shown in Figure 4.8 and Table 4.4.

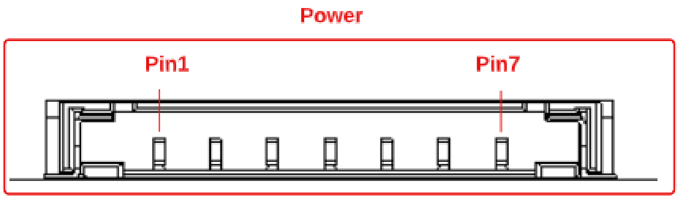


Figure 4.8: ANT2150-DUP S-PWR connector pinout.

Pin	Signal	Description
1	ABBON	External power control pin: Low <0.4 V, High >2.5 V (max 18 V) **Low:** Antenna is OFF **High:** Antenna is ON (Antenna enters IDLE mode when ABBON pin is asserted)
2	GND	
3	GND	
4	GND	
5	VIN	Supply voltage 8 V to 18 V
6	VIN	Supply voltage 8 V to 18 V
7	VIN	Supply voltage 8 V to 18 V

Table 4.4: ANT2150-DUP S-PWR control pinout table.

4.3.3 ANT8250 Power

ANT8250 is powered via a PicoBlade, 53398-0771, 1.25 mm pitch Molex connector. The connector pinout is shown in Figure 4.9 and Table 4.5.

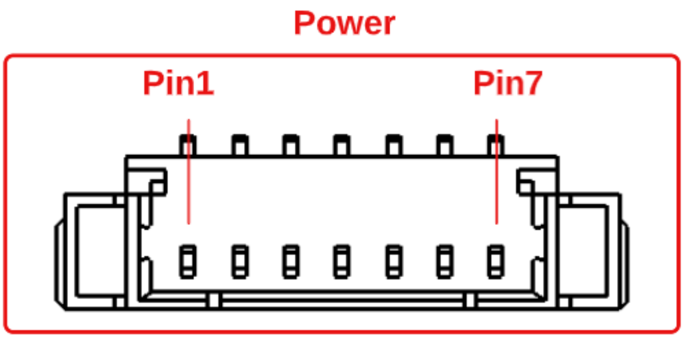


Figure 4.9: ANT8250 X-PWR connector pinout.

Pin	Signal	Description
1	VCOM	Communication interface supply (Regulated 4.9 V to 5.1 V).
2	GND	
3	GND	
4	GND	
5	GND	
6	VBAT	Frontend supply voltage 12 V to 32 V
7	VBAT	Frontend supply voltage 12 V to 32 V

Table 4.5: ANT8250 control pinout table.

4.4 Control and Data Interfaces

4.4.1 SDR MK3 CAN and RS422

SDR MK3 is equipped with two Gecko G125-MH12005L1R 1.25 mm pitch high-reliability connectors with latches from Harwin for access to its main communication interface. The individual pins of the two connectors are interconnected, which allow the SDR to be used in different bus topologies. The secondary connector can be used for interconnecting with other devices in multidrop bus configuration or for bus terminations if it is the last node in the system.

Of all the signals present in the main communication interface connectors, it is only CAN1 (Pin 2 and 4) and RS422 (Pin 14, 16, 18 and 20) that are used on NanoCom Link for control and data.

The connector pinout is shown in Figure 4.10 and Table 4.6.

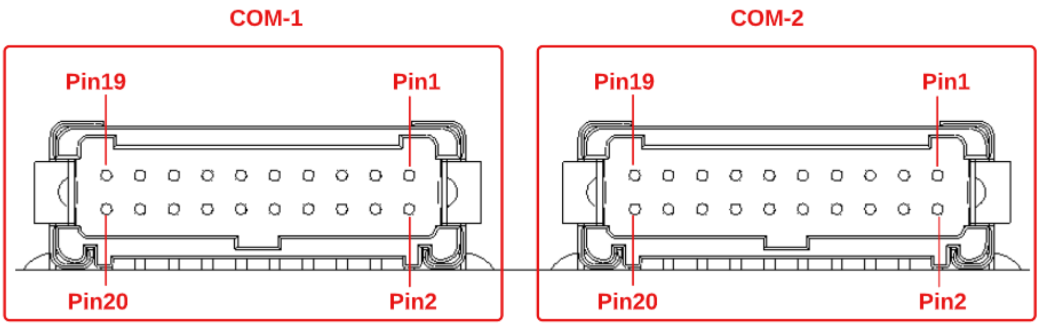


Figure 4.10: COM-1 and COM-2 pinout.

Pin	Signal	Description
1	I2C0-SDA	I2C0 serial data line
2	CAN1-P	CAN1 positive line used for CSP control interface
3	GND	
4	CAN1-N	CAN1 negative line used for CSP control interface
5	I2C0-SCL	I2C0 serial clock line
6	CAN2-P	CAN2 positive line dedicated frontend control via TR600[1]
7	GND	
8	CAN2-N	CAN2 negative line dedicated frontend control via TR600[1]
9	PPS-P	PPS LVDS positive input line
10	CLK-P	Ext reference clock LVDS positive input line
11	PPS-N	PPS LVDS negative input line
12	CLK-N	Ext reference clock LVDS negative input line
13	UART0-TX	UART transmitter output
14	RS422-TX-P	RS422 Noninverting driver output for payload data interface
15	GND	
16	RS422-TX-N	RS422 Inverting driver output for payload data interface
17	UART0-RX	UART receiver input
18	RS422-RX-P	RS422 Noninverting receiver input for payload data interface
19	GND	
20	RS422-RX-N	RS422 Inverting receiver input for payload data interface

Table 4.6: SDR MK3 pinout table.

[1] CAN2 is dedicated to frontend control on NanoCom Link. It should not be interconnected to other CAN networks. For proper operation a CAN network is to be equipped with 120 Ω terminations on the outer ends. ANT2150-DUP and ANT8250 are both equipped with 120 Ω CAN terminations. Therefore, on NanoCom Link SX, proper CAN2 termination is secured by the RF frontends. On NanoCom Link S and X, which are only equipped with one RF frontend, CAN2 termination must be present on the SDR MK3 side as well. In this case a termination plug containing a 120 Ω resistor on CAN2 is included with the product. The termination can be inserted into either COM-1 or COM-2.

4.4.2 SDR MK3 SpaceWire

SDR MK3 is equipped with three independent bi-directional, full-duplex SpaceWire interfaces for payload data transfer. It uses Gecko G125-MH11005L1R 1.25 mm pitch high-reliability connectors with latches from Harwin for each of the three interfaces, as seen in Figure 4.11.

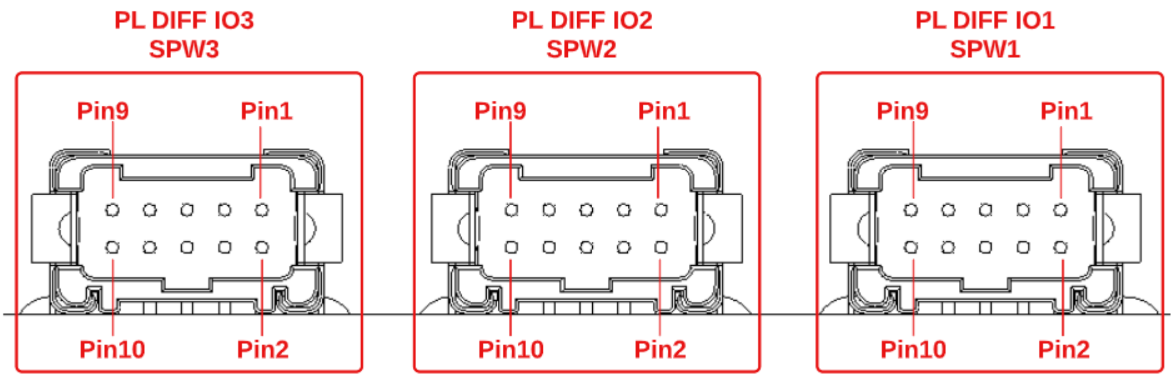


Figure 4.11: SPW1, SPW2 and SPW3 pinout.

Each SpaceWire interface uses two signals, data and strobe, in receive and transmit direction to send serial bit streams. The signals are based on LVDS according to the ANSI TIA/EIA-644 Standard and require two pins for each signal. The signals are named as presented in Table 4.7.

Pin	Signal	Description
1	Dout-	LVDS Data output negative line
2	Sin+	LVDS Strobe input positive line[1]
3	Dout+	LVDS Data output positive line
4	Sin-	LVDS Strobe input negative line[1]
5	GND	GND connection for inner cable shielding[2]
6	GND	GND connection for outer cable shielding[2]
7	Sout-	LVDS Strobe output negative line
8	Din+	LVDS Data input positive line[1]
9	Sout+	LVDS Strobe output positive line
10	Din-	LVDS Data input negative line[1]

Table 4.7: SDR MK3 SpaceWire interface signals.

[1] Din and Sin inputs are equipped with 100 Ω termination resistors across the positive and negative terminals. The terminations reside internal to Z7000 and is realized using programmable logic (PL). Meaning the SDR MK3 needs to be powered for the termination to be present. When unpowered the inputs are high impedance.

[2] Two pins for inner and outer cable shielding are available in each SpaceWire interface. A SpaceWire cable contain four twisted pair of wires with a characteristic impedance of 100 Ω. In case of shielding, it is possible to use the GND pins to terminate inner (around each twisted pair) and outer shielding by connecting to those pins.

4.4.3 SDR MK3 Debug Interface

The SDR MK3 DOCK is equipped with a debug connector for production and debug purposes. It uses a Picoblade, 53261-0971 1.25 mm pitch high-reliability connector from Molex. The DEBUG connector pinout can be seen in Figure 4.12 and Table 4.8.

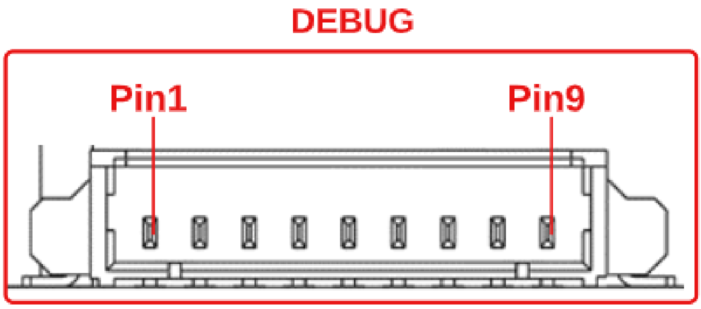


Figure 4.12: DEBUG connector pinout.

Pin	Signal	Description
1	TDO	JTAG Test Data Out
2	TCK	JTAG Test Clock
3	TMS	JTAG Test Mode Select
4	TDI	JTAG Test Data In
5	SYS_RST	System Reset
6	3.3V	3.3 V from the NanoCom SDR
7	UART_RX	Debug UART Receive Line
8	UART_TX	Debug UART Transmit Line
9	GND	N/A

Table 4.8: DEBUG pinout table.

Each NanoCom Link product is delivered with the required hardware to interface between the debug UART and universal serial bus (USB) (DB1, DB2, and DB3 in 4.1). By connecting the USB to a personal computer (PC), it is possible to access the Linux command line interface on the SDR using a terminal program. The interface is not intended to be used in flight or integrated with the satellite bus.

4.4.4 SDR MK3 TR600 AFE Control Interface

Each TR600 module is equipped with two AFE CTRL connectors, dedicated configuration, and control of the RF frontends. It uses Picoblade, 53261-0971, 1.25 mm pitch high-reliability connectors from Molex. The two connectors are interconnected and have similar pin-out, see Figure 4.13 and Table 4.9.

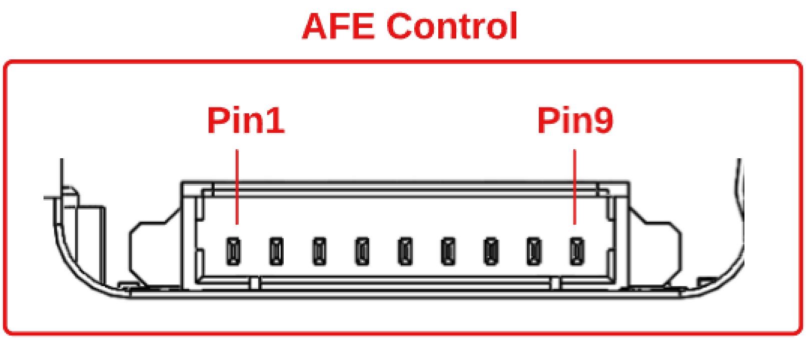


Figure 4.13: TR600 AFE CTRL connector pinout.

Pin	Signal	Description
1	CAN2-P	CAN2 positive line used for RF CSP control
2	CAN2-N	CAN2 negative line used for RF CSP control
3	GND	
4	I2C-SCL	I2C serial clock line used for RF CSP control
5	I2C-SDA	I2C serial data line used for RF CSP control
6	PSU	Output 4.6 V power supply
7	AUXDAC2	TR600 transceiver AD9361-AUXDAC2
8	AUXADC	TR600 transceiver AD9361-AUXADC
9	GND	

Table 4.9: TR600 AFE CTRL connector pinout table.

ANT2150 S-CTRL interface uses CAN2-P, CAN2-N and GND for control and configuration. ANT8250 X-CTRL interface uses CAN2-P, CAN2-N, I2C-SCL, I2C-SDA and GND for control and configuration. The other pin/interfaces are not used on NanoCom Link and must be left ‘not connected’.

4.4.5 ANT2150-DIP Control Interface

ANT2150-DUP is equipped with an S-CTRL connector, dedicated configuration, and control. It uses a PicoLock, 504050-1091, 1.5 mm pitch high-reliability connector from Molex, see Figure 4.14 and Table 4.10.

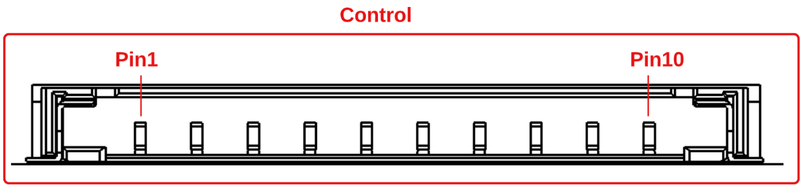


Figure 4.14: ANT2150-DUP S-CTRL connector pinout.

Pin	Signal	Description
1	GND	
2	GND	
3	I2C-SCL	I2C serial clock line
4	I2C-SDA	I2C serial data line
5	CAN2-N	CAN2 negative line used for RF CSP control
6	CAN2-P	CAN2 positive line used for RF CSP control
7	GND	
8	TXEN	TX Enable control pin
9	TXON	TX ON control pin
10	RXON	RX ON control pin

Table 4.10: ANT2150-DUP S-CTRL connector pinout table.

ANT2150-DUP uses CAN2-P, CAN2-N and GND for control and configuration. The other pin / interfaces are not used on NanoCom Link and must be left ‘not connected‘.

4.4.6 ANT8250 Control Interface

ANT8250 is equipped with an X-CTRL connector, dedicated configuration, and control. It uses a Picoblade, 53398-1071, 1.25 mm pitch high-reliability connector from Molex. See 4.15 and 4.11.

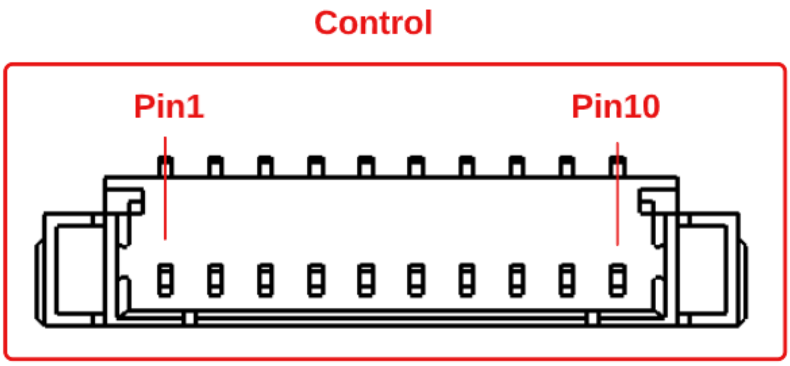


Figure 4.15: ANT8250 X-CTRL connector pinout.

Pin	Signal	Description
1	GND	
2	GP_Spare	Not used
3	PPS L	Not used
4	PPS H	Not used
5	GND	
6	I2C-SDA	I2C serial data line used for RF CSP control
7	GND	
8	I2C-SCL	I2C serial clock line used for RF CSP control
9	CAN2-N	CAN2 negative line used for RF CSP control
10	CAN2-P	CAN2 positive line used for RF CSP control

Table 4.11: ANT8250 X-CTRL connector pinout table.

ANT8250 uses CAN2-P, CAN2-N, I2C-SCL, I2C-SDA, and GND for control and configuration. The other pin/interfaces are not used on NanoCom Link and must be left ‘not connected‘.

4.5 RF Interfaces

NanoCom Link is delivered with the required coax cables to interconnect SDR MK3 TR600 with ANT2150-DUP and ANT8250. The product is tested and qualified based with the characteristics of those specific cables.

Depending on NanoCom Link variant the connectors showcased in Table 4.12 are used to interconnect SDR MK3 TR600 with ANT2150-DUP and ANT8250.

SDR MK3 TR600	Connector	RF Frontend	Connector	Signal	Frequency
Slot A	T1	ANT2150-DUP	S-RF TX	S-RF TX	2200 MHz to 2290 MHz
	R1		S-RF RX	S-RF RX	2025 MHz to 2120 MHz
Slot B	T1	ANT8250	RF IN	X-IF	1150 MHz

Table 4.12: Connectors of the NanoCom Link variants.

4.5.1 SDR MK3 TR600 RF Connectors

Each TR600 module is equipped with four SMPM RF connectors 925-126J-51P from Amphenol, see pinout in Figure 4.16 and Table 4.13.

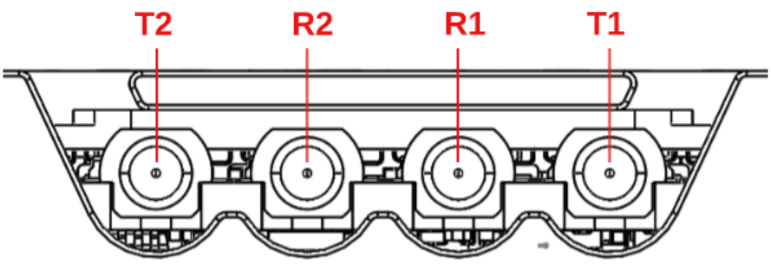


Figure 4.16: TR600 RF connector pinout.

RF Connector	Type	Manufacturer/Part Number	Description
T1	SMPM	Amphenol / 925-126J-51P	TR600 TX output 1
R1	SMPM	Amphenol / 925-126J-51P	TR600 RX input 1
T2	SMPM	Amphenol / 925-126J-51P	TR600 TX output 2
R2	SMPM	Amphenol / 925-126J-51P	TR600 RX input 2

Table 4.13: TR600 module SMPM RF connectors table.

4.5.2 ANT2150-DUP RF Connectors

ANT2150-DUP is equipped with two RF connectors 73413-0040 from Molex, see pinout in Figure 4.17 and Table 4.14.

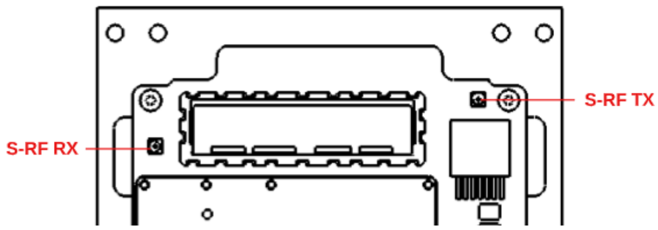


Figure 4.17: ANT2150-DUP RF connector pinout.

RF Connector	Type	Manufacturer/Part Number	Description
S-RF TX	SSMCX	Molex / 73413-0040	ANT2150-DUP TX frequency input from SDR MK3 TR600 T1 in Slot A
S-RF RX	SSMCX	Molex / 73413-0040	ANT2150-DUP RX frequency output to SDR MK3 TR600 R1 in Slot A

Table 4.14: ANT2150-DUP RF connector table.

4.5.3 ANT8250 RF Connectors

ANT8250 is equipped with three RF connectors, see pinout in Figure 4.18 and Table 4.15.

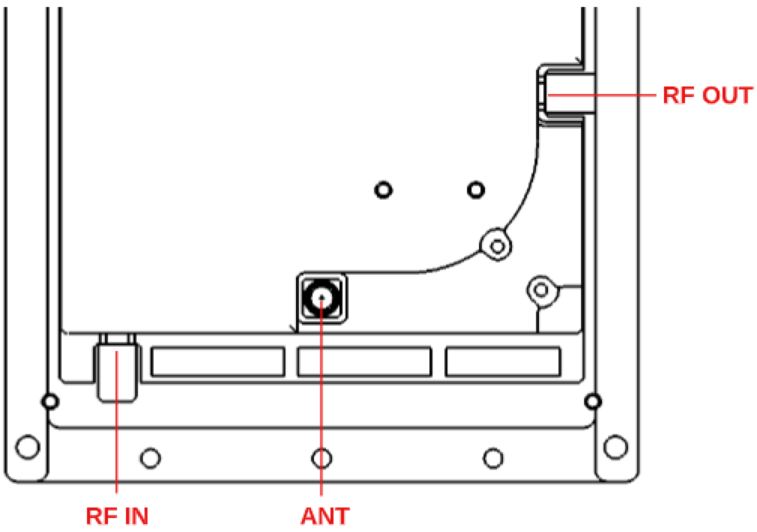


Figure 4.18: ANT8250 RF connector pinout.

In the standard configuration RF IN is to be connected to TR600 Slot B T1 using the X-IF cable (see Table 4.1). And RF OUT is to be connected to the ANT port using the X-RF cable (see Table 4.1).

