NanoCom
TR-600

Datasheet
Nano-satellite transceiver

Product name: NanoCom TR-600

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Confidentiality Notice

1 Table of Contents

2 Overview

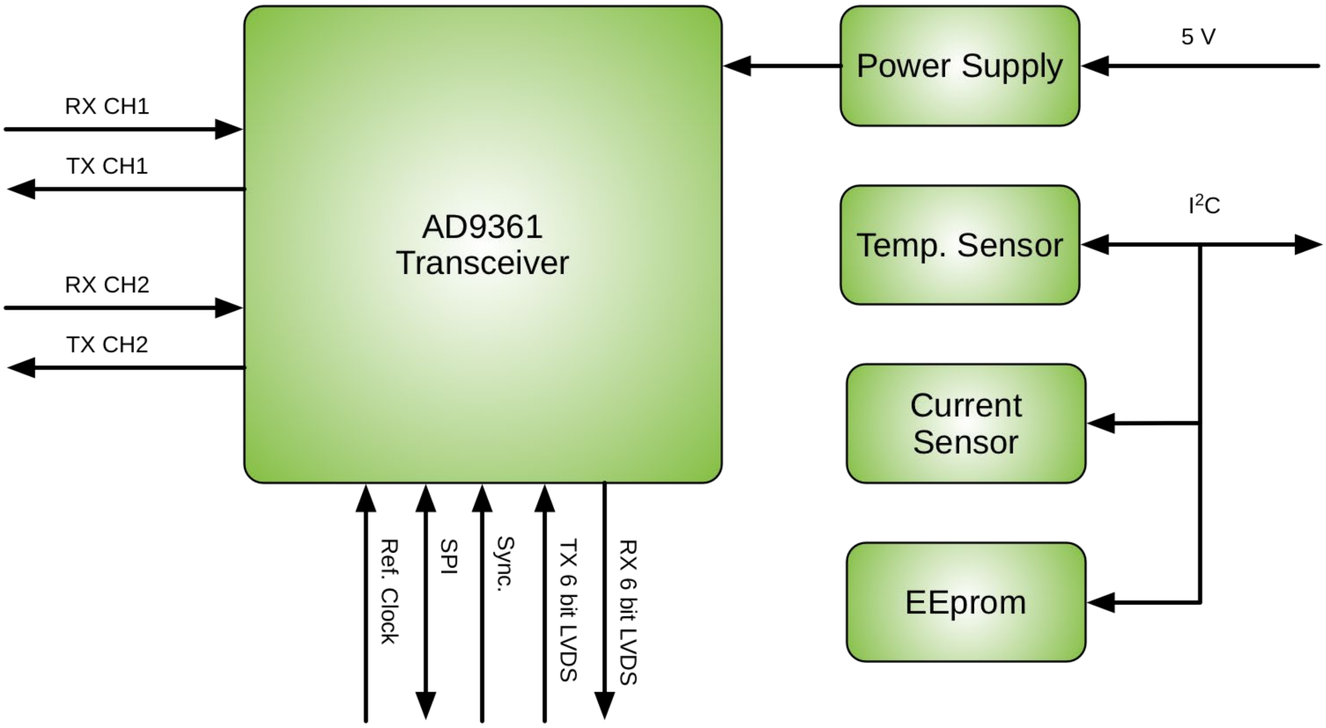
The NanoCom TR-600 is a radio daughterboard to be used in nano-satellites. It can be fully reconfigured in-orbit. With 4 antenna connectors, up to four antennas can be operated per module.

The TR-600 fits on top a GomSpace NanoDock SDR, which makes it possible to fit up to three radio daughterboards.