In case the 'DSN Filter Kit' option has been selected, the X-IF cable is to be replaced by DSN X-IF1, X-IF2 with the DSN X-IF Filter fitted (see Table 4.2). And X-RF cable is to be replaced by DSN X-RF1, X-RF2 with the DSN X-RF Filter fitted (see Table 4.2).

RF Connector	Type	Manufacturer/Part Number	Description
RF IN	SMPM	Amphenol / 925-126J-51P	ANT8250 RF IF input from SDR MK3 TR600 T1 in Slot B
RF OUT	SMPM	Amphenol / 925-126J-51P	ANT8250 RF output of the amplified and up-converted signal going to the X-Band patch antenna
ANT	SMP	Amphenol / SMP-MSLD-PCT-10	Input of the X-Band patch antenna

Table 4.15: ANT8250 RF connector table.

5 Electrical Characteristics

5.1 SDR MK3 Interfaces

Connector	Symbol	Description	Min	Typ	Max	Unit
Power PWR-1 PWR-2	V_{IN}	Supply voltage	12		32	V
	I_{IN}	Supply current			1.0	A
	EN_{THHIGH}	Enable signal threshold, EN rising	0.95	1.01	1.07	V
	EN_{HYST}	Enable signal hysteresis		45		mV
	$EN_{PIN\_CUR\_5V}$	EN pin current, EN=5 V, VIN=12 V to 32 V	146		350	µA
	$EN_{PIN\_CUR\_0V}$	EN pin current, EN=0 V, VIN=12 V to 32 V	−320		−120	µA
SpaceWire[1] PL DIFF IO1 PL DIFF IO2 PL DIFF IO3	SPW_{INDIFF}	Differential input voltage, ICM=1.25 V	100	350	600	mV
	SPW_{INCM}	Input common mode voltage, IDIFF=±350 mV	0.3	1.2	1.425	V
	SPW_{INTERM}	Input termination resistance		100		Ω
	$SPW_{OUTDIFF}$	Differential output voltage, RT = 100 Ω	247	350	600	mV
	SPW_{OUTCM}	Output common mode voltage, RT = 100 Ω	1.0	1.25	1.425	V
RS422[2] COM-1 COM-2	$RS422_{INDIFF}$	Differential input threshold voltage	−0.2		0.2	V
	$RS422_{INHYS}$	Differential input hysteresis		50		mV
	$RS422_{INPV}$	Receiver input voltage range	0		4	V
	$RS422_{OUTDIFF}$	Differential output voltage, RT = 100 Ω	±2.0			V
	$RS422_{OUTCM}$	Output common mode voltage, RT = 100 Ω			3	V
CAN[3] COM-1 COM-2	$CAN1\text{-}P_{OUT}$	CAN bus output voltage dominant	2.15	2.9	3.3	V
	$CAN1\text{-}N_{OUT}$	CAN bus output voltage dominant	0.5	0.9	1.65	V
	$CAN1_{OUTDIFF}$	Differential output voltage recessive, no RT	−0.5	0	0.05	V
	$CAN1_{OUTCM}$	Common mode output voltage recessive and dominant, RT = 60 Ω	1.45	1.95	2.45	V
	$CAN1_{INDIFF}$	Differential input threshold voltage	500		900	mV
	$CAN1_{INHYS}$	Differential input hysteresis		150		mV
	$CAN1_{INCM}$	Input common mode voltage			±25	V

Table 5.1: SDR MK3 Interfaces.

[1] In- and output lines are equipped with electrostatic discharge (ESD) protection to withstand ±25 kV and comply with IEC 61000-4-2 level 4.

[2] The RS422 input on COM-1 and COM-2 is equipped with 120 Ω differential termination between RS422-RX-P and RS422-RX-N terminals (see Figure 5.1). For failsafe operation the differential input is equipped with a resistive divider network to terminate the input of the RS422 transceiver when nothing is connected. The resistive network consists of a 390 Ω pullup via a schottky diode to 3.3 V supply and a 390 Ω pulldown to GND. In- and out-put lines are equipped with ESD protection to withstand ±15 kV and comply with IEC 61000-4-2 level 4.

[3] The CAN1 port on COM-1 and COM-2 is without any differential termination between CAN1-P and CAN1-N terminals. Differential termination will have to be fitted externally at the outer ends of the CAN network. The inputs can withstand up to ±25 kV human-body model (HBM).

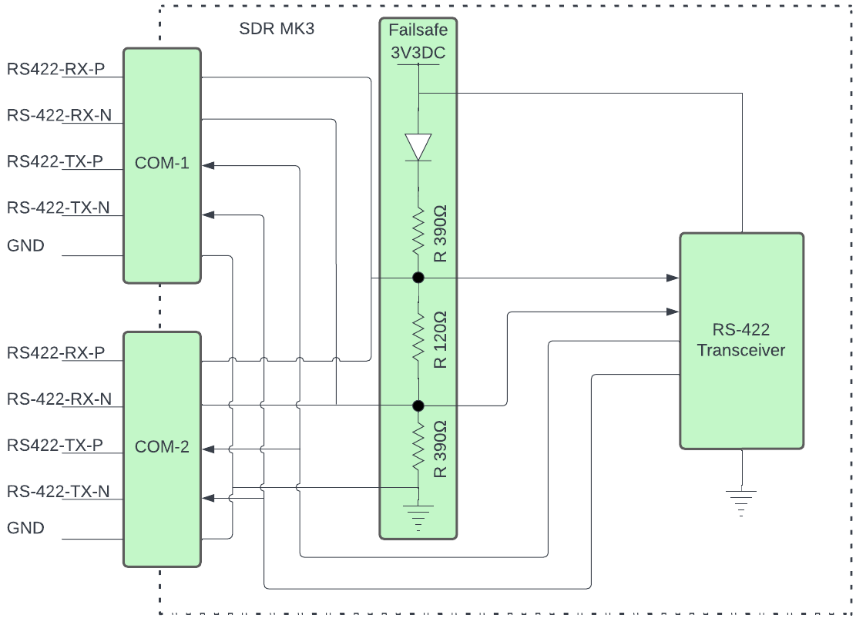


Figure 5.1: RS-422 COM-1 and COM-2 interface.

5.2 AMT2150-DUP Power Supply

Connector	Symbol	Description	Min	Typ	Max	Unit
S-PWR	V_{IN}	Supply voltage	8		18	V
	I_{IN}	Supply current[1]			1.5	A
	$V_{ABBON\text{-}HIGH}$	ABBON high level = Antenna is ON	2.5		18	V
	$V_{ABBON\text{-}LOW}$	ABBON high level = Antenna is OFF	0		0.4	V
	I_{ABBON}	ABBON input current 8 V to 18 V	0.06		0.8	mA

Table 5.2: ANT2150-DUP power supply table.

5.3 AMT8250 Power Supply

Connector	Symbol	Description	Min	Typ	Max	Unit
X-PWR	V_{BAT}	Frontend supply voltage	12		32	V
	I_{BAT}	Frontend supply current[1]			2	A
	V_{COM}	Communication interface supply voltage	4.9	5.0	5.1	V
	I_{COM}	Communication Interface supply current[2]			1	A

Table 5.3: ANT8250 power supply table.

[1] V_{IN} input sees about 2.2 µF input capacitance, and additional 10 µF when ABBON is asserted.

[2] V_{COM} input includes an electromagnetic interference (EMI) filter with about 45 µF input capacitance. To protect the circuit inrush current should be limited to 1 A.

5.4 System Power Consumption

Power consumption is defined for three modes of operation, as seen on Figure 5.2.

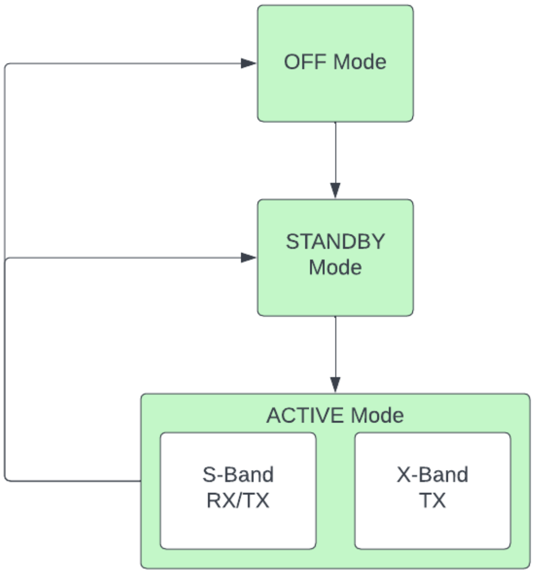


Figure 5.2: Modes of operation.

The modes are defined as in Table 5.4.

Modes of operation	Description
OFF Mode	All supply voltages are present except for V_{SDR} which is powered OFF.
STANDBY Mode	All supply voltages are present. SDR has booted and is in idle waiting for commands on the control interface
ACTIVE Mode	All supply voltages are present. S-Band or/and X-Band RF links are active.

Table 5.4: Modes of operation of the NanoCom Link.

The power consumption of the different modes is specified in Tables 5.5, 5.7 and 5.11 for NanoCom Link S, X and SX respectively.

5.4.1 NanoCom Link S Power Consumption

Typical values are expected average power consumption at +25 °C. Min. and Max. are worst case power consumption across modulation, symbol rate, power level, frequency, and temperature extremes. The return loss of the antenna is assumed to be −10 dB or better.

Mode	Module	Net	VDC	Min	Typ	Max	Unit
OFF	SDR MK3	V_{SDR}	0	0.0	0.0	0.0	W
	ANT2150	$V_{MAIN\text{-}2150}$	8 to 18	0.1	0.1	0.3	W
STANDBY	SDR MK3	V_{SDR}	12 to 32	3.5	5.0	7.0	W
	ANT2150	$V_{MAIN\text{-}2150}$	8 to 18	0.1	0.1	0.3	W
ACTIVE	SDR MK3	V_{SDR}	12 to 32	5.0	6.3	9.0	W
	ANT2150	$V_{MAIN\text{-}2150}$	8 to 18	2.0	Table 5.6	15.0	W

Table 5.5: Power Consumption Specifications.

TX PWR LVL	−30 °C		+25 °C		+55 °C		Unit
	Min	Max	Min	Max	Min	Max	
0	2.8	4.1	3.1	4.0	3.1	3.9	W
1	2.9	4.4	3.2	4.2	3.3	4.2	W
2	3.1	4.7	3.3	4.5	3.4	4.4	W
3	3.3	5.1	3.5	4.8	3.6	4.7	W
4	4.6	6.7	4.7	6.3	4.7	6.1	W
5	4.9	7.1	5.0	6.7	5.0	6.4	W
6	5.1	7.6	5.4	7.1	5.3	6.8	W
7	5.5	8.0	5.8	7.6	5.7	7.1	W
8	7.0	10.4	7.3	9.7	7.2	9.2	W
9	7.5	10.8	7.8	10.1	7.6	9.6	W
10	7.7	11.0	8.4	10.6	8.1	10.1	W
11	8.3	11.4	9.0	10.9	8.7	10.5	W
12	9.0	11.6	9.5	11.1	9.2	10.7	W

Table 5.6: ANT2150 Power Consumption for Power Level 0 to 12, $V_{MAIN\text{-}2150} = 8\,V$ to $18\,V$.

5.4.2 Nanocom Link X Power Consumption

Typical values are expected average power consumption at +25 °C. Min. and Max. are worst case power consumption across MODCOD, symbol rate, power level, frequency, and temperature extremes. The return loss of the antenna is assumed to be −10 dB or better.

Mode	Module	Net	VDC	Min	Typ	Max	Unit
OFF	SDR MK3	V_{SDR}	0	0.0	0.0	0.0	W
	ANT8250	$V_{MAIN\text{-}8250}$	12 to 32	0.0	0.0	0.0	W
		$V_{COM\text{-}8250}$	5	0.4	0.6	1.0	W
STANDBY	SDR MK3	V_{SDR}	12 to 32	3.5	5.4	7.0	W
	ANT8250	$V_{MAIN\text{-}8250}$	12 to 32	0.0	0.0	0.0	W
		$V_{COM\text{-}8250}$	5	0.3	0.7	1.0	W
ACTIVE	SDR MK3	V_{SDR}	12 to 32	4.5	5.9	8.0	W
	ANT8250	$V_{MAIN\text{-}8250}$	12 to 32	5.0	Tables 5.8, 5.9 and 5.10	20.0	W
		$V_{COM\text{-}8250}$	5	2.0	2.4	3.0	W

Table 5.7: Power consumption specifications for NanoCom Link X.

MODCOD	$V_{MAIN\text{-}8250}$	−30 °C		+25 °C		+55 °C		Unit
		Min	Max	Min	Max	Min	Max	
1-23	12VDC	5.8	6.1	5.9	6.2	5.9	6.3	W
	28VDC	6.1	6.4	6.2	6.5	6.2	6.5	W
	32VDC	6.2	6.4	6.2	6.6	6.3	6.6	W
24-28	12VDC	9.2	9.3	9.2	9.3	9.2	9.3	W
	28VDC	9.6	9.7	9.6	9.7	9.6	9.7	W
	32VDC	9.6	9.7	9.6	9.7	9.6	9.7	W

Table 5.8: ANT8250 $V_{MAIN\text{-}8250}$ Power Consumption Power Level 0.

MODCOD	$V_{MAIN\text{-}8250}$	−30 °C		+25 °C		+55 °C		Unit
		Min	Max	Min	Max	Min	Max	
1-23	12VDC	7.5	8.7	7.6	8.9	7.7	8.9	W
	28VDC	7.9	9.1	8.0	9.3	8.0	9.3	W
	32VDC	8.0	9.2	8.1	9.3	8.1	9.4	W
24-28	12VDC	14.6	14.7	14.6	14.7	14.6	14.7	W
	28VDC	15.0	15.2	15.0	15.2	15.0	15.2	W
	32VDC	15.2	15.3	15.2	15.3	15.2	15.3	W

Table 5.9: ANT8250 $V_{MAIN\text{-}8250}$ Power Consumption Power Level 1.

MODCOD	$V_{MAIN\text{-}8250}$	−30 °C		+25 °C		+55 °C		Unit
		Min	Max	Min	Max	Min	Max	
1-28	12VDC	12.9	15.0	12.9	15.0	12.9	14.9	W
	28VDC	13.4	15.5	13.5	15.4	13.4	15.4	W
	32VDC	13.5	15.6	13.5	15.6	13.5	15.5	W

Table 5.10: ANT8250 $V_{MAIN\text{-}8250}$ Power Consumption Power Level 2.

5.4.3 NanoCom Link SX Power Consumption

Typical values are expected average power consumption at +25 °C. Min. and Max. are worst case power consumption across modulation, symbol rate, MODCOD, power level, frequency, and temperature extremes. The return loss of the antenna is assumed to be −10 dB or better.

Mode	Module	Net	VDC	Min	Typ	Max	Unit
OFF	SDR MK3	V_{SDR}	0	0.0	0.0	0.0	W
	ANT2150	$V_{MAIN-2150}$	8 to 18	0.1	0.1	0.3	W
	ANT8250	$V_{MAIN-8250}$	12 to 32	0.0	0.0	0.0	W
		$V_{COM-8250}$	5	0.4	0.6	1.0	W
STANDBY	SDR MK3	V_{SDR}	12 to 32	4.5	6.1	7.5	W
	ANT2150	$V_{MAIN-2150}$	8 to 18	0.1	0.1	0.3	W
	ANT8250	$V_{MAIN-8250}$	12 to 32	0.0	0.0	0.0	W
		$V_{COM-8250}$	5	0.3	0.7	1.0	W
ACTIVE	SDR MK3	V_{SDR}	12 to 32	5.0	8.1	10.2	W
	ANT2150	$V_{MAIN-2150}$	8 to 18	2.0	Table 5.6	16.0	W
	ANT8250	$V_{MAIN-8250}$	12 to 32	5.0	Tables 5.8, 5.9 and 5.10	20.0	W
		$V_{COM-8250}$	5	2.0	2.4	3.0	W

Table 5.11: Power consumption specifications for NanoCom Link SX.

6 RF Performance Characteristics

All performance parameters listed in this section refer to the RF output of AFE2150 or AFE8250. This is shown as the reference plane in Figure 6.1.

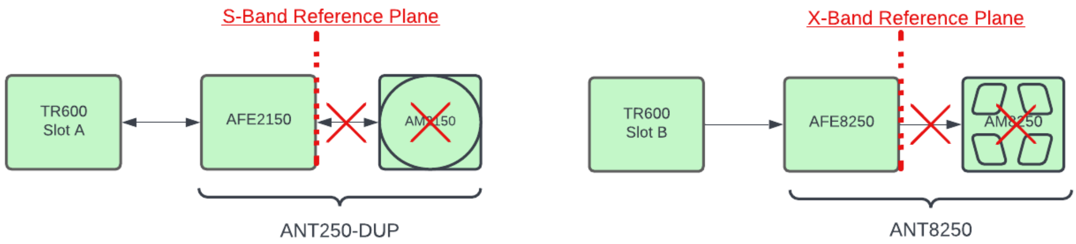


Figure 6.1: Reference plane RF performance characteristics.

6.1 S-Band Receiver

Unless otherwise stated the listed data in Table 6.1 is valid for BPSK and QPSK modulation, all temperatures, and supply voltages.

Symbol	Description	Min	Typ	Max	Unit
RX_{FREQ}[1]	RX Frequency Range	2025		2110	MHz
RX_{SYM}	RX symbol rate	1.0		7.5	MBd
RX_{BIT_BPSK}[2]	RX bit rate BPSK	1.0		7.5	Mbit/s
RX_{BIT_QPSK}[2]	RX bit rate QPSK	2.0		15	Mbit/s
$RX_{Pull\_In\_QPSK}$	RX frequency pull-in range QPSK			$\pm\frac{RX_{SYM}}{32}$	MHz
$RX_{Pull\_In\_BPSK}$	RX frequency pull-in range BPSK			$\pm\frac{RX_{SYM}}{8}$	MHz
RX_{Input_Level}	Maximum input level			−40.0	dBm
RX_{RSSI_Step}	RSSI step size		0.25		dB
RX_{Noise_Figure}	System noise figure:				
	RX_{Input_Level} ≤−90 dBm, T_{AMB} = +25 °C		2.1	2.6	dB
	RX_{Input_Level} ≤−90 dBm, T_{AMB} = −40 °C to +55 °C			3.1	dB
RX_{Sens_Level}[3]	BPSK 1.0 MBd, CC+RS coded, BER $\leq 10 \cdot 10^{-6}$		−111.5		dBm
	BPSK 2.0 MBd, CC+RS coded, BER $\leq 10 \cdot 10^{-6}$		−108.5		dBm
	BPSK 4.0 MBd, CC+RS coded, BER $\leq 10 \cdot 10^{-6}$		−105.5		dBm
	BPSK 7.5 MBd, CC+RS coded, BER $\leq 10 \cdot 10^{-6}$		−103.0		dBm
	QPSK 1.0 MBd, CC+RS coded, BER $\leq 10 \cdot 10^{-6}$		−108.5		dBm
	QPSK 2.0 MBd, CC+RS coded, BER $\leq 10 \cdot 10^{-6}$		−105.5		dBm
	QPSK 4.0 MBd, CC+RS coded, BER $\leq 10 \cdot 10^{-6}$		−102.5		dBm
	QPSK 7.5 MBd, CC+RS coded, BER $\leq 10 \cdot 10^{-6}$		−100.0		dBm
RX_{FREQ_INIT}	Initial RX frequency error vs temperature	−6.0		+6.0	ppm
RX_{FREQ_AGE}	RX frequency error due to aging	−2.0		+2.0	ppm

Table 6.1: S-Band receiver characteristics.

[1] Effective RX frequency range which must cover RXSYM/2 of the received signal. E.g., for an RX symbol rate of 2 MBd the lowest supported RX center frequency is 2026 MHz and the highest supported RX center frequency is 2109 MHz.

[2] Uncoded bit rate. Actual throughput is depending on coding and signalling overhead. Refer to Section 8.2 for further information on achievable throughput.

[3] Input level where bit error rate (BER) $\leq 10 \cdot 10^{-6}$ at $T_{AMB} = +25\,°C$. Bits are concatenated coded according to CCSDS 131.0-B-3[2] , with rate ½ convolutional inner code and Reed-Solomon (255, 223) outer code, with an interleaving dept of 8 blocks. Refer to Figure 6.4 for further information on BER performance.

6.1.1 RX RSSI Reporting

RX RSSI reporting is a relative figure which presents the level of the received signal in dB. The figure can be used to monitor received signal levels throughout a mission. RSSI is not production calibrated or compensated. Any system related deviation on RX gain is included in the reporting.

Typical RSSI reporting versus input level at $RX_{FREQ} = 2067\,\mathrm{MHz}$ and 2.0 MBd symbol rate, see Figure 6.2.

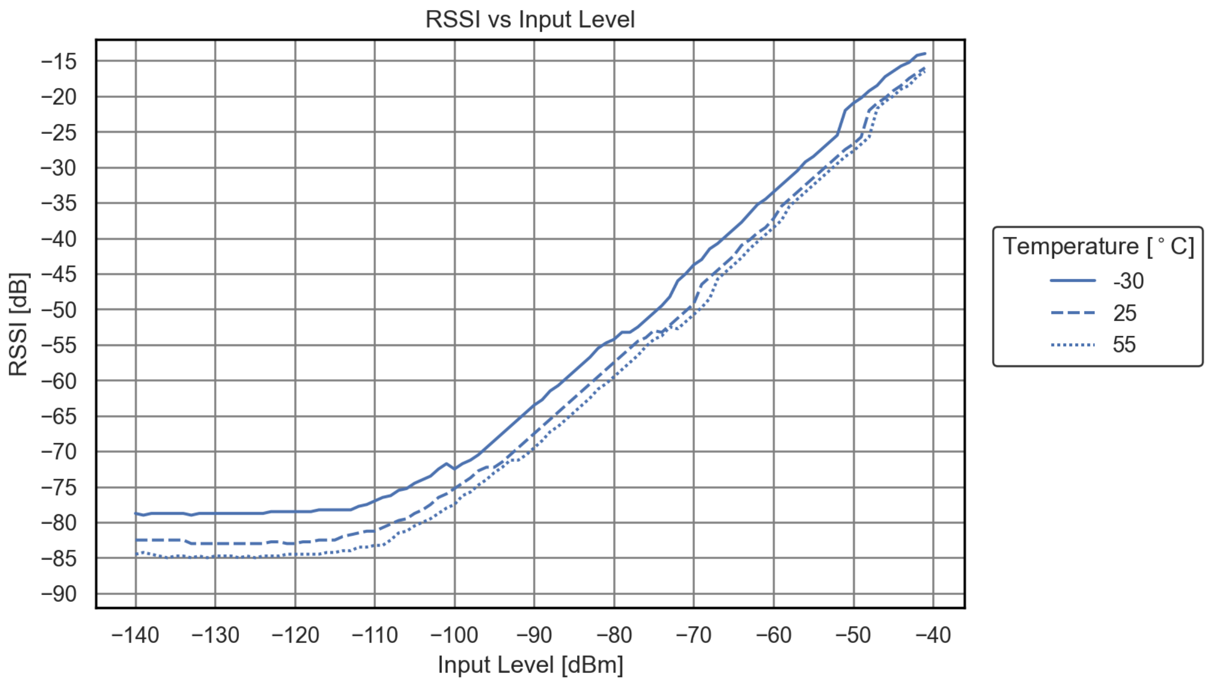


Figure 6.2: Typical RSSI reporting vs RX input level at $RX_{FREQ} = 2067\,\mathrm{MHz}$ and 2.0 MBd symbol rate.

Typical RSSI reporting versus frequency for a fixed input level of −60 dBm and −80 dBm, see Figure 6.3.

6.1.2 RX Sensitivity

Typical receiver sensitivity at $RX_{FREQ} = 2067\,\mathrm{MHz}$ and $T_{AMB} = +25\,^{\circ}\mathrm{C}$ versus input level, for different symbol rates and modulation, see Figure 6.4. Bits are concatenated coded according to CCSDS 131.0-B-3[2], with rate ½ convolutional inner code and Reed-Solomon $(255, 223)$ outer code, with an interleaving depth of 8 blocks.

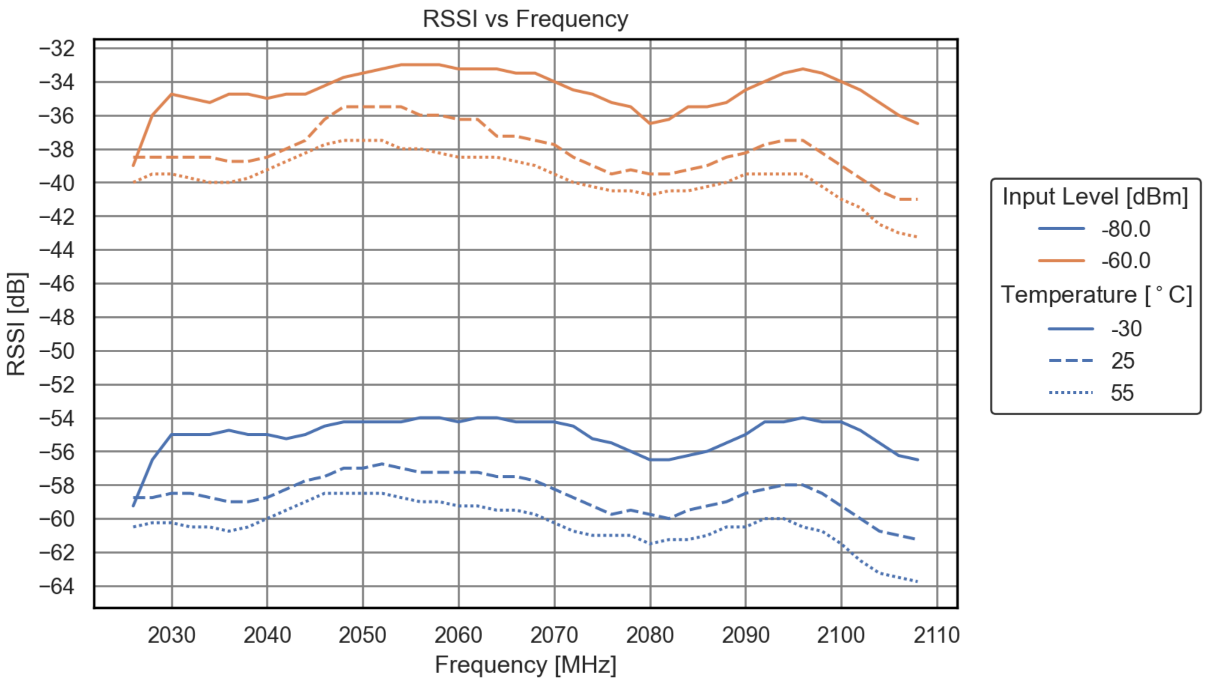


Figure 6.3: Typical RSSI reporting for a fixed RX input level of −60 dBm and −80 dBm.

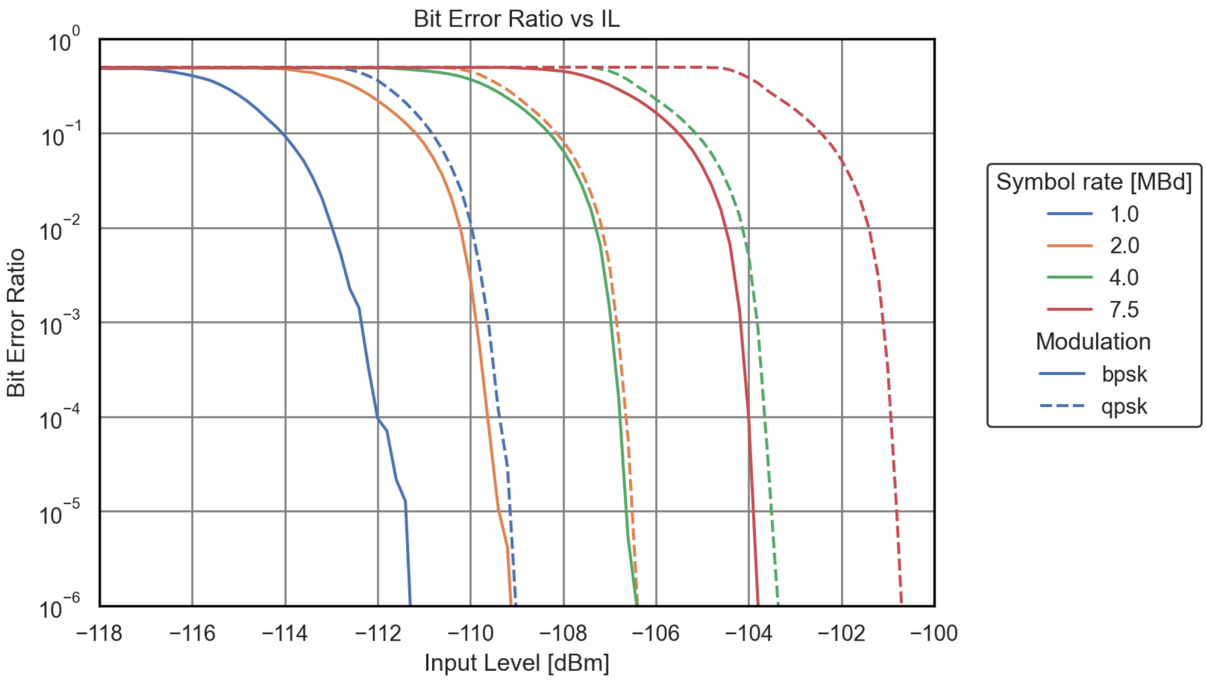


Figure 6.4: Typical BER vs RX input level at $RX_{FREQ} = 2067\,\mathrm{MHz}$ and $T_{AMB} = +25\,^{\circ}\mathrm{C}$

6.2 S-Band Transmitter

The S-Band transmitter has thirteen power level settings, 0 to 12, for controlling the RF output power. Unless otherwise stated the listed data in Table 6.2 is valid for BPSK and QPSK modulation, all supported symbol rates, temperatures, and supply voltages.

Table 6.2: S-Band transmitter characteristics.

Symbol	Description	Min	Typ	Max	Unit
TX_{FREQ}[1]	TX Frequency Range	2200		2290	MHz
TX_{SYM}	TX symbol rate	0.5		7.5	MBd
TX_{BIT_BPSK}[2]	TX bit rate BPSK	0.5		7.5	Mbit/s
TX_{BIT_QPSK}[2]	TX bit rate QPSK	1.0		15	Mbit/s
TX_{Pout_Nom}[3]	Nominal TX PWR LVL 0 to 12 range	20.0		31.5	dBm
TX_{Pout_Step}[3]	TX PWR LVL 0 to 12 step size	0.5	1	1.5	dB
TX_{Pout_Freq}[3]	Frequency variation TX PWR LVL 12	−2		1	dB
TX_{Pout_Temp}[3]	Temperature variation TX PWR LVL 12	−1		1	dB
TX_{SPUR_EM}[4]	TX spurious emission			−15	dBm
TX_{FREQ_INIT}	Initial TX frequency error vs temperature	−6.0		+6.0	ppm
TX_{FREQ_AGE}	TX frequency error due to aging	−2.0		+2.0	ppm
TX_{OCP_BW}	99 % occupied bandwidth:				
	0.5 MBd		0.6		MHz
	2.0 MBd		2.2		MHz
	7.5 MBd		8.3		MHz
TX_{SEM_MARGIN}[5]	QPSK out-of-band margin:				
	Power level 12	1.0	2.0		dB
	Power level 11	2.0	4.0		dB
	Power level 10	4.0	6.0		dB
	BPSK out-of-band margin:				
	Power level 10	1.0	2.0		dB
	Power level 9	2.0	4.0		dB
	Power level 8	4.0	6.0		dB

Table 6.2: S-Band transmitter characteristics. (Continued)

Symbol	Description	Min	Typ	Max	Unit
TX_{EVM}	QPSK RMS error vector magnitude				
	Power level 12		−23	−16	dB
	Power level 11		−24	−17	dB
	Power level 10		−25	−18	dB
	BPSK RMS error vector magnitude				
	Power level 10		−24	−16	dB
	Power level 9		−25	−17	dB
	Power level 8		−26	−18	dB

[1] Effective TX frequency range which must cover $\frac{TX_{SYM}}{2}$ of the transmitted signal. E.g., for a TX symbol rate of 4 MBd the lowest supported TX center frequency is 2202 MHz and the highest supported TX center frequency is 2288 MHz.

[2] The actual throughput is depending on coding and signalling overhead. Refer to Section 8.2 for further information on achievable throughput.

[3] Refer to Table 6.3 for further details on S-Band TX RF output power characteristics and ITU out-of-band (OOB) spectrum emission compliance.

[4] TX spurious emission according to ITU-R SM.329[8].

[5] Minimum spectrum emission margin according to ITU-R SM.1541 [9, Figure 16], refer to Section 6.2.3 for typical performance. Performance is optimized to fulfil the spectrum mask requirements, while keeping the power consumption as small as possible.

6.2.1 TX Channel Power

Typical channel power measurement versus frequency for different conditions can be seen in Table 6.3.

TX PWR LVL	Conditions	ITU OOB Comp		Min	Typ	Max	Unit
		BPSK	QPSK				
12	Nominal	Red[1]	Full		31.7		dBm
	Extreme	Red[1]	Full	−1.1		1.7	dB
11	Nominal	Red[1]	Full		31.2		dBm
	Extreme	Red[1]	Full	−1.6		2.0	dB
10	Nominal	Full	Full		30.6		dBm
	Extreme	Full	Full	−1.9		2.2	dB
9	Nominal	Full	Full		29.8		dBm
	Extreme	Full	Full	−1.4		2.8	dB
8	Nominal	Full	Full		29.1		dBm
	Extreme	Full	Full	−1.6		2.9	dB
7	Nominal	Full	Full		27.7		dBm
	Extreme	Full	Full	−1.7		3.2	dB
6	Nominal	Full	Full		26.6		dBm
	Extreme	Full	Full	−1.5		3.5	dB
5	Nominal	Full	Full		25.4		dBm
	Extreme	Full	Full	−1.4		4.0	dB
4	Nominal	Full	Full		24.6		dBm
	Extreme	Full	Full	−1.6		3.9	dB
3	Nominal	Full	Full		23.3		dBm
	Extreme	Full	Full	−1.8		4.2	dB
2	Nominal	Full	Full		22.1		dBm
	Extreme	Full	Full	−1.9		4.5	dB
1	Nominal	Full	Full		21.0		dBm
	Extreme	Full	Full	−1.9		4.6	dB
0	Nominal	Full	Full		20.1		dBm
	Extreme	Full	Full	−2.0		4.3	dB

Table 6.3: Typical S-Band TX RF output power characteristics and ITU out-of-band compliance vs TX PWR LVL setting.

Nominal conditions: Typical Pout $TX_{FREQ} = 2245\,\mathrm{MHz}$, $T_{AMB} = +25\,°\mathrm{C}$, $V_{MAIN\text{-}2150} = 12\,\mathrm{VDC}$ all supported symbol rates and modulation.

Extreme conditions: Minimum and maximum recorded Pout across TX frequency, temperature, supply voltage, symbol rate and modulation.

[1] ITU OOB compliance according to ITU-R SM.1541 [9, Figure 16] may be reduced under certain temperatures and frequencies due to spectral regrowth at TX PWR LVL 12 and 11 with BPSK modulation.

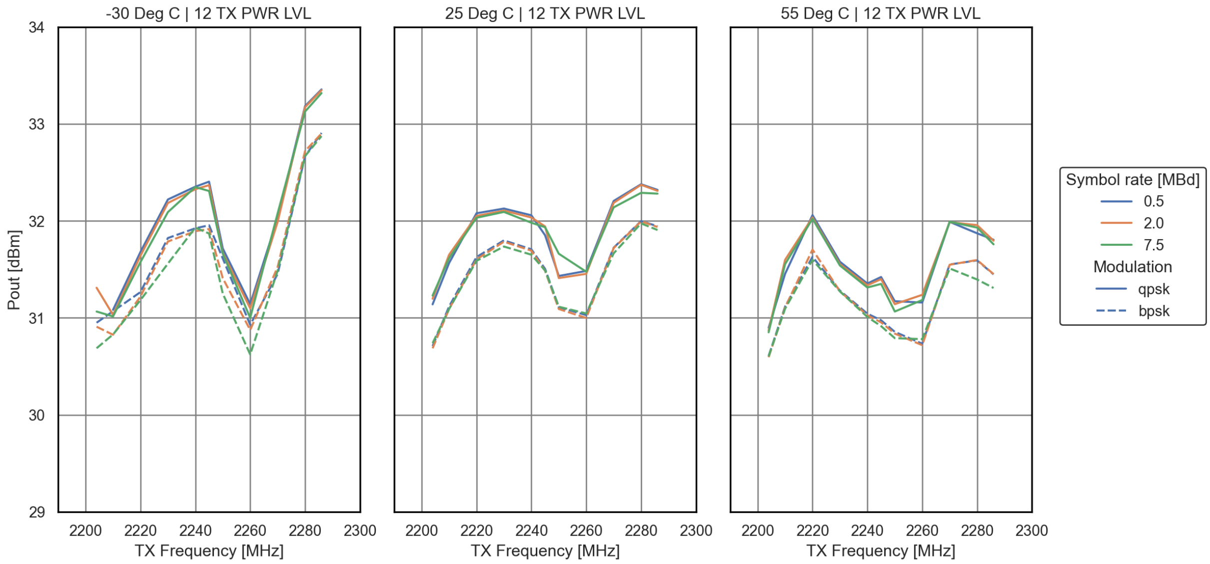


Figure 6.5: Typical channel power vs frequency at TX PWR LVL 12, $V_{MAIN\text{-}2150} = 12\,VDC$.

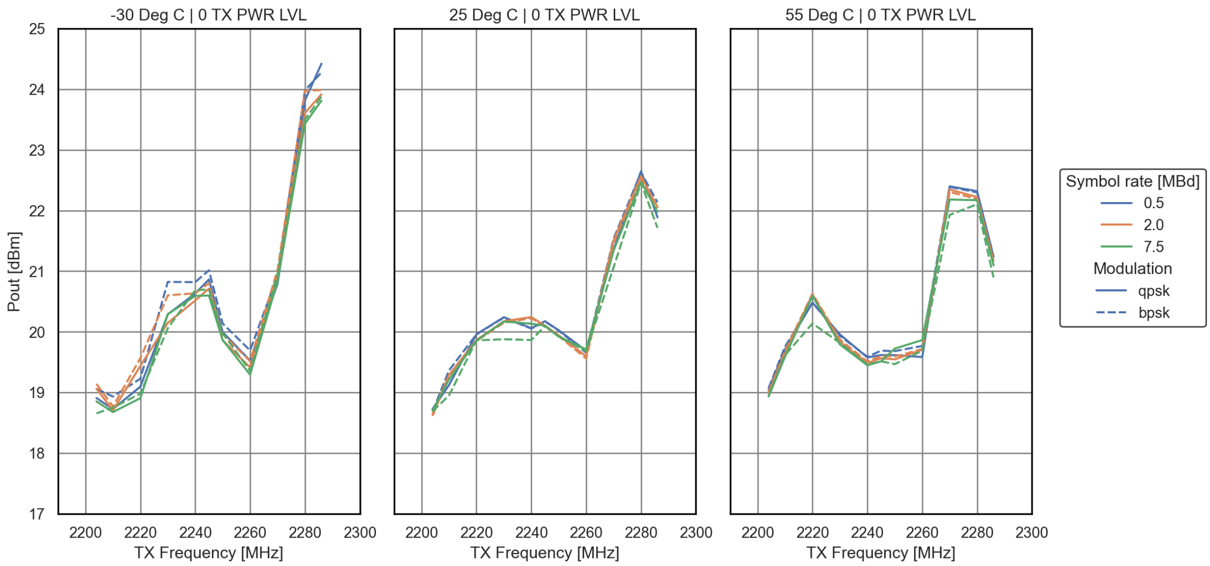


Figure 6.6: Typical channel power vs frequency at TX PWR LVL 0, $V_{MAIN\text{-}2150} = 12\,VDC$.

6.2.2 TX Occupied Bandwidth

Typical TX occupied bandwidth vs symbol rate and power level can be seen in Table 6.4. Data is measured across frequency, temperature, and supply voltage. The occupied bandwidth is the bandwidth within which 99 % of a measured power trace is contained.

Symbol Rate	Modulation	TX PWR LVL	Min	Typ	Max	Unit
0.5 MBd	BPSK	8	0.5	0.5	0.6	MHz
	BPSK	9	0.5	0.5	0.7	MHz
	BPSK	10	0.5	0.6	0.8	MHz
	QPSK	10	0.5	0.5	0.6	MHz
	QPSK	11	0.5	0.5	0.7	MHz
	QPSK	12	0.5	0.6	0.8	MHz
2.0 MBd	BPSK	8	2.1	2.2	2.3	MHz
	BPSK	9	2.1	2.2	2.7	MHz
	BPSK	10	2.1	2.2	3.1	MHz
	QPSK	10	2.1	2.2	2.4	MHz
	QPSK	11	2.1	2.2	2.8	MHz
	QPSK	12	2.1	2.2	3.3	MHz
7.5 MBd	BPSK	8	8.0	8.1	8.6	MHz
	BPSK	9	8.0	8.2	9.2	MHz
	BPSK	10	8.0	8.2	10.8	MHz
	QPSK	10	8.0	8.1	8.7	MHz
	QPSK	11	8.0	8.2	9.8	MHz
	QPSK	12	8.0	8.3	11.9	MHz

Table 6.4: Typical TX occupied bandwidth.

6.2.3 TX Spectral Emission Mask

Typical spectral emissions across frequency for different symbol rates and temperatures in the OOB domain are shown in Figures 6.7 and 6.8. Trace axes are normalized to directly compare against the spectrum mask from ITU-R SM.1541 [9, Figure 16]. OOB domain is defined as the area from the necessary bandwidth until ±2.5 times the necessary bandwidth. Necessary bandwidth is defined in ITU RR-2020-Vol.I [10, section 1.152]. The bandwidth used in the NanoCom Link S QPSK receiver is set to 1.2 times the symbol rate and is the necessary bandwidth for adequate link performance.

All measurements plots are with $V_{MAIN\text{-}2150} = 12\,\text{VDC}$ at $T_{AMB} = +25\,°\text{C}$.