2.1 Highlighted Features

- AD9361 IC
- 2 × 2 transceiver with integrated DACs and ADCs
- Band: 70 MHz to 6 GHz
- Channel bandwidth is tunable from 200 kHz to 56 MHz
- Supports TDD and FDD operation.
- Multichip synchronization
- LVDS/single-ended digital BB interface
- Fits on top a NanoDock SDR
- Flight proven
- Precision milled anodized aluminum heat sink to control thermal load and provide EMI shielding
- Temperature and current sensors
- EEprom for persistent configuration storage
- Operational temperature: -40 °C to +85 °C (TRX IC)
- PCB material: glass/polyimide ESA ECSS-Q-ST-70-11-C
- IPC-A-610 Class 3A assembly

2.2 Block Diagram



2.3 AD9361 Transceiver Datasheet

Datasheet for the AD9361 Transceiver is available on the www.analog.com.

2.4 Time Sync

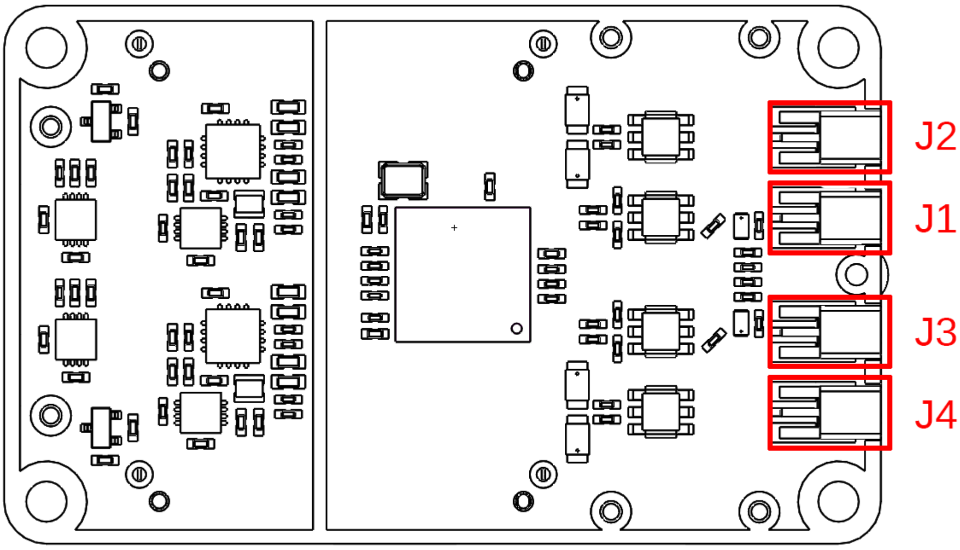
A time sync signal can be received through a connector pin on one of the Samtec connectors. As an example, J12 pin 12 can be used and be configured to 3.3 V or 1.8 V LVCMOS.

3 Connector Pinout

The pinouts of the 2x 100 pin Samtec connectors can by acquired upon request from GomSpace.

3.1 Connector Location

Seen from the top, under the shield.



3.1.1 J1 – Rx 1

Molex SSMCX EDGE 73415-4670

Pin	Description
1	Rx 1
2	GND

3.1.2 J2 – Tx 1

Molex SSMCX EDGE 73415-4670

Pin	Description
1	Tx 1
2	GND

3.1.3 J3 – Rx 2

Molex SSMCX EDGE 73415-4670

Pin	Description
1	Rx 2
2	GND

3.1.4 J4 – Tx 2

Molex SSMCX EDGE 73415-4670

Pin	Description
1	Tx 2
2	GND

4 Data Interface

The TR-600 can be configured through a SPI interface.

The RX/TX I and Q data is send/received over a 12 bit LVDS interface (LVDS 6-bit TX differential input bus with internal LVDS termination + 6-bit RX differential output bus with internal LVDS termination).

I^2C is used for housekeeping data and EEprom.

5 Absolute Maximum Ratings

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the TR-600. Exposure to absolute maximum rating conditions for extended periods may affect the reliability.

Symbol	Description	Min.	Max.	Unit
VCC	Supply voltage	4,5	5.5	V
I	Supply current draw	-	4.0	A
T_{amb} (TRX IC)	Operating Temperature	-40	85	°C
$T_{Junction}$	Junction temperature		110	°C
V_{io}	Voltage on I^2C pins	-0.3	3.6	V
I^2C pullup	Default 100k Ω	1.2k	100k	Ω

6 Electrical characteristics

Symbol	Description	Min.	Typ.	Max.	Unit
VCC	Supply voltage	4.5	5	5.5	V

7 Physical Characteristics

Description	Value	Unit
Mass of PCB	16.8	g
Mass total PCB + shield	65.3	g
Size	65.0 x 40.0 x 14.8	mm

8 Environment Testing

To simulate the harsh conditions of launch and space, the TR-600 has been exposed to a number of environment tests. For detailed information about the tests please contact GomSpace.

The TR-600 has been in space and performed perfectly.

9 RF Characteristics

This chapter presents captured measurement results and deployed test conditions. Temperature conditions have been controlled and involved test cases are executed at following ambient temperature steps: -40°C, 25°C and 60°C. The upper limit of 60°C is chosen in respect to temperature characteristics of the NanoMind Z7000 module operated in conjunction with TR-600.

9.1 Transmitter P_{out}

During output power measurements, the following conditions are applied: BB signal is 1 MHz CW, analog filter BW is 18 MHz and BB signal scaling (ddc_scale) is set to 1.

The Tx output power is measured at four gain step configurations, namely at maximum level corresponding to 0 dB Tx attenuation, 10 dB, 20 dB and at 30 dB attenuation setting. Resulting output power with 0 dB attenuation is visualized in Figure 1.