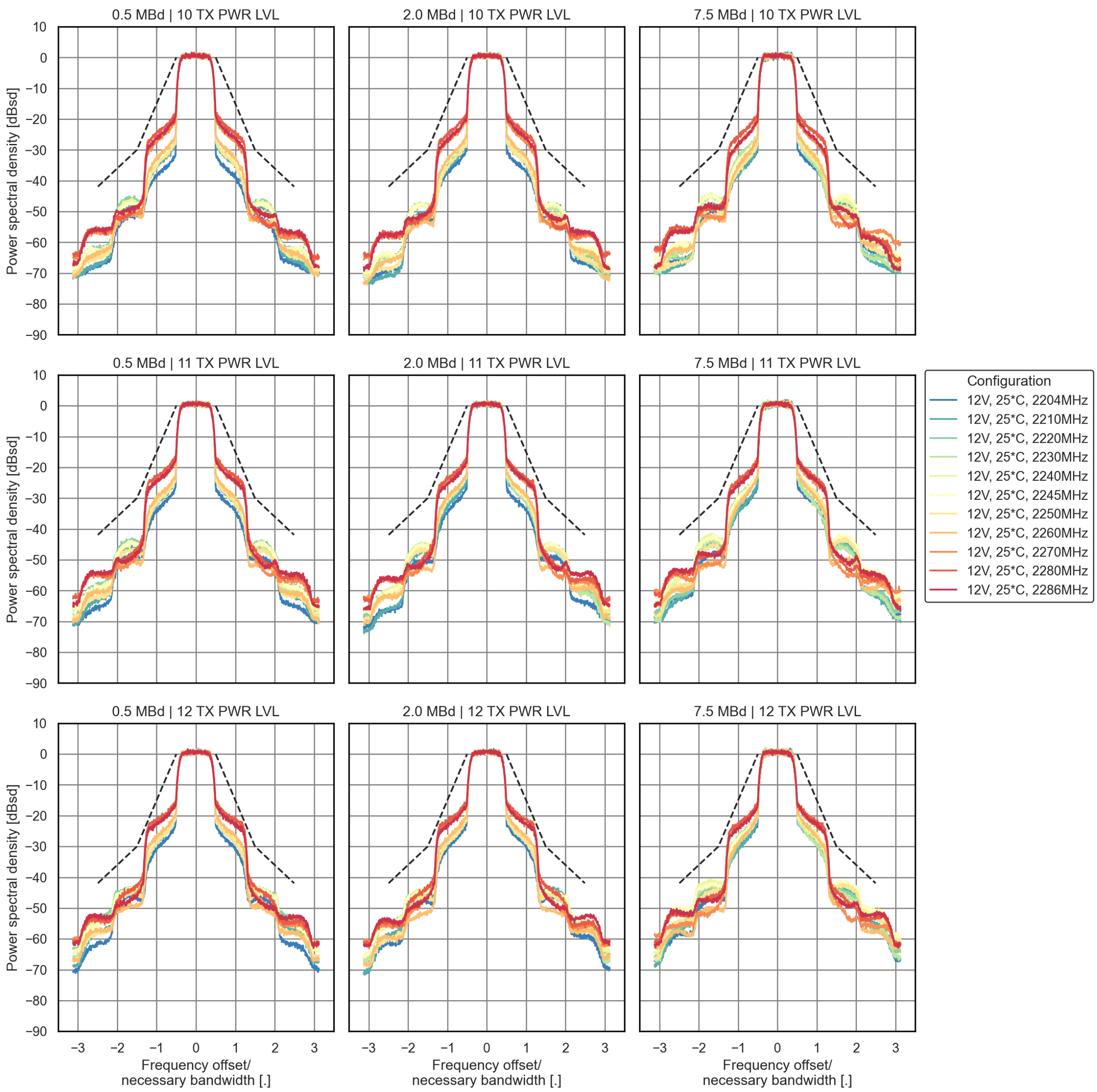


Figure 6.7: Typical spectral emission QPSK, TX PWR LVL 10, 11 and 12.

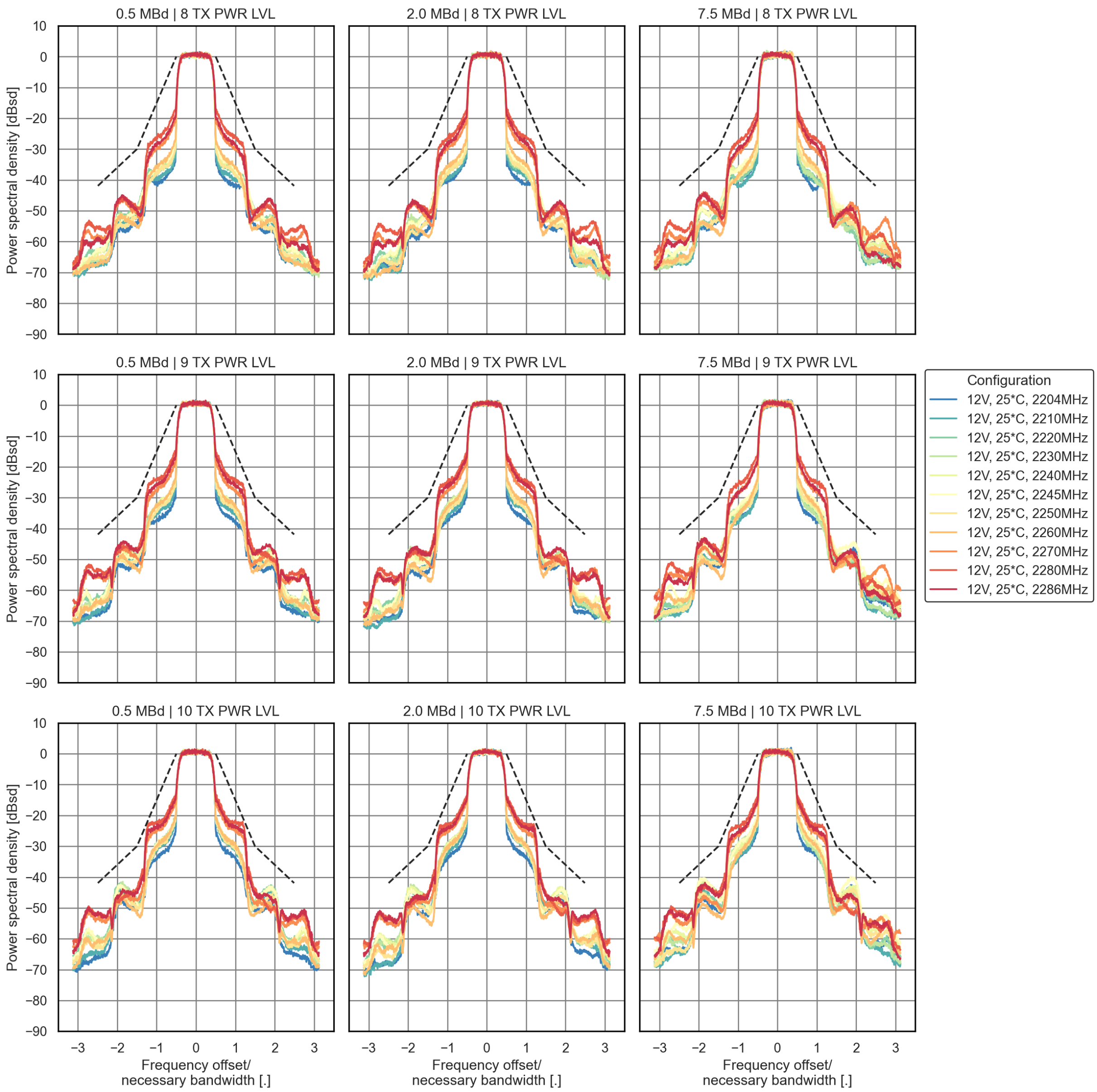


Figure 6.8: Typical spectral emission BPSK, TX PWR LVL 8, 9 and 10.

6.2.4 TX Spurious Emission

Typical spurious emissions at $TX_{FREQ} = 2245\,\mathrm{MHz}$ for TX PWR LVL 10, 11 and 12 with QPSK and BPSK modulation are shown in Figure 6.9. The spurious limit is from ITU-R SM.329 [8]. For the supported power levels, the spurious limit is fixed to −13 dBm. The spurious domain is the area outside the 2.5 times the necessary bandwidth, where necessary bandwidth is defined as 1.2 times the symbol rate. Each trace represents the maximum level recorded at $T_{AMB} = -30\,°\mathrm{C}$, $+25\,°\mathrm{C}$ and $+55\,°\mathrm{C}$.

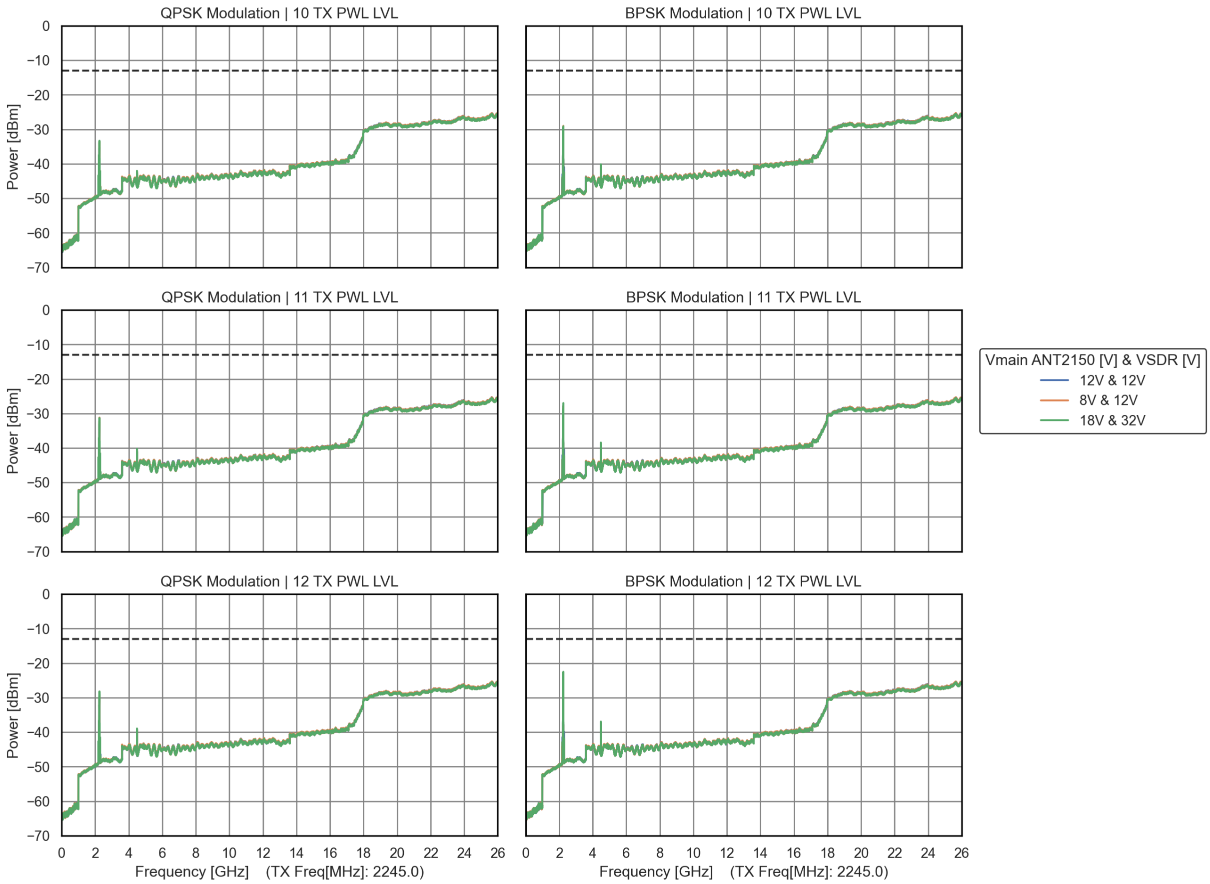


Figure 6.9: Typical spurious emission across extreme conditions.

6.3 X-Band Transmitter

Unless otherwise stated the listed data is valid for all MODCODs, symbol rates, temperatures, and supply voltages in the standard configuration without the 'DSN Filter Kit'. A detailed overview of the supported MODCODs and symbol rates are available in Table 6.6.

Table 6.5: X-Band transmitter characteristics.

Symbol	Description	Min	Typ	Max	Unit
TX_{FREQ}	TX Frequency Range	8000		8400	MHz
TX_{SYM}	TX symbol rate	2		50	MBd
TX_{BIT} [1]	TX bit rate (Max limited by variant)	1		225	Mbit/s
TX_{SPUR_EM} [2]	TX spurious emission			−15.0	dBm
TX_{FREQ_INIT}	Initial TX frequency error vs temperature	−2.0		+2.0	ppm
TX_{FREQ_AGE}	TX frequency error due to aging	−2.0		+2.0	ppm
TX_{PWR_LVL2}	Power level 2, T_{AMB} = +25 °C	32.0	33.0	34.0	dBm
	Power level 2, T_{AMB} = −40 °C to +55 °C	31.5		34.5	dBm
TX_{PWR_LVL1}	Power level 1, T_{AMB} = +25 °C	29.0	30.0	31.0	dBm
	Power level 1, T_{AMB} = −40 °C to +55 °C	28.5		31.5	dBm
TX_{PWR_LVL0}	Power level 0, T_{AMB} = +25 °C	26.0	27.0	28.0	dBm
	Power level 0, T_{AMB} = −40 °C to +55 °C	25.5		28.5	dBm
TX_{OCP_BW}	99 % Occupied BW, 2 MBd		2.2		MHz
	99 % Occupied BW, 30 MBd		32.8		MHz
	99 % Occupied BW, 50 MBd		53.3		MHz
TX_{SEM_MARGIN} [3]	Power level 2, T_{AMB} = +25 °C	3.4	5.7	9.6	dB
	Power level 2, T_{AMB} = −40 °C to +55 °C	2.5			dB
	Power level 1, T_{AMB} = +25 °C	4.6	6.8	9.9	dB
	Power level 1, T_{AMB} = −40 °C to +55 °C	2.5			dB
	Power level 0, T_{AMB} = +25 °C	1.4	7.6	9.5	dB
	Power level 0, T_{AMB} = −40 °C to +55 °C	0.3			dB
TX_{EVM}	RMS EVM. Power level 2, 30 MBd, MODCOD 1 to 23		−22.0	−18.0	dB
	RMS EVM. Power level 2, 30 MBd, MODCOD 24 to 28		−20.0	−15.0	dB
	RMS EVM. Power level 1, 30 MBd, MODCOD 1 to 28		−23.0	−19.0	dB

Continued on next page

Table 6.5: X-Band transmitter characteristics. (Continued)

Symbol	Description	Min	Typ	Max	Unit
	RMS EVM. Power level 1, 30 MBd, MODCOD 1 to 28		−24.0	−20.0	dB

[1] The maximum bit rate is depending on the purchased variant of the NanoCom Link product. The following maximum bitrates are available: 50 Mbit/s, 150 Mbit/s and 225 Mbit/s.

[2] TX spurious emission according to ITU-R SM.329[8].

[3] Minimum spectrum emission margin according to ITU-R SM.1541 [9, Figure 16], refer to section Section 6.3.3 for typical performance. Performance is optimized to fulfil the spectrum mask requirements, while keeping the power consumption as small as possible.

MODCOD	Modulation	Code Rate	Bit Rate [Mbit/s]		Symbol Rate [MBd]	
			Min	Max	Min	Max
1	QPSK	1/4	1.0	25.0	2	50
2	QPSK	1/3	1.3	33.3	2	50
3	QPSK	2/5	1.6	40.0	2	50
4	QPSK	1/2	2.0	50.0	2	50
5	QPSK	3/5	2.4	60.0	2	50
6	QPSK	2/3	2.7	66.7	2	50
7	QPSK	3/4	3.0	75.0	2	50
8	QPSK	4/5	3.2	80.0	2	50
9	QPSK	5/6	3.3	83.3	2	50
10	QPSK	8/9	3.6	88.9	2	50
11	QPSK	9/10	3.6	90.0	2	50
12	8PSK	3/5	3.6	90.0	2	50
13	8PSK	2/3	4.0	100.0	2	50
14	8PSK	3/4	4.5	112.5	2	50
15	8PSK	5/6	5.0	125.0	2	50
16	8PSK	8/9	5.3	133.3	2	50
17	8PSK	9/10	5.4	135.0	2	50
18	16APSK	2/3	5.3	133.3	2	50
19	16APSK	3/4	6.0	150.0	2	50
20	16APSK	4/5	6.4	160.0	2	50
21	16APSK	5/6	6.7	166.7	2	50
22	16APSK	8/9	7.1	177.8	2	50
23	16APSK	9/10	7.2	180.0	2	50
24	32APSK	3/4	7.5	187.5	2	50
25	32APSK	4/5	8.0	200.0	2	50
26	32APSK	5/6	8.3	208.3	2	50
27	32APSK	8/9	8.9	222.2	2	50
28	32APSK	9/10	9.0	225.0	2	50

Table 6.6: Supported MODCODs and symbol rates.

The 225 Mbit/s variant of the product supports a symbol rate of 2 MBd to 50 MBd. For the 50 Mbit/s and 150 Mbit/s variants the maximum configurable symbol rate is limited on certain MODCOD configurations. Refer to Table 6.7 for further information for maximum configurable symbol rate and resulting bit rate for the different variants.

MODCOD	50 Mbit/s Variant		150 Mbit/s Variant		225 Mbit/s Variant	
	Max Symbol Rate [MBd]	Bit Rate [Mbit/s]	Max Symbol Rate [MBd]	Bit Rate [Mbit/s]	Max Symbol Rate [MBd]	Bit Rate [Mbit/s]
1	50.0	25.0	50.0	25.0	50.0	25.0
2	50.0	33.3	50.0	33.3	50.0	33.3
3	50.0	40.0	50.0	40.0	50.0	40.0
4	50.0	50.0	50.0	50.0	50.0	50.0
5	41.7	50.0	50.0	60.0	50.0	60.0
6	37.5	50.0	50.0	66.7	50.0	66.7
7	33.3	50.0	50.0	75.0	50.0	75.0
8	31.2	49.9	50.0	80.0	50.0	80.0
9	30.0	50.0	50.0	83.3	50.0	83.3
10	28.1	50.0	50.0	88.9	50.0	88.9
11	27.8	50.0	50.0	90.0	50.0	90.0
12	27.8	50.0	50.0	90.0	50.0	90.0
13	25.0	50.0	50.0	100.0	50.0	100.0
14	22.2	50.0	50.0	112.5	50.0	112.5
15	20.0	50.0	50.0	125.0	50.0	125.0
16	18.8	50.1	50.0	133.3	50.0	133.3
17	18.5	50.0	50.0	135.0	50.0	135.0
18	18.8	50.1	50.0	133.3	50.0	133.3
19	16.7	50.1	50.0	150.0	50.0	150.0
20	15.6	49.9	46.9	150.1	50.0	160.0
21	15.0	50.0	45.0	150.0	50.0	166.7
22	14.1	50.1	42.2	150.0	50.0	177.8
23	13.9	50.0	41.7	150.1	50.0	180.0
24	13.3	49.9	40.0	150.0	50.0	187.5
25	12.5	50.0	37.5	150.0	50.0	200.0
26	12.0	50.0	36.0	150.0	50.0	208.3
27	11.2	49.8	33.8	150.2	50.0	222.2
28	11.1	50.0	33.3	149.9	50.0	225.0

Table 6.7: Maximum supported symbol rate and bit rate vs MODCODs for different variants.

6.3.1 TX Channel Power

Typical channel power measurement versus frequency for different symbol rates, MODCODs, and temperature at $V_{MAIN\text{-}8250} = 12\,\text{VDC}$ is shown in Figure 6.10.

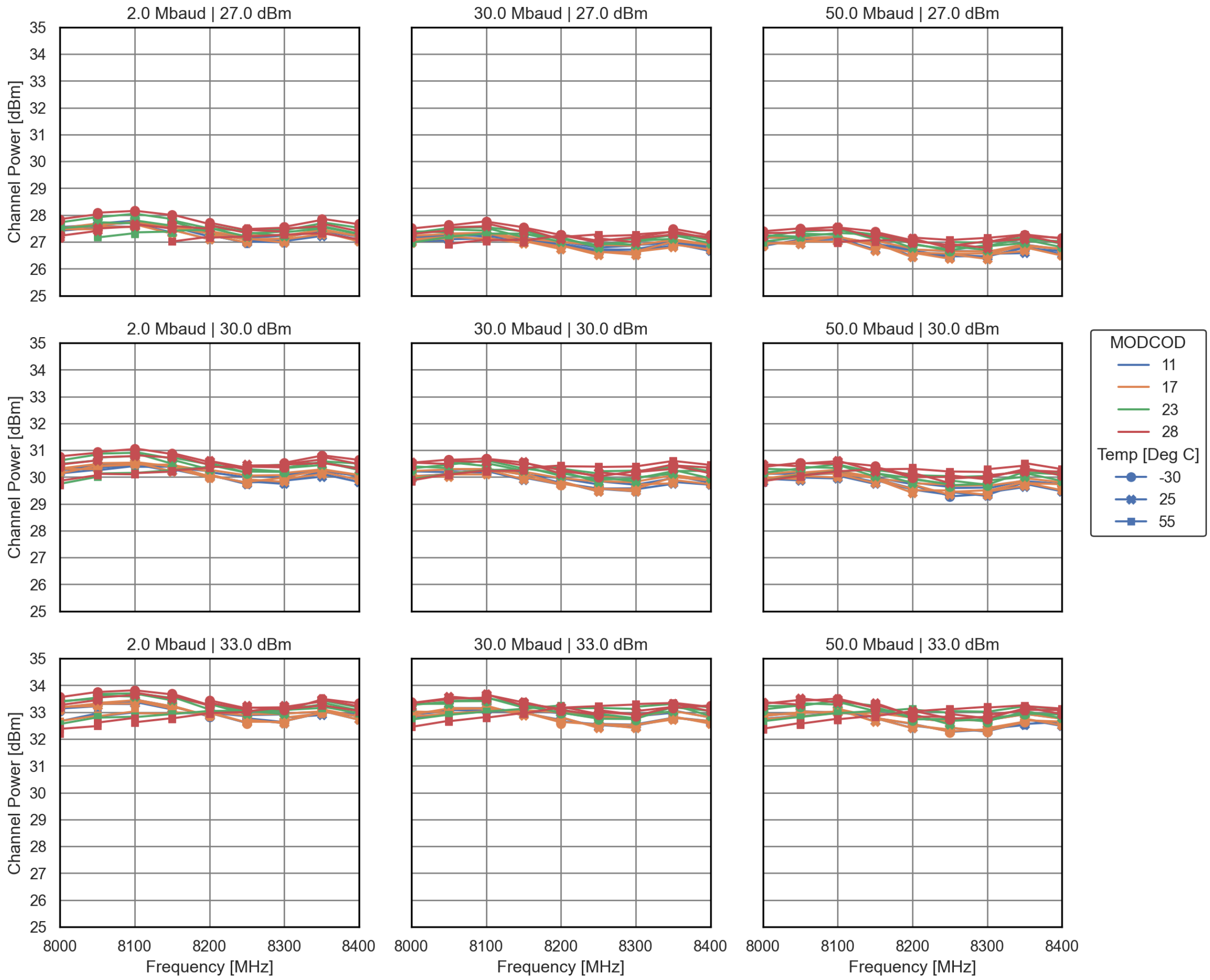


Figure 6.10: Typical channel power vs frequency.