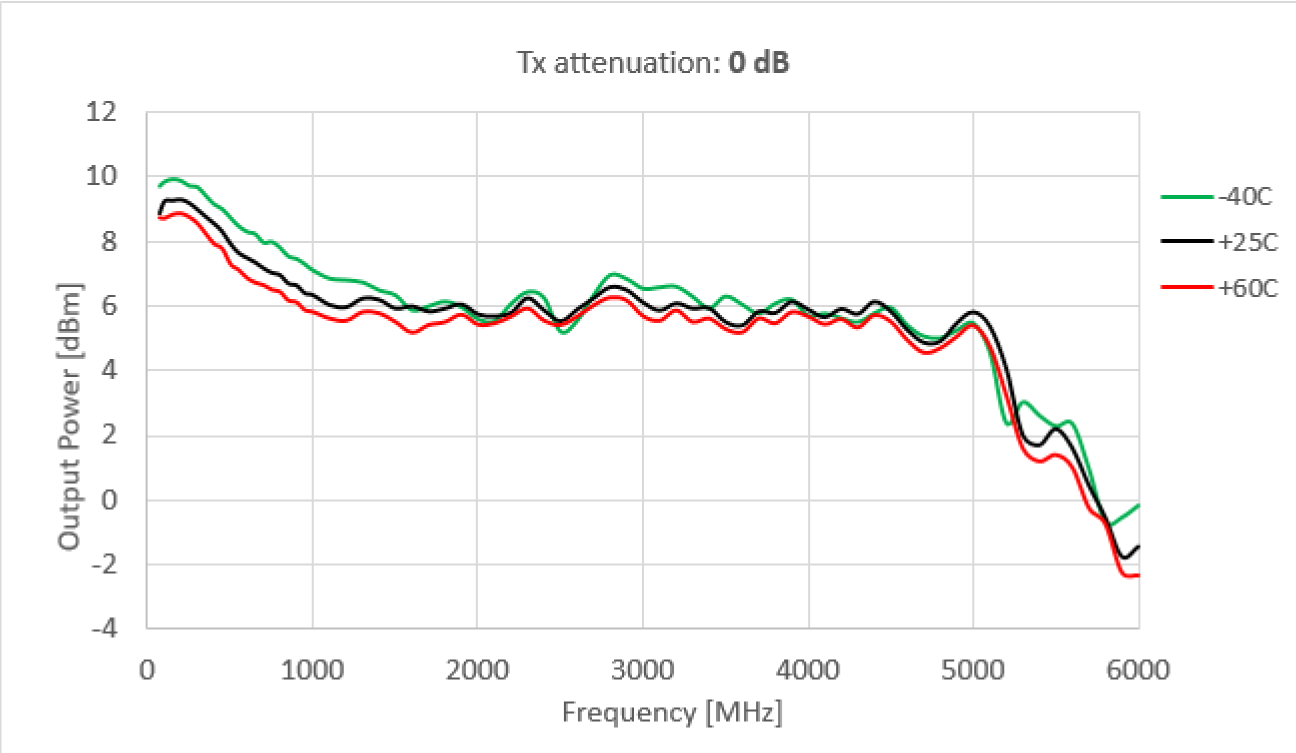


Figure 1: Tx output power at 0 dB attenuation.

As illustrated in Figure 1, the Tx output power has its peak value at lower frequencies while a constant value of approximately 6 dBm is found in the range from approximately 1 GHz to 5 GHz. In the upper part of the spectrum i.e. from 5 GHz to 6 GHz, the maximum output power exhibits decreasing behavior resulting into a level of approximately -1,5 dBm at 6 GHz when operated at 25°C.

The corresponding output power with 10 dB attenuation is illustrated in Figure 2.

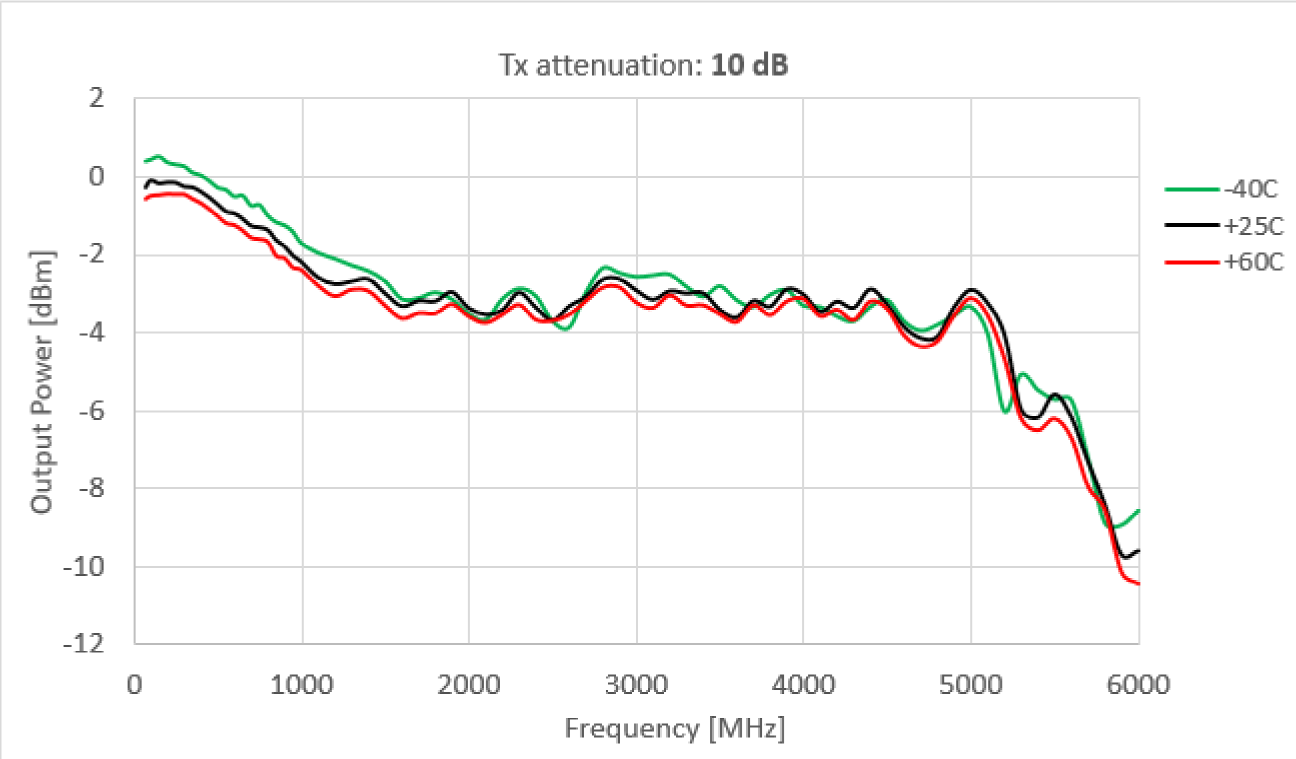


Figure 2: Tx output power at 10 dB attenuation.