6.3.2 TX Occupied Bandwidth

Typical TX occupied bandwidth vs symbol rate and power level. Data is measured across frequency, temperature, MODCOD, and supply voltage. The occupied bandwidth is the bandwidth within which 99 % of a measured power trace is contained.

Symbol Rate	Power Level	Min	Typ	Max	Unit
2 MBd	0 (27 dBm)	2.2	2.2	2.2	MHz
	1 (30 dBm)	2.2	2.2	2.3	MHz
	2 (33 dBm)	2.2	2.2	2.3	MHz
30 MBd	0 (27 dBm)	32.2	32.4	32.4	MHz
	1 (30 dBm)	32.4	32.9	33.3	MHz
	2 (33 dBm)	32.6	33.3	34.2	MHz
50 MBd	0 (27 dBm)	51.8	52.5	52.5	MHz
	1 (30 dBm)	52.5	53.3	54.0	MHz
	2 (33 dBm)	52.5	54.0	56.3	MHz

Table 6.8: Typical TX occupied bandwidth.

6.3.3 TX Spectral Emission Mask

Typical spectral emissions across frequency for different symbol rates, MODCODs, and temperatures in the out-of-band domain. Trace axes are normalized to directly compare against the spectrum mask from ITU-R SM.1541 [9, Figure 16].

Out of band domain is defined as the area from the necessary bandwidth until ±2.5 times the necessary bandwidth. The necessary bandwidth is defined as 1.111 times the symbol rate which is the occupied bandwidth of the ETSI DVB-S2 upper spectrum mask with a roll-off factor of 0.2.

All measurements plots are with $V_{MAIN\text{-}8250}$ 12 VDC. Results obtained with $V_{MAIN\text{-}8250}$ 28 VDC and 32 VDC show similar performance.

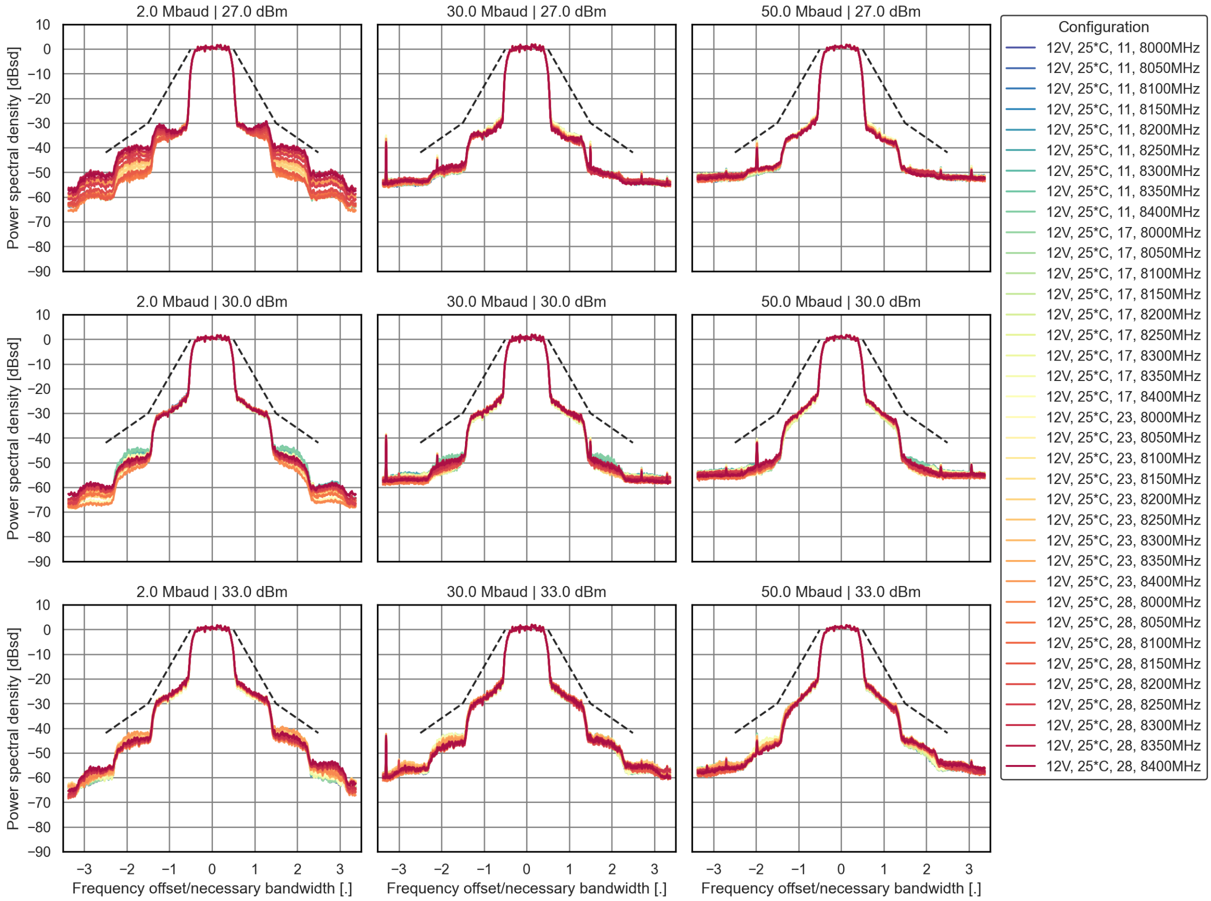


Figure 6.11: Typical spectral emission $V_{MAIN\text{-}8250} = 12\,\text{VDC}$ and $T_{AMB} = +25\,°C$.

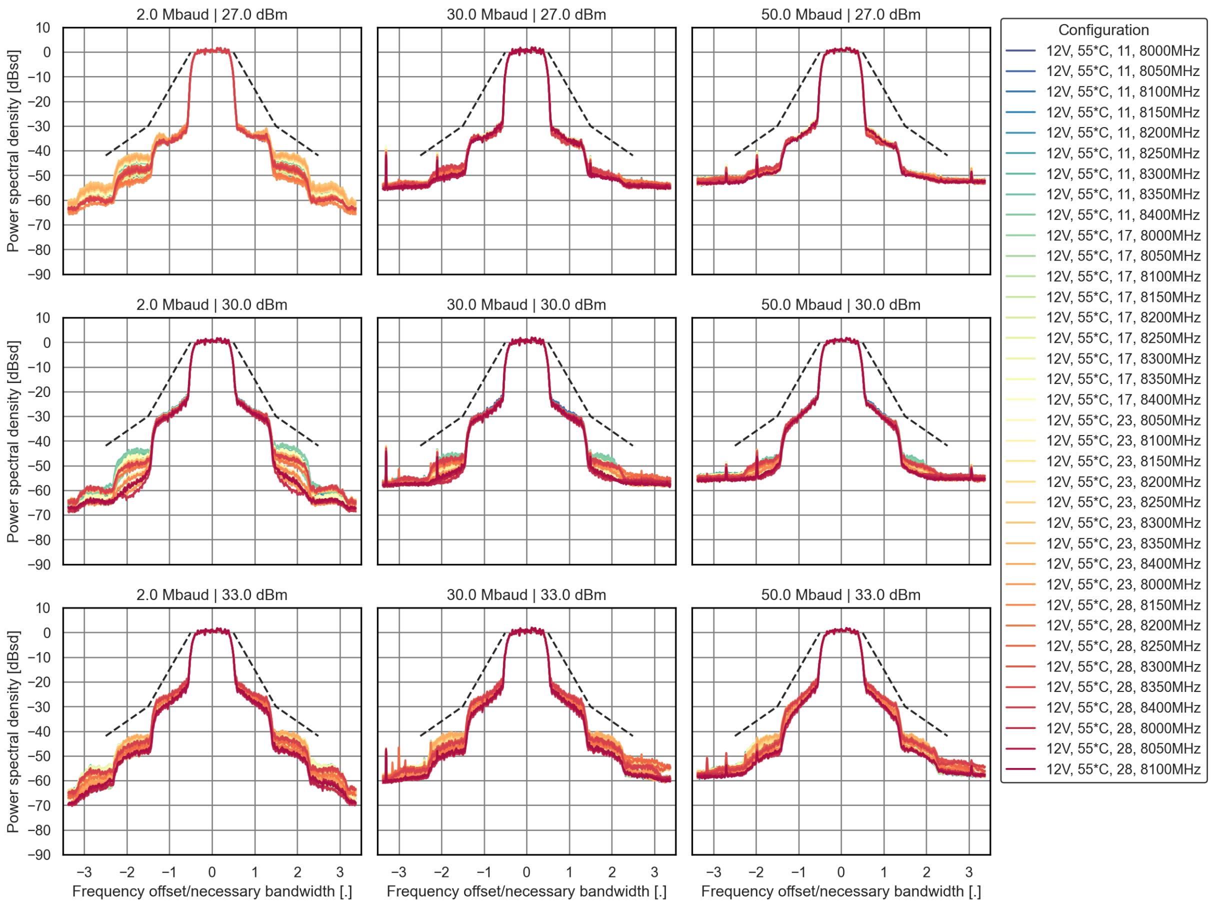


Figure 6.12: Typical spectral emission $V_{MAIN\text{-}8250} = 12\,VDC$ and $T_{AMB} = +55\,°C$.

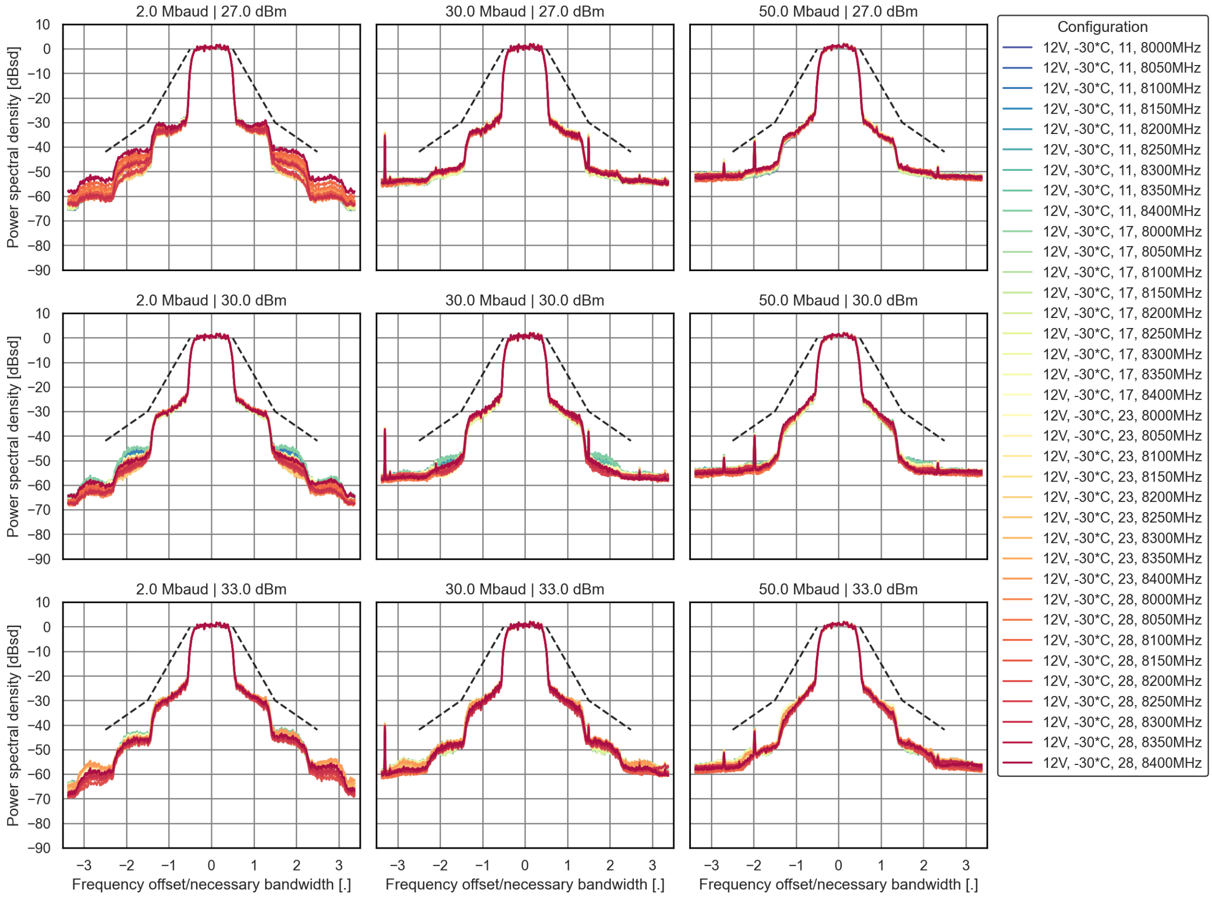


Figure 6.13: Typical spectral emission $V_{MAIN\text{-}8250} = 12\,\text{VDC}$ and $T_{AMB} = -30\,°\text{C}$.

6.3.4 TX Spurious Emission

Typical spurious emissions across frequency for different symbol rates, MODCODs, and TX frequencies.

The spurious limit is from ITU-R SM.329[8]. For the supported power levels, the spurious limit is fixed to −13 dBm. The spurious domain is the area outside the 2.5 times the necessary bandwidth, where necessary bandwidth is defined as 1.111 times the symbol rate. Each trace represents the maximum level recorded with $V_{MAIN\text{-}8250}$ = 12 VDC, 28 VDC and 32 VDC and T_{AMB} = −30 °C, +25 °C and +55 °C.

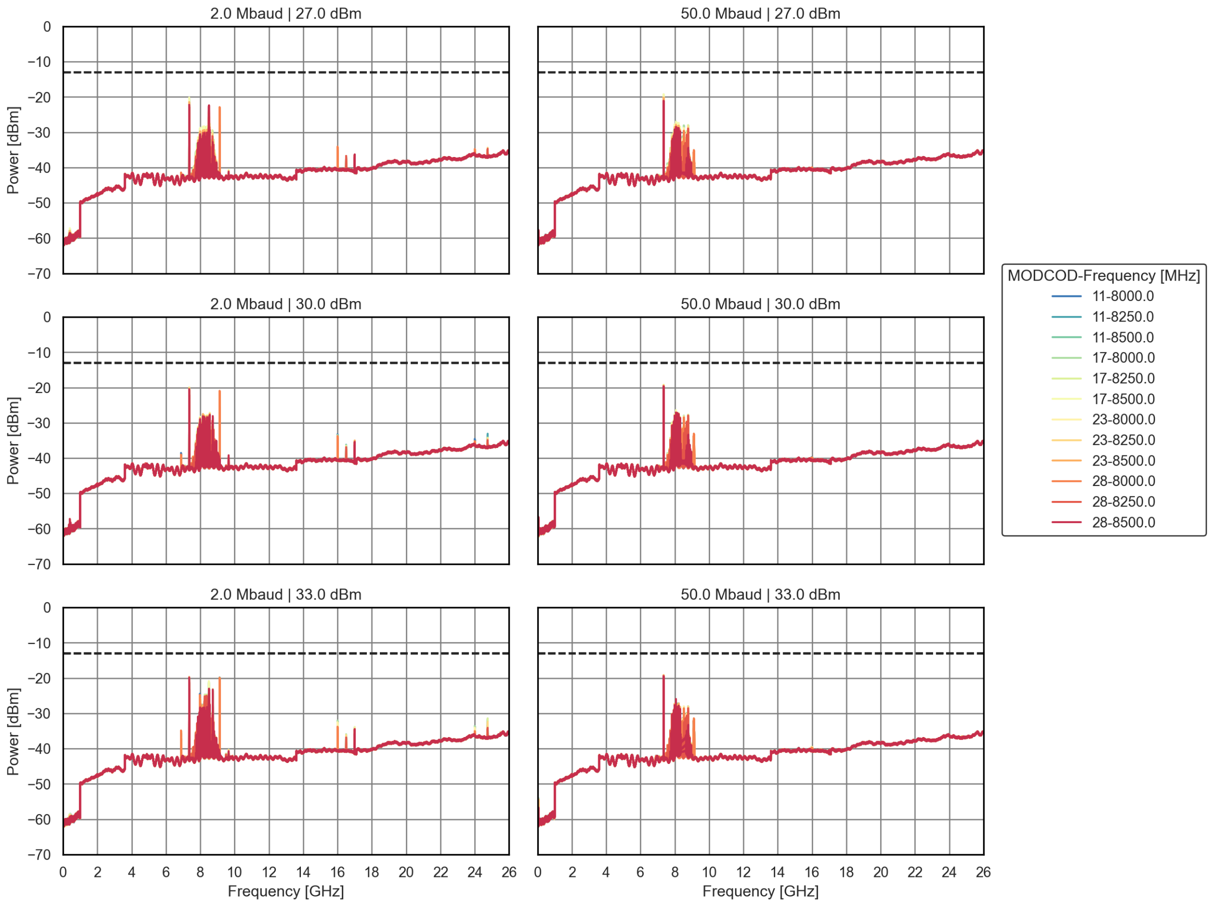


Figure 6.14: Typical spurious emission across extreme conditions.

6.4 Deep-Space Network Regulations

DSN uses very large antennas for communication with spacecrafts and to perform scientific or observer related tasks. DSN stations are located in The United States (California), Spain (Madrid) and Australia (Canberra).

Regulations are put in place by ITU to protect the DSN stations from external interference to ensure reliable communication. Due to the high sensitivity and narrow bandwidths used by DSN the permissible interference levels are very low in the frequency bands used by the network.

NanoCom Link X is evaluated against the power flux density (PFD) limits in Table 6.9. This is done for various orbit heights (h) and distance (De) between satellite nadir point on Earth and the DSN station using the geometry shown in Figure 6.15.

DSN Band [GHz]	Maximum interference power flux density at DSN location [dB W Hz/m^2]
S-band: 2.29 to 2.30	−257.0
X-band: 8.40 to 8.45	−255.1
Ku-band: 12.75 to 13.25	−254.3
Ka-band: 31.8 to 32.3	−249.3

Table 6.9: ITU-R SA.1157 [11] requirements for deep-space earth station interference compliance.

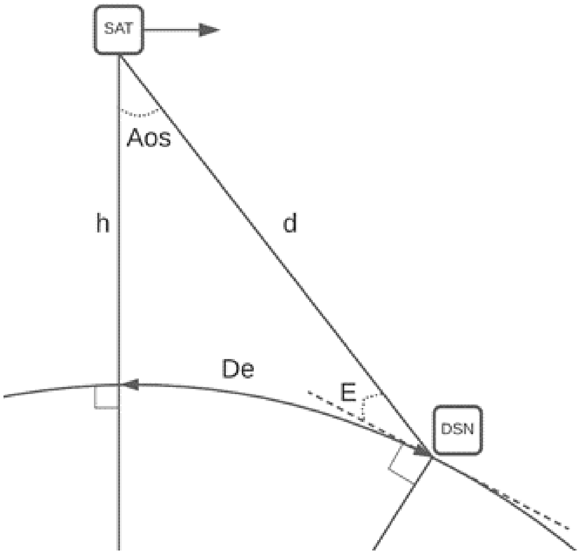


Figure 6.15: Satellite and DSN station geometry.

The noise level and discrete spurious signals in the various DSN bands are measured at the antenna connector of AFE8250 with 2 W RF output (using MODCOD 11, Table 6.6) and the PFD at the DSN station is evaluated using the AM8250 satellite antenna gain and slant range (d). Spurious signals are assumed to have a 1 Hz bandwidth (worst case) and the X-band antenna is pointing nadir.

It is recommended that the NanoCom Link X is only activated in areas where PFD at DSN station is below limits. In cases where the PFD limits are not met then the recommended solution is to use the NanoCom Link X with the optional 'DSN Filter Kit'. The compliance matrix is shown in Table 6.10.

DSN Band [GHz]	Symbol Rate [MBd]	No Filter	DSN Filter Kit	Antenna Gain/Spurious
S-band 2.29 to 2.30	10 to 50	Compliant	Compliant	Antenna Gain: Estimate −3 dBi Spurious is 2 times IF at 2300 MHz
X-band 8.40 to 8.45	10 to 50	Compliant[1]	Compliant[3]	Antenna Gain: Measured data Spurious: Discrete, clock related
Ku-band 12.75 to 13.25	10 to 50	Compliant	Compliant	Antenna Gain: Same as X-band No spurious
Ka-band 31.8 to 32.3	10 to 50	Compliant[2]	Compliant[2]	Antenna Gain: Estimated −3 dBi Spurious is 4th harmonic of TX

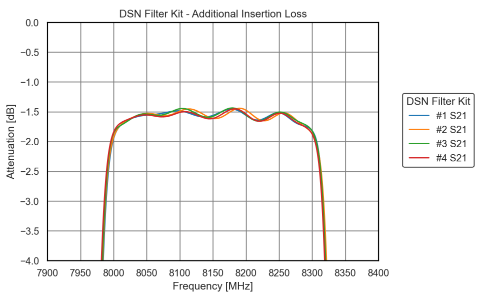
Table 6.10: NanoCom Link X DSN compliance table.

The NanoCom Link X with 'DSN Filter Kit' complies to the ITU recommendation in the frequency band 8.0 GHz to 8.25 GHz with one exception. For frequencies below 8.1 GHz the satellite must be below horizon seen from the DSN station when transmitter is active to comply to the DSN frequency band 31.8 GHz to 32.3 GHz.

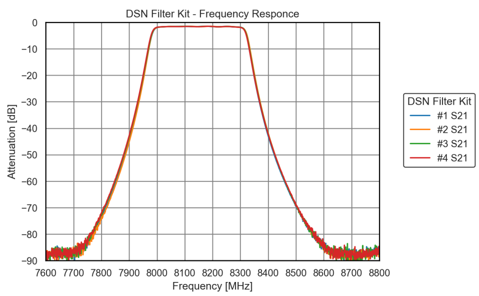
6.4.1 X-Band DSN Filter Kit

The content of the DSN Filter Kit is detailed in Section 4.1. It includes an IF and RF bandpass filter and necessary coax cables to interconnect the filters. The IF filter is mounted on the Slot-C cover shield on SDR MK3, next to the TR-600 in Slot-B providing the X-band IF signal to ANT8250. The RF filter is inserted between the ANT8250 and the AM8250.

The RF filter and coax cable will result in additional loss that is not compensated by the power control in the transmitter, and the additional loss should therefore be included in link budgets etc. The expected additional loss for the RF filter is shown in Figure 6.16a and the frequency response in Figure 6.16b. Data is based on four different kits.



(a) Expected additional loss of the RF filter and coax cables.



(b) Frequency response of the RF filter in the DSN Filter Kit.

Figure 6.16: Loss and frequency response of DSN Filter Kit

[1] Compliant when the satellite is below horizon seen from the DSN station when transmitter is active.

[2] Compliant for Fc ≥8.10 GHz. For Fc <8.10 GHz the satellite must be below horizon seen from the DSN station when transmitter is active.

[3] Compliant for Fc <8.25 GHz and De >200 km. Not suitable for frequencies above 8.28 GHz due to high loss of the RF filter.

7 Antenna Performance Characteristics

Both S-Band and X-Band uses low profile right hand circular polarized patch antennas. Key performance is listed below including plots of measured data on realized gain, axial ratio, and half power beamwidth. The propagation direction $\theta = 0°$ is perpendicular to the face of the antenna.

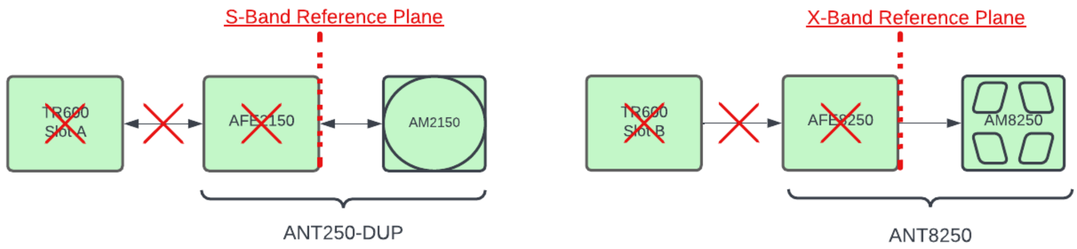


Figure 7.1: Reference plane antenna performance characteristics.

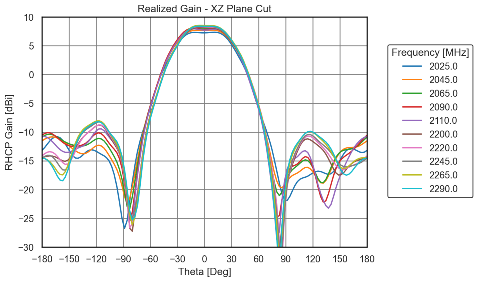
7.1 S-Band Patch (AM2150)

The S-Band patch uses right hand circular polarization (RHCP).

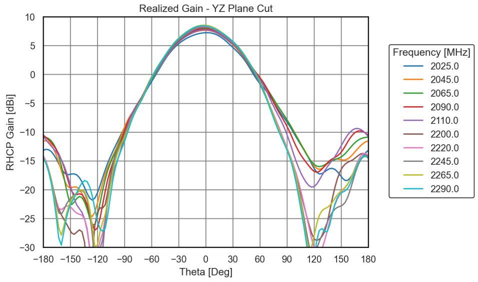
Parameter	Min	Max	Unit
Frequency range	2025	2290	MHz
Realized gain, $\theta = 0°$	7	-	dBi
Axial ratio, $\theta = 0°$ to $\pm 40°$	-	4.5	dB
Half power beamwidth	55	80	°
Insertion loss feed	-	0.5	dB

Table 7.1: S-Band patch antenna characteristics.

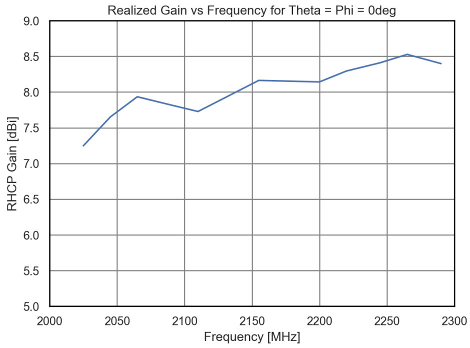
7.1.1 S-Band Realized Gain



(**a**) S-Band realized gain vs Theta, XZ plane.



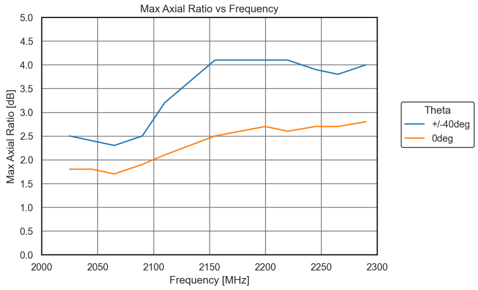
(**b**) S-Band realized gain vs Theta, YZ plane.



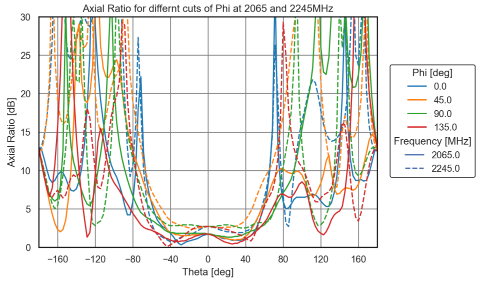
(**c**) S-Band realized gain for Theta = Phi = 0°.

Figure 7.2: S-band realized gain

7.1.2 S-Band Axial Ratio



(a) S-Band max axial ratio vs frequency.



(b) S-Band axial ratio at 2065 MHz to 2245 MHz.

Figure 7.3: S-band axial ratio

7.1.3 S-Band Half Power Beamwidth

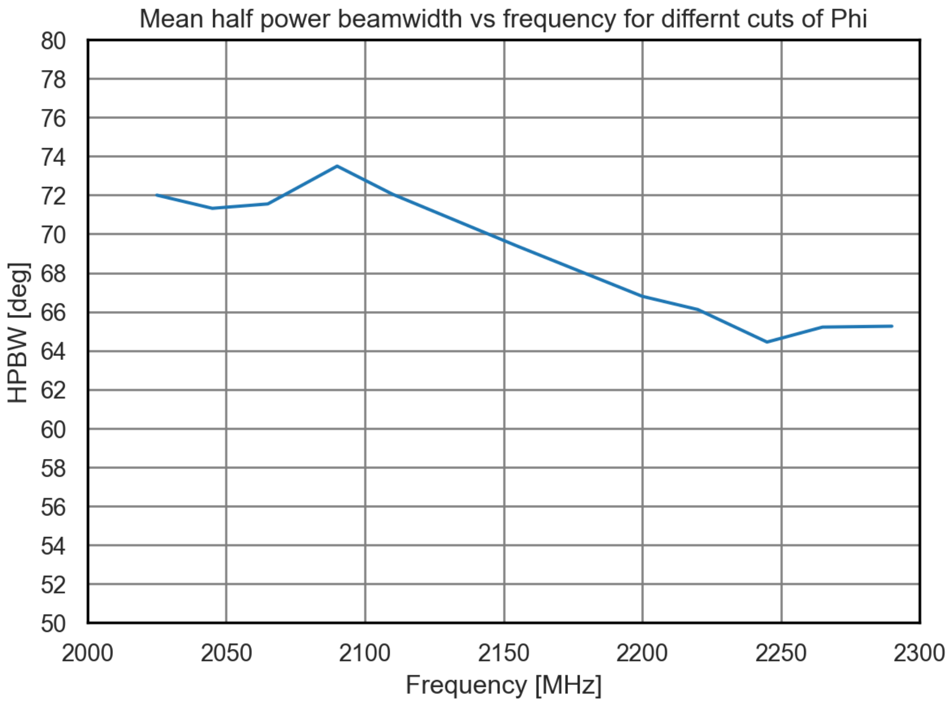


Figure 7.4: S-Band half power beamwidth.

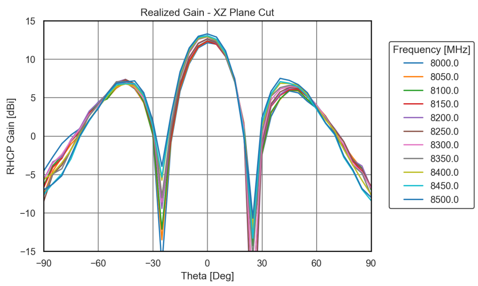
7.2 X-Band Patch (AM8250)

The X-Band patch uses RHCP.

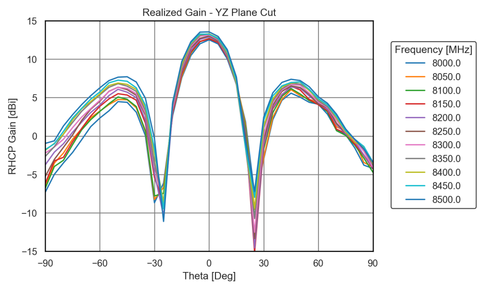
Parameter	Min	Max	Unit
Frequency range	8000	8500	MHz
Realized gain, $\theta = 0°$	12	-	dBi
Axial ratio, $\theta = 0°$ to $\pm 40°$	-	7.0	dB
Half power beamwidth	20	40	°
Insertion loss feed	-	0.5	dB

Table 7.2: X-Band patch antenna characteristics.

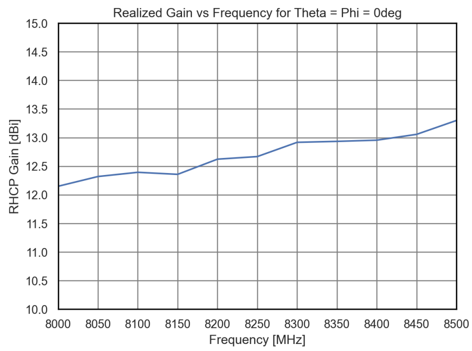
7.2.1 X-Band Realized Gain



(a) X-Band realized gain vs Theta, XZ plane.



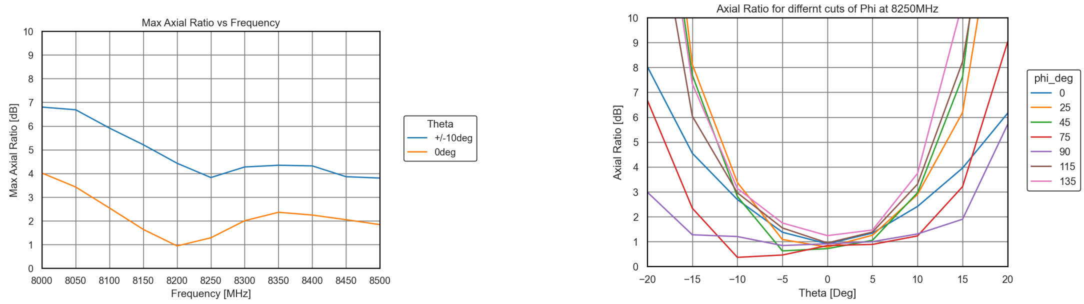
(b) X-Band realized gain vs Theta, YZ plane.



(c) X-Band realized gain for Theta = Phi = 0°.

Figure 7.5: X-band realized gain

7.2.2 X-Band Axial Ratio



(a) X-Band max axial ratio vs frequency.

(b) X-Band axial ratio at 8520 MHz.

Figure 7.6: X-band axial ratio

7.2.3 X-Band Half Power Beamwidth

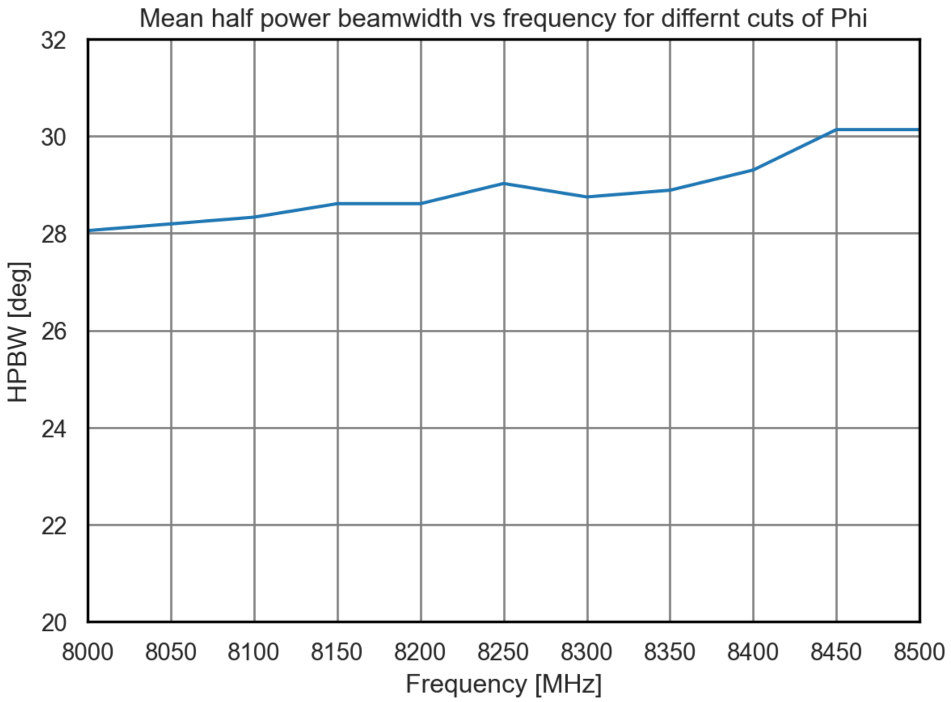


Figure 7.7: X-Band half power beamwidth.

8 Processing System Performance

8.1 Storage Performance

eMMC	Access Mode	Read [Mbit/s]	Write [Mbit/s]	Read/Write [Mbit/s]
Primary	Sequential	184	168	88
Secondary	Sequential	184	168	88
Primary	Random	176	168	88
Secondary	Random	176	168	88
Striped	Sequential	360	326	167
Striped	Random	380	346	180

Table 8.1: Storage performance.

The striped embedded multi-media controller (eMMC) storage performance is achieved with a storage volume that logically spans both *primary* and *secondary* eMMCs to achieve increased read and write performance compared to using a volume on a single eMMC. A striped volume is intended for payload data only e.g. data to be downlinked with X-band at rate exceeding the single eMMC read rates.

The eMMC performance characteristics are derived using the *fio* benchmarking application. See `https://fio.readthedocs.io/en/latest/fio_doc.html`.

8.2 Data Transfer Performance

Interface	Mode	Transfer scenario	Data transfer rate
SpaceWire	File	File dump to striped eMMC	145 Mbit/s @ 1 MB files
			155 Mbit/s @ 5 MB files
			155 Mbit/s @ 100 MB files
SpaceWire	IP	Measured using iperf3. All rates apply for UDP and TCP. MTU set to 9000 B.	**One interface streaming in one direction:**
			150 Mbit/s
			Three interfaces streaming in one direction:
			150 Mbit/s per interface
			Three interfaces streaming in both directions:
			80 Mbit/s per interface
RS422	IP	Measured using iperf3 configured to use TCP/IP.	80.6 kbit/s @ 115.2 kBd
			0.70 Mbit/s @ 1 MBd
			1.40 Mbit/s @ 2 MBd
			2.10 Mbit/s @ 3 MBd

Table 8.2: Data transfer rate

Protocol	Transfer scenario	Data transfer rate
GSUFTP		**Non-striped eMMC:**
		170 Mbit/s @ MODCOD 28, 50 MBd
		Striped eMMC:
		200 Mbit/s @ MODCOD 28, 50 MBd
		206 Mbit/s @ MODCOD 28, 50 MBd
		137 Mbit/s @ MODCOD 19, 50 MBd
		45 Mbit/s @ MODCOD 4, 50 MBd

Table 8.3: X-Band data transfer rate

Protocol	Transfer scenario	Data transfer rate
IP	Measured using iperf3. All rates apply for UDP and TCP.	375 kbit/s @ BPSK, 1 MBd
		5.6 Mbit/s @ QPSK, 7.5 MBd

Table 8.4: S-Band data transfer rate

9 Security

9.1 RF Security

The NanoCom Link product family supports authenticated encryption and cryptographic key management aligned with CCSDS 355.0-B-2 [4] and CCSDS 354.0-M-1 [5]. This provides confidentiality, data integrity, and authentication of the data transmitted over the RF links.

The key parameters of the implemented security features are summarized in Table 9.1.

Parameter	Description
Authenticated encryption algorithm	AES-GCM
Key size	256 bit
Key management	Symmetric keys, with key derivation of session keys from pre-shared master keys.
Key storage	Separate key stores for each link and direction.
Number of keys	512 keys per key store [1].

Table 9.1: RF Security Features

With encryption enabled, all traffic over the RF links is encrypted and authenticated. This includes IP header and payload.

The security feature on NanoCom Link is complemented by the security features of NanoGround Link Connect.

For more information on the security features, please refer to the NanoCom Link S, X, SX User Manual [1].

[1] Concurrent available keys for S-band uplink is limited to 64

10 Thermal Characteristics

NanoCom Link is qualified for an operational interface temperature between −40 °C to +53 °C.

10.1 Thermal Model ANT8250

The ANT8250 module requires a good thermal interface to the satellite structure to maximize transmission time and to avoid any thermal damage. Consequently, a poor thermal interface between the module and the satellite structure lowers the maximum transmission time as the power amplifier shuts down when the temperature becomes too high. A graphite sheet is included with the module to maximize thermal conductivity to the structure.

Assuming a 6U structure used as a heatsink with the thermal interfaces depictured in Figure 10.1, the ANT8250 can transmit for approximately 20 min before reaching thermal limits.

A first order lumped parameter model (LPM) derived from experimental thermal vacuum (TVAC) data of the Y-mount configuration on a 6U satellite is given in Equation (10.1)

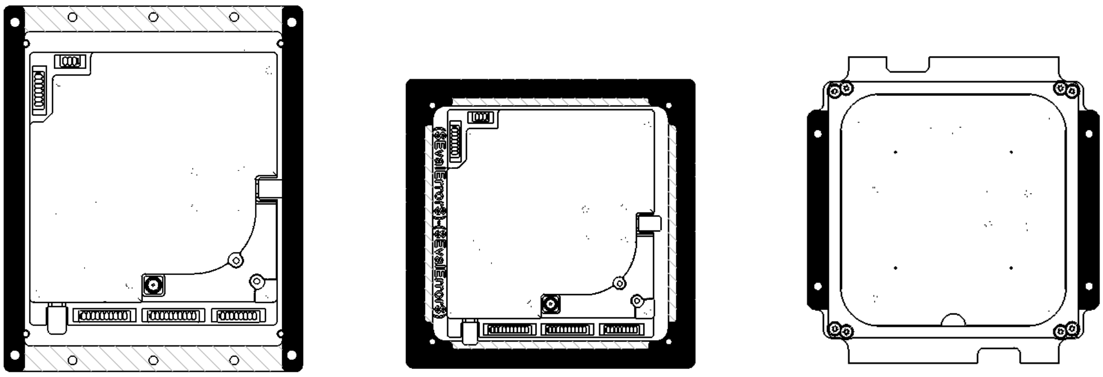
$$T_{PA}(t) = R(1 - e^{\frac{-t}{RxC}})P_{DC}(t) + T_{IF}(t) \tag{10.1}$$

where T_{PA} is the predicted temperature of the power amplifier (PA) (critical component), R is the thermal resistance at T_{IF}, C is the heat capacity of the ANT8250 module, P_{DC} is the direct current (DC) power consumption of the AFE8250 as a function of time, T_{IF} is the thermal interface temperature as a function of time and t is the time.

Parameter	Typical value	Unit	Recommended operating range
T_{PA}(t)	63.2	°C	−35 °C to +75 °C (up to +80 °C non-operating)
R	0.61	K/W	
C	371	J/K	
P_{DC}(t)	18	W	Refer to Table 5.7
T_{IF}(t)	57	°C	−35 °C to +75 °C (up to +80 °C non-operating)
T	600	s	0 min to 20 min

Table 10.1: LPM parameters.

The standard thermal interface towards the structure is the dark shaded areas on the outer rim of the XYZ mounting brackets in Figure 10.1. Graphite sheets with outlines matching the black shaded areas are included with the product for X and Y side mount to minimize thermal resistance towards the structure.



(**a**) X Side Mount (**b**) Y Side Mount. (**c**) Z Side Mount

Figure 10.1: ANT8250 Standard Thermal Interface (dark shaded areas).

11 Mechanical Characteristics

All dimensions are in mm.

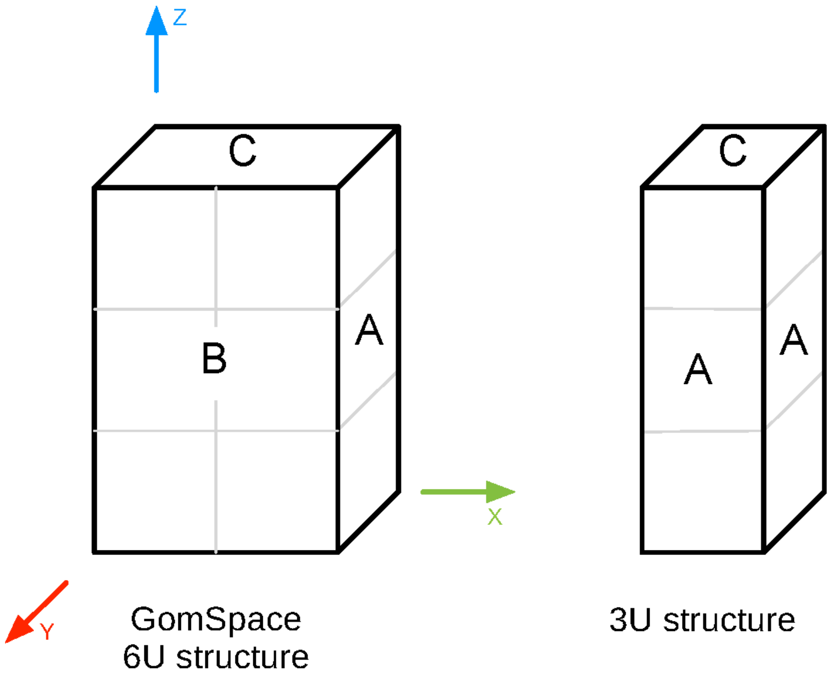


Figure 11.1: Antenna mounting plate Type ABC and XYZ side definitions.

Different mounting plates are available for the ANT2150-DUP and XT8250 to support direct placement on the X/Y/Z sides of standard GomSpace structures. Other mounting configurations are possible by using custom adaptation between the antenna mounting plate and structure.

When purchasing the product, it is possible to select between the different mounting plates using the option sheet.

11.1 SDR MK3 - NanoCom Link X

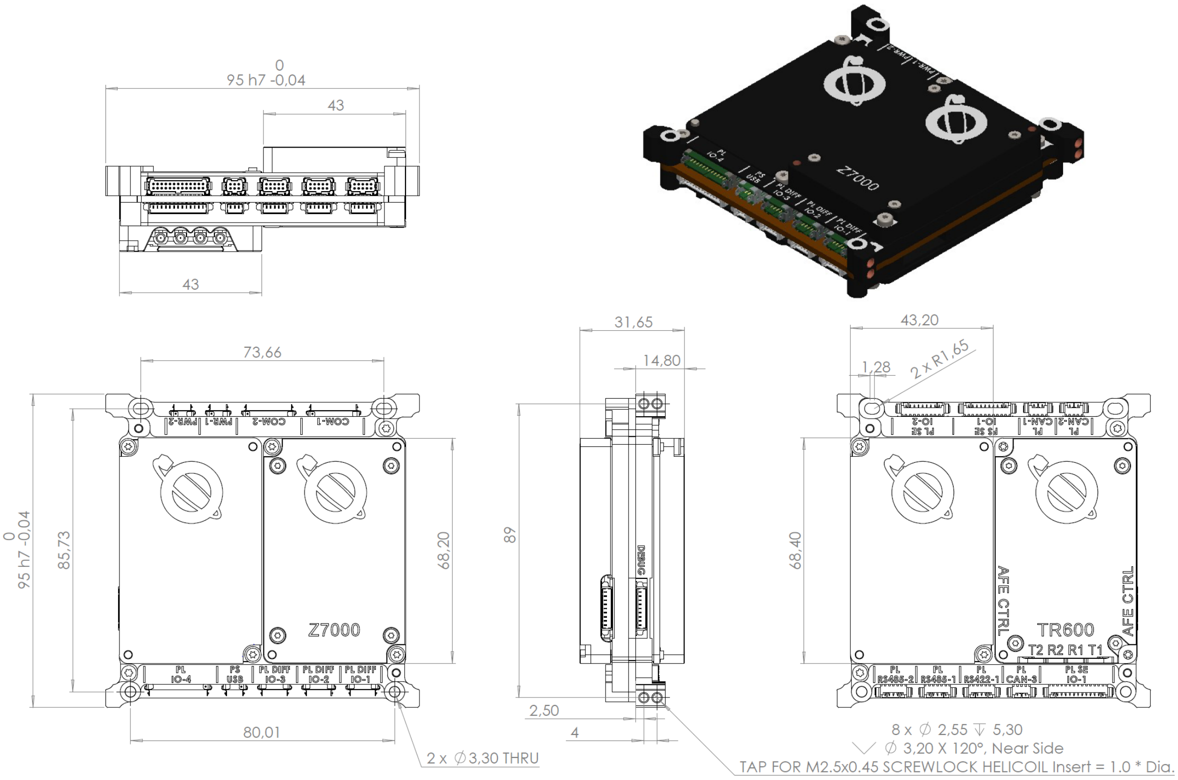


Figure 11.2: SDR MK3 - NanoCom Link X.

11.2 SDR MK3 - NanoCom Link S

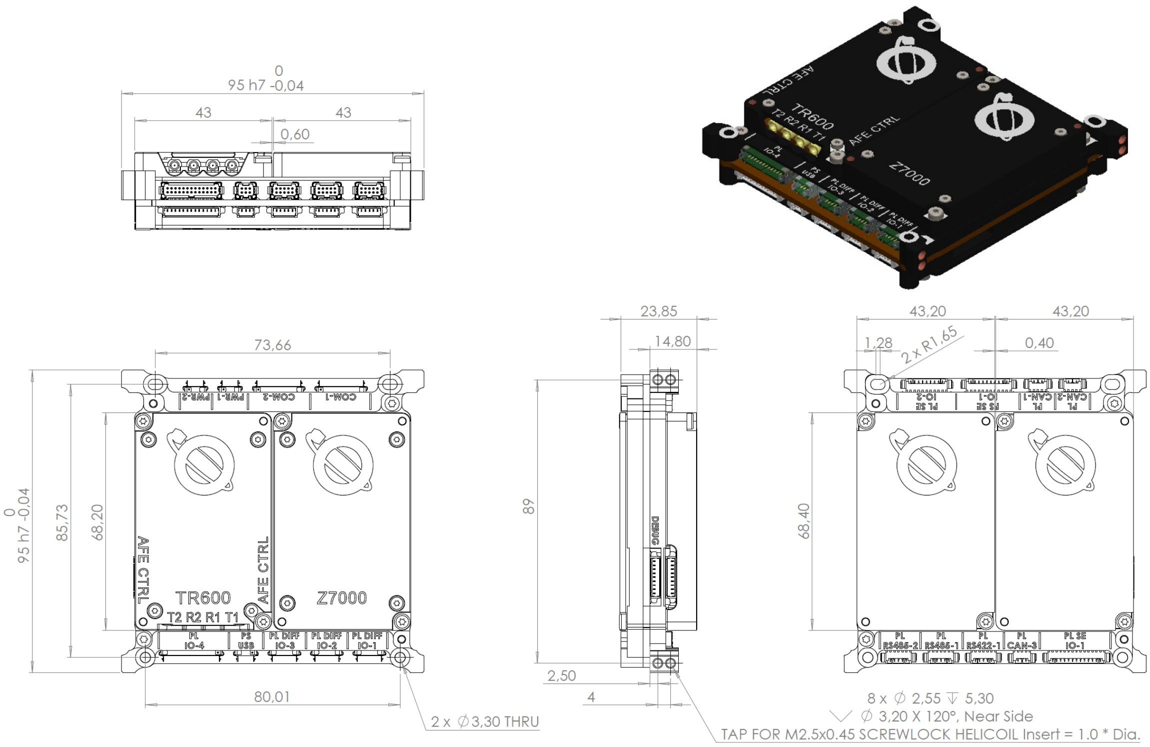


Figure 11.3: SDR MK3 - NanoCom Link S.

11.3 SDR MK3 - NanoCom Link SX

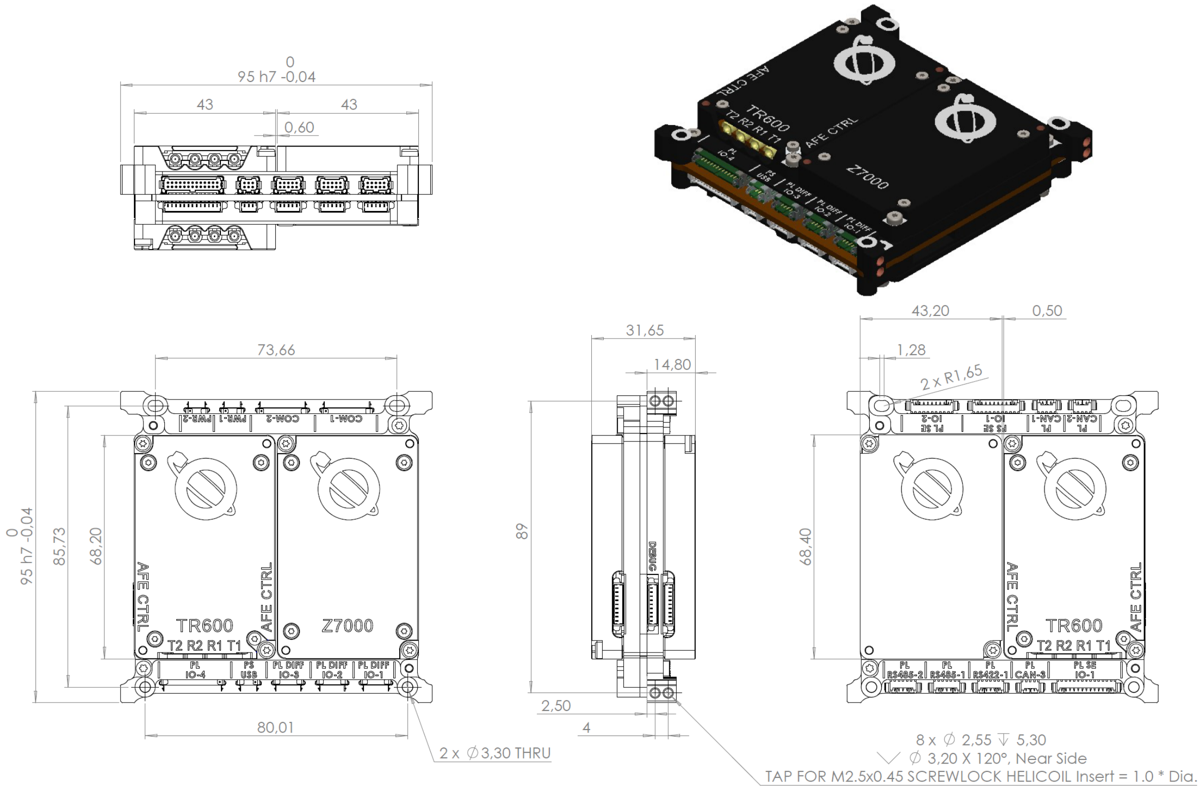


Figure 11.4: SDR MK3 - NanoCom Link SX.

11.4 ANT2150 Backplate X and Y

ANT2150 backplate for X or Y side mounting on GomSpace 3U and X side mounting on GomSpace 6U structure. Type A backplate in option sheet.

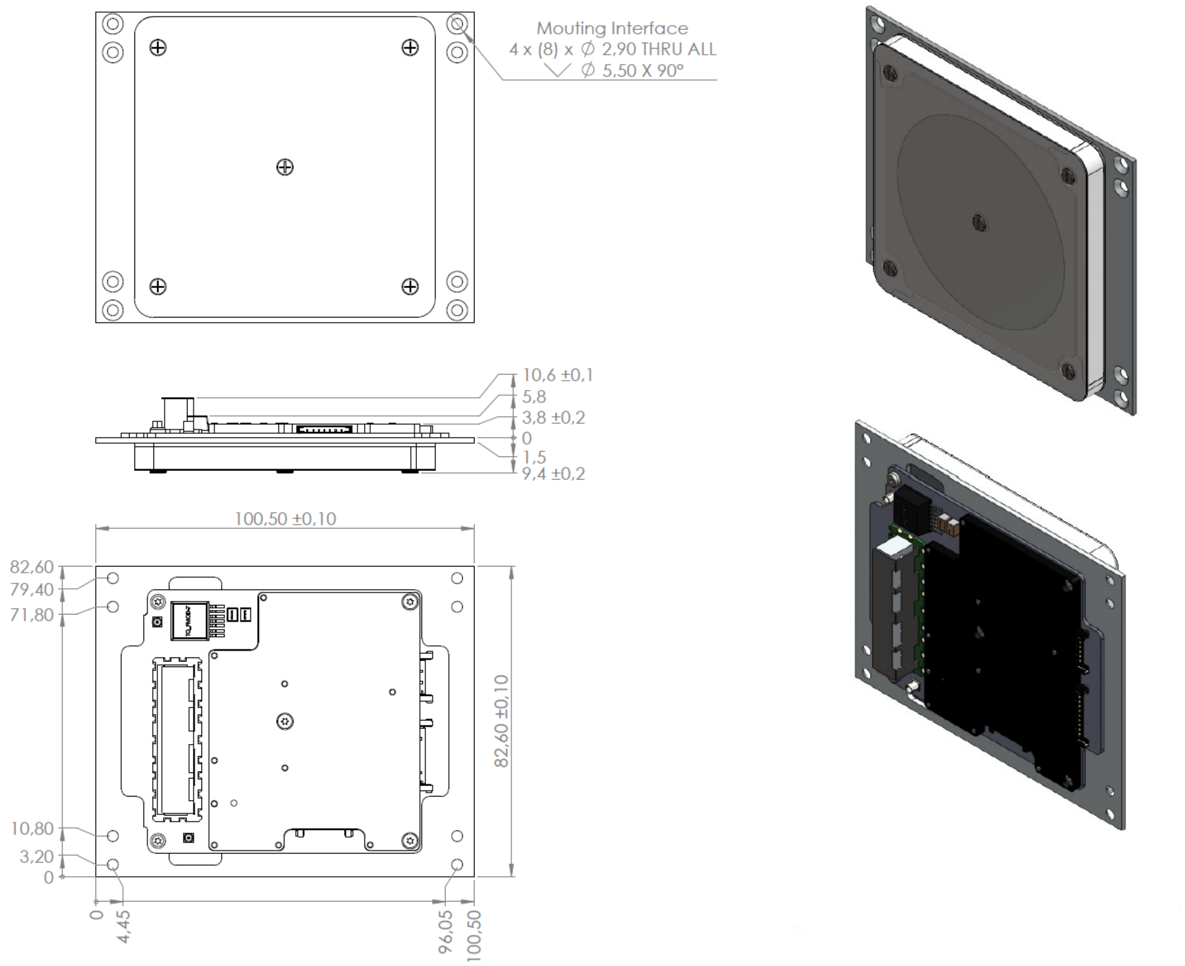


Figure 11.5: ANT2150 Backplate Type A.

11.5 ANT2150 Backplate Z

ANT2150 backplate for Z side mounting on GomSpace 3U structure. Type C backplate in option sheet.

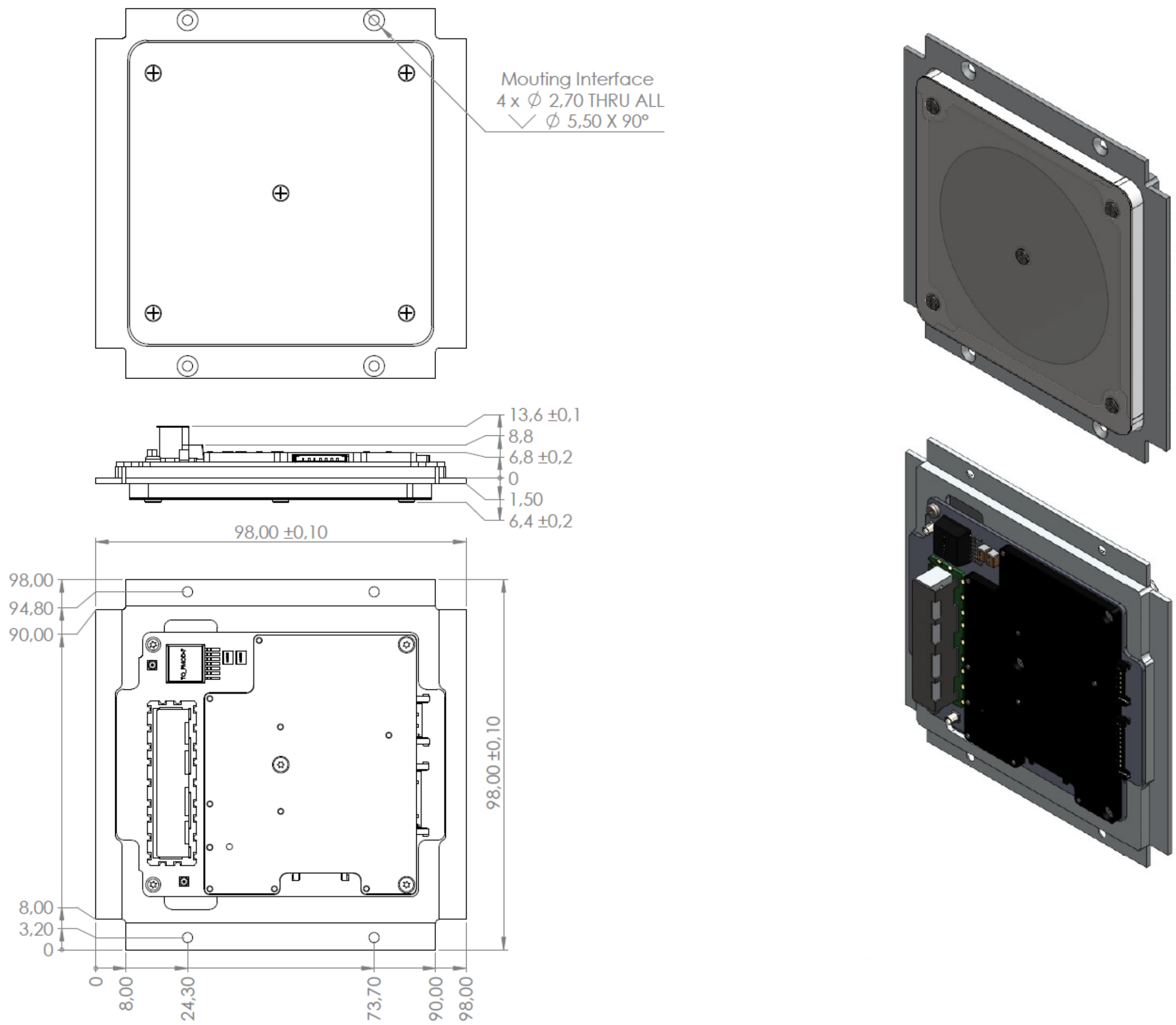


Figure 11.6: ANT2150 Backplate Type C.

11.6 ANT8250 Backplate X

ANT8250 backplate for X side mounting on GomSpace 6U structure.

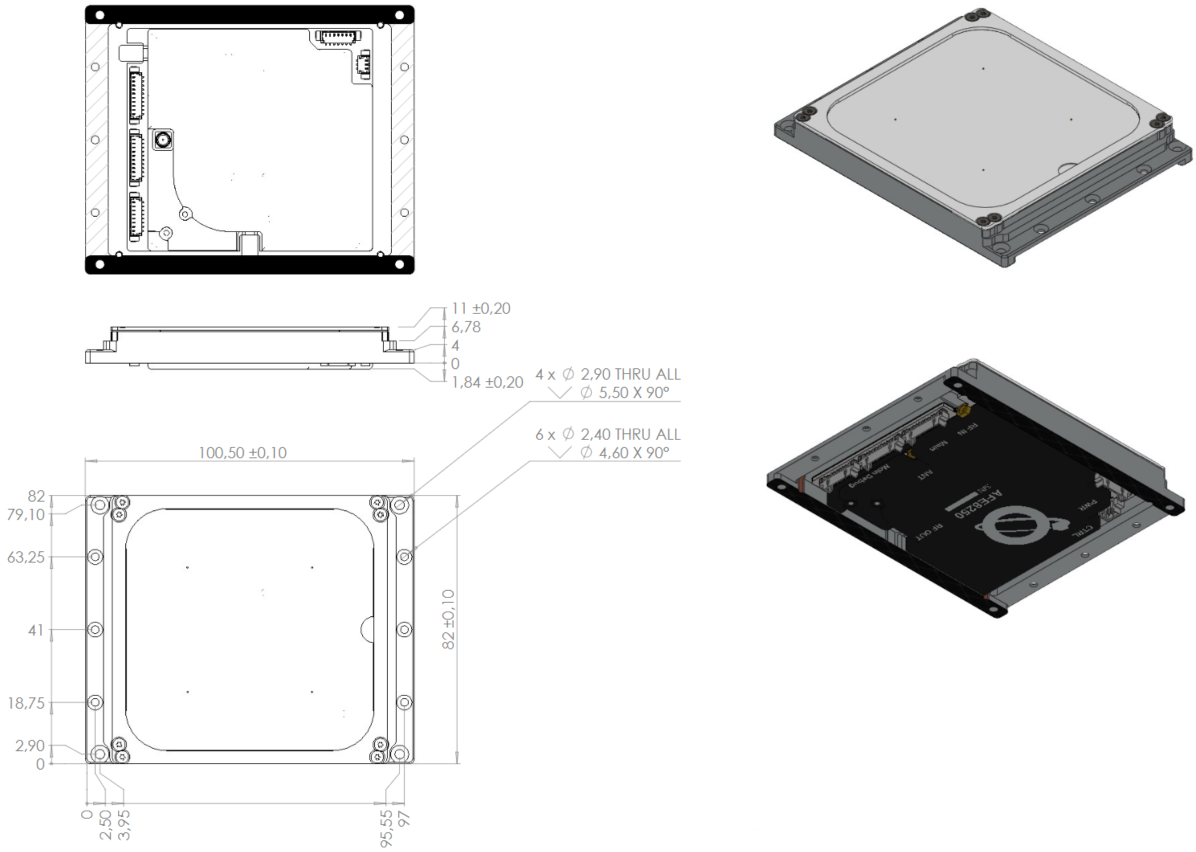


Figure 11.7: ANT8250 Backplate X side.

11.7 ANT8250 Backplate Y

ANT8250 backplate for Y side mounting on GomSpace 6U structure.

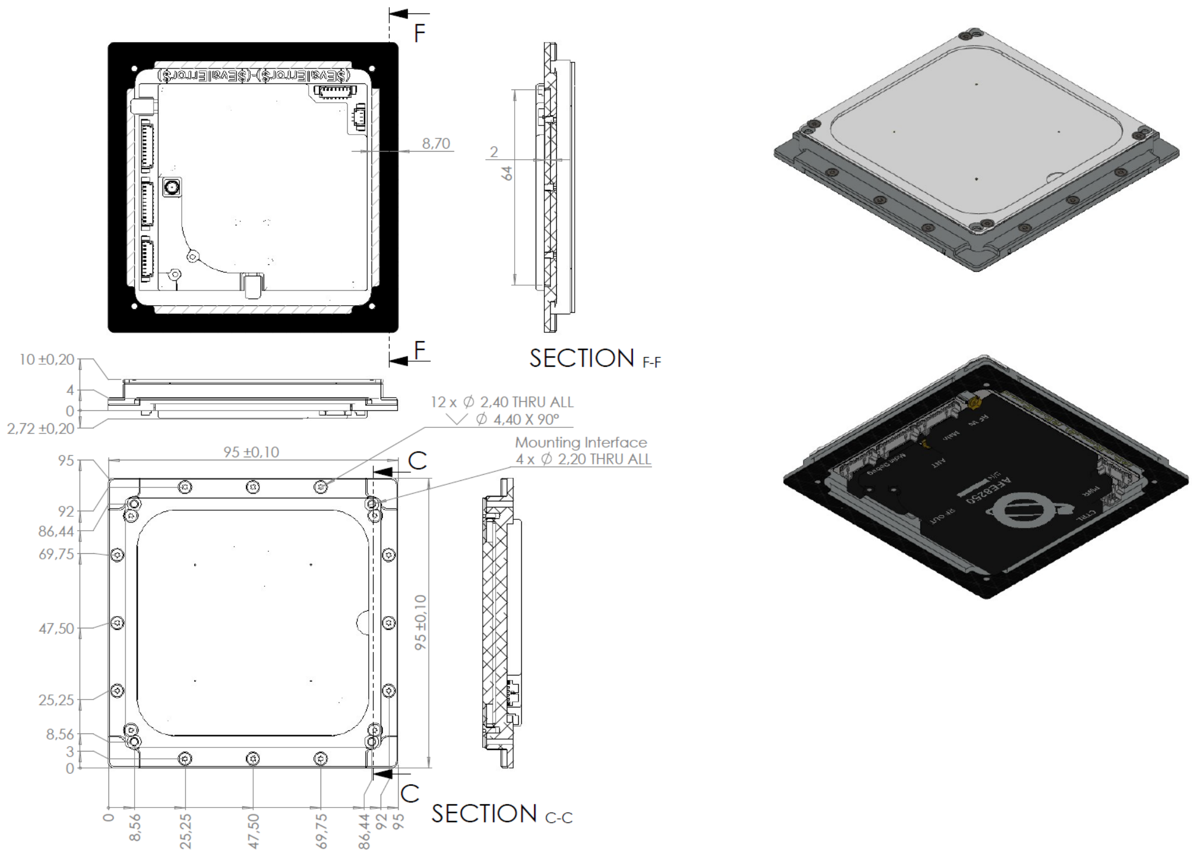


Figure 11.8: ANT8250 Backplate Y side.

11.8 ANT8250 Backplate Z

ANT8250 backplate for Z side mounting on GomSpace 6U structure.

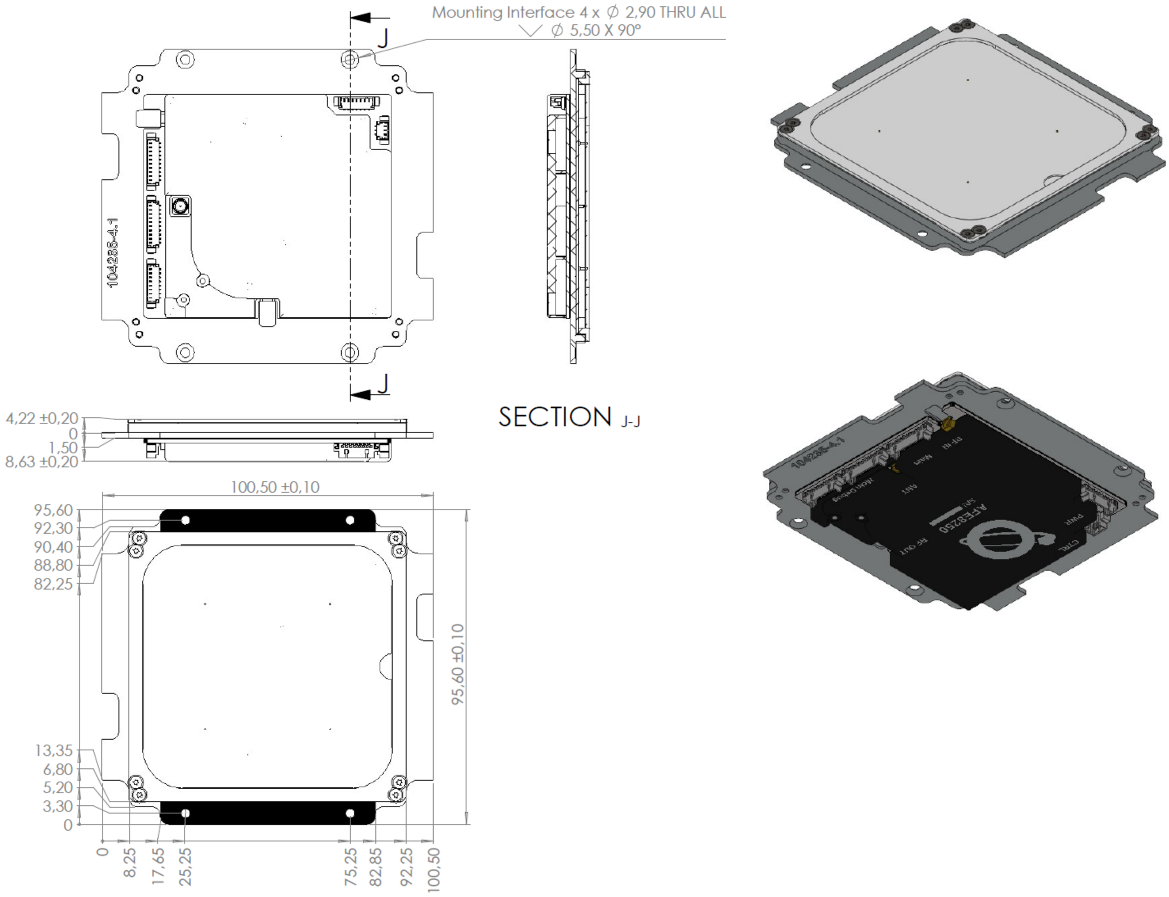


Figure 11.9: ANT8250 Backplate Z side.

11.9 DSN Filter Kit

The DSN Filter Kit contains a RF and IF bandpass filter and necessary coax cables to interconnect the filters. A detailed content list of the DSN Filter Kit is available in Section 4.1.

11.9.1 RF Filter

The RF filter is attached to a mounting bracket that is PC104 compliant and equipped with siderails for integration with GomSpace structures. The siderails are preferred over PC104 for mounting for maximizing thermal coupling. Coax cables are included to insert the RF filter between the output of AFE8250 and input of AM8250.

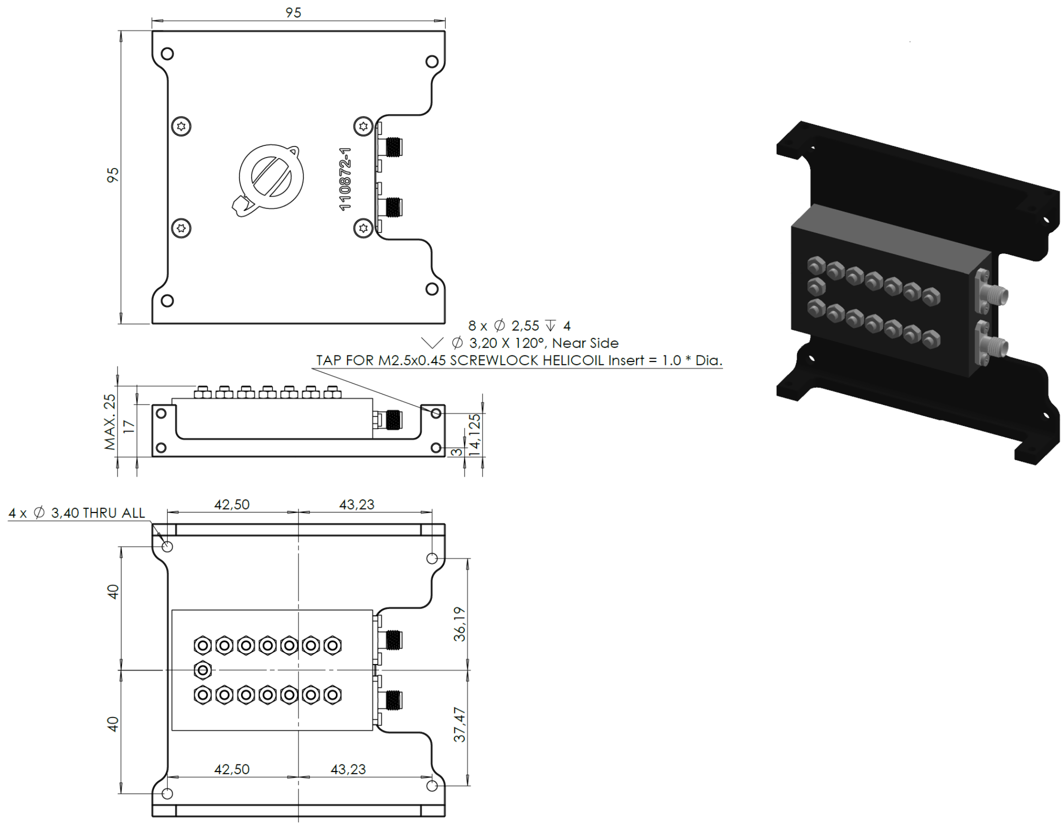


Figure 11.10: RF filter with mounting bracket.

11.9.2 IF Filter

The IF filter is fixated to the Slot-C cover shield on the SDR MK3. Coax cables are included to connect T1 from TR600 in Slot-B to the IF filter and further from the IF filter to ANT8250.

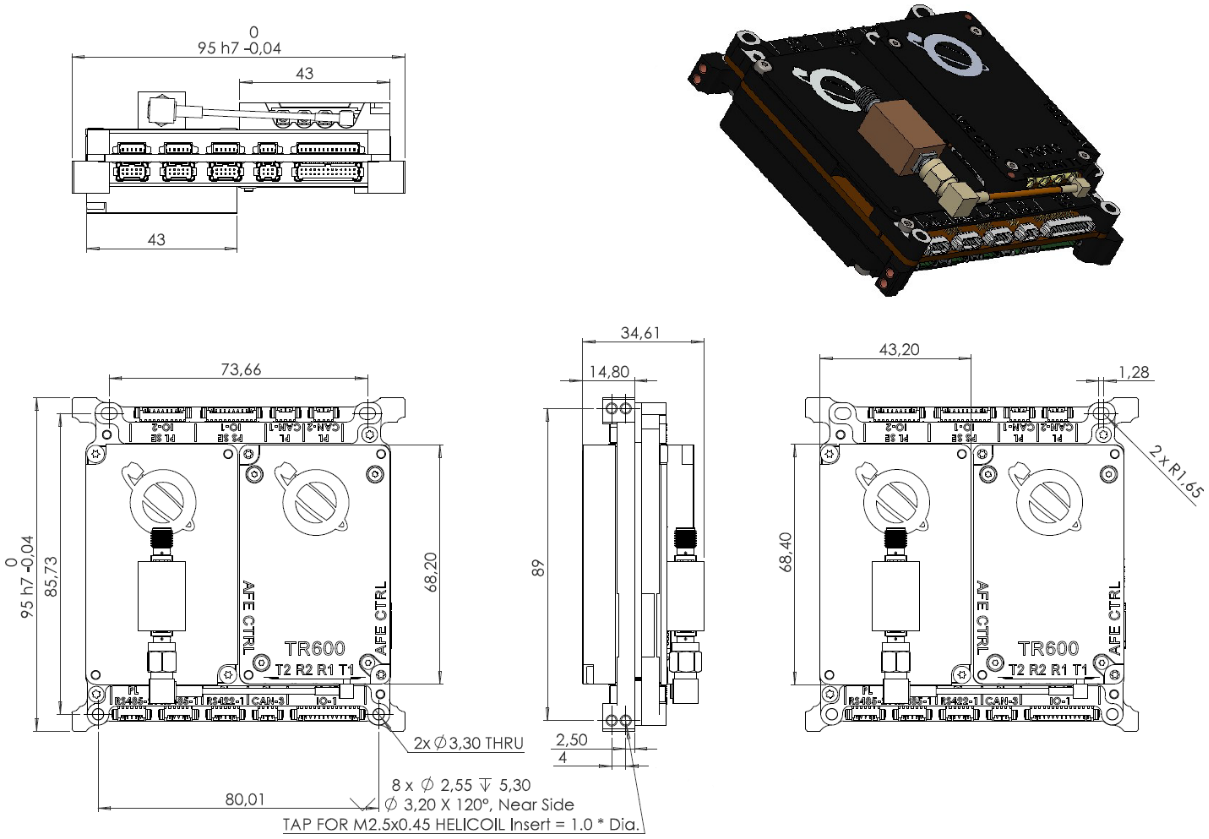


Figure 11.11: IF filter attached to SDR MK3 Slot-C cover shield.

12 Mass

Below is an overview of the typical mass of the different configurations of NanoCom Link. All readings have been rounded up to the nearest whole number.

12.1 SDR MK3

Variant	Mass	Unit
NanoCom Link S	272	g
NanoCom Link X	272	g
NanoCom Link SX	315	g

Table 12.1: SDR MK3 mass.

12.2 ANT2150-DUP

Mounting Configuration	Mass	Unit
Type A	112	g
Type C	123	g

Table 12.2: ANT2150-DUP mass.

12.3 ANT8250

Mounting Configuration	Mass	Unit
X side	144	g
Y side	150	g
Z side	131	g

Table 12.3: ANT8250 mass.

12.4 DSN Filter Kit

Configuration	Mass	Unit
RF, IF filter and coax cables	221	g

Table 12.4: DSN Filter Kit mass.

12.5 Product Cable Kit

The mass of the different cables, except those being part of the 'DSN Filter Kit' and those intended for debug only, are listed below.

ID	Description	S	X	SX	Mass	Unit
PWR	SDR MK3 power to flying leads	✓	✓	✓	6	g
S-PWR	ANT2150 power to flying leads	✓	N/A	✓	6	g
X-PWR	ANT8250 power to flying leads	N/A	✓	✓	6	g
S-RF	RG-178 Coax cable, SSMCX to SMPM	✓	N/A	✓	6	g
X-IF	RG-178 Coax cable, SMPM to SMPM	N/A	✓	✓	6	g
X-RF	SMPM to SMP .085" semi rigid coax cable	N/A	✓	✓	2	g
S-CTRL	TR600 MK3 to ANT2150 control harness	✓	N/A	✓	4	g
X-CTRL	TR600 MK3 to ANT8250 control harness	N/A	✓	✓	5	g
TERM1	SDR MK3 Mainbus CAN2 120 Ω termination	✓	✓	N/A	1	g

Table 12.5: Product cable kit mass.

13 Qualifications

The individual devices of NanoCom Link have been exposed to several environmental tests to simulate the harsh conditions of launch and space. Contact GomSpace for further information.

14 Revision History

Table 14.1: Revision history.

Revision	Date	Description
1.0	23-12-2022	First release.
2.0	10-02-2023	Updated Feature Overview (Section 1). Added section on Processing System Performance (Section 8). Added section on mass (Section 12). Added 3U/6U structure side definitions on compatibility with standard antenna mounting plates (Section 11). Added further details on power consumption (Section 5.4.2). Updated specificaiton on EVM (Section 6.3). Added limitations maximum configurable symbol rate vs MODCODs for the different supported variants (Section 6.3). Updated system block diagram with further information on supported interfaces (Section 4).
3.0	27-03-2023	Updated minimum thermal interface temperature on SDR, ANT8250 and ANT2150 from -40 °C to -35 °C (Section 3). Updated mass figure ANT8250 Y side mount from 142g to 150g (Section 12). Added pinout information on RF, S-CTRL and X-CTRL interface connectors on Nanocom TR600 MK3 and ANT2150-DUP and ANT8250 (Section 4). Added pinout information on Debug interface connector on NanoDock MK3 (Section 4).
4.0	30-05-2023	Updated processing system performance (Section 8).
5.0	13-06-2023	Added USB cable to product cable kit (Section 4). Corrected ANT8250 max voltage from 33V to 32V (Section 5).
6.0	25-08-2023	Added Link-S performance characteristics, and Link-SX power consumption data (Section 5.4, Section 6.1 and Section 6.2). Updated note on SpaceWire termination (Section 4.4.2).
7.0	22-08-2024	Updated USB cable length Table 4.1 from 10 to 100cm (Section 4). Added further clarification on EN signal utilization SDR MK3 power interface (Section 4.3.1). Updated X-band initial TX frequency error vs temperature Table 6.5 from $\pm$ 1.5 to 2.0 PPM (Section 6.3).

continued on next page …

Table 14.1 continued: Revision history.

Revision	Date	Description
8.0	28-10-2024	Added note on SpaceWire performance MTU size.
9.0	05-11-2024	Updated S-band initial RX and TX frequency error vs temperature Table 6.1 and Table 6.2 to ± 3.0 to ± 6.0 PPM.
10.0	21-01-2025	Updated specification for GSUFTP transfer rate (Section 8.2).
11.0	10-12-2025	Update to reflect that all hardware is TRL 9 (Section 1). Add chapter on Security (Section 9).
12.0	22-01-2026	Clarify that only one downlink link can be used on SX variant at a time.

15 References

[1] **GomSpace**
MAN 1076241
NanoCom Link S, X, SX User Manual
Cited on pages 1, 4, 63

[2] **Consultative Committee for Space Data Systems (CCSDS)**
Blue Book 131.0-B-3
TM Synchronization and Channel Coding
Sept. 2017, Issue 3
Available at `https://public.ccsds.org/Pubs/131x0b3e1.pdf`
Cited on pages 1, 2, 32, 33.

[3] **European Telecommunications Standards Institute (ETSI)**
European Standard EN 302 307-1
Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications; Part 1: DVB-S2
July 2014, V1.4.1
Available at `https://tinyurl.com/y5vuwykh`
Cited on pages 1, 3.

[4] **Consultative Committee for Space Data Systems (CCSDS)**
Blue Book 355.0-B-2
Space Data Link Security Protocol
July 2022, Issue 2
Available at `https://public.ccsds.org/Pubs/355x0b2.pdf`
Cited on pages 2, 63.

[5] **Consultative Committee for Space Data Systems (CCSDS)**
Magenta Book 354.0-M-1
Symmetric Key Management
Dec. 2023, Issue 1
Available at `https://public.ccsds.org/Pubs/354x0m1.pdf`
Cited on pages 2, 63.

[6] **GomSpace**
ICD 1076240
NanoCom Link S, X, SX RF Interface
Cited on page 3

[7] **rsync**
Software tool
Available at `https://rsync.samba.org/`
Cited on page 4

[8] **ITU-R**
Recommendation SM.329
Unwanted emissions in the spurious domain
Sept. 2024, Revision 13
Available at `https://www.itu.int/rec/R-REC-SM.329/en`
Cited on pages 36, 42, 44, 52.

[9] **ITU-R**
Recommendation SM.1541
Unwanted emissions in the out-of-band domain
Sept. 2024, Revision 7
Available at `https://www.itu.int/rec/R-REC-SM.1541/en`
Cited on pages 36, 37, 40, 44, 49.

[10] **International Telecommunication Union (ITU)**
Regulation Vol. 1
Radio Regulations
2020
Available at https://www.itu.int/dms_pub/itu-r/opb/reg/R-REG-RR-2020-ZPF-E.zip
Cited on page 40.

[11] **ITU-R**
Recommendation SA.1157
Protection criteria for deep-space research
Mar. 2006, Revision 1
Available at https://www.itu.int/rec/R-REC-SA.1157/en
Cited on page 53.

16 Glossary

Cubesat Space Protocol Small network-layer delivery protocol designed for cubesats enabling distributed and embedded systems to deploy a service-oriented network topology.

Deep Space Network A worldwide network of U.S. spacecraft communication facilities that supports NASA's interplanetary spacecraft missions. It also performs radio and radar astronomy observations for the exploration of the Solar System and the universe, and supports selected Earth-orbiting missions. The DSN is part of the NASA Jet Propulsion Laboratory.

GomSpace Stream Encapsulation Custom GomSpace protocol for encapsulation of packets in a continuous datastream. GSSE handles fragmentation, synchronization, de-fragmentation and verification.

GomSpace Unidirectional File Transfer Protocol Custom GomSpace protocol for flexible, block-based trans-fer of files with delayed/omitted acknowledgements.

Joint Test Action Group Industry standard for verifying designs and testing printed circuit boards after manufacture.

SpaceWire SpaceWire is a spacecraft communication network based in part on the IEEE 1355 standard of communications. It is coordinated by the European Space Agency (ESA) in collaboration with international space agencies including NASA, JAXA, and RKA.