The measured output power with 20 dB attenuation is depicted in Figure 3.

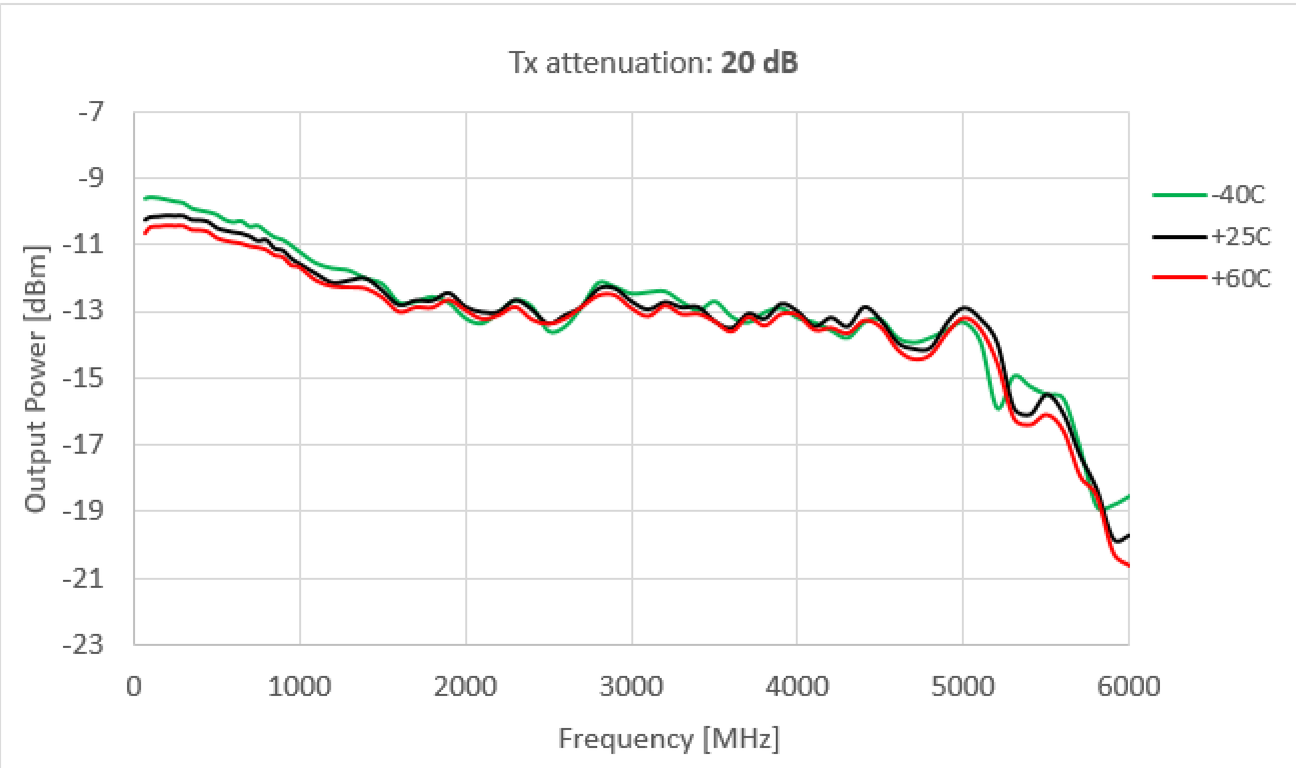


Figure 3: Tx output power at 20 dB attenuation.

The transmitter output power with 30 dB attenuation is visualized in Figure 4.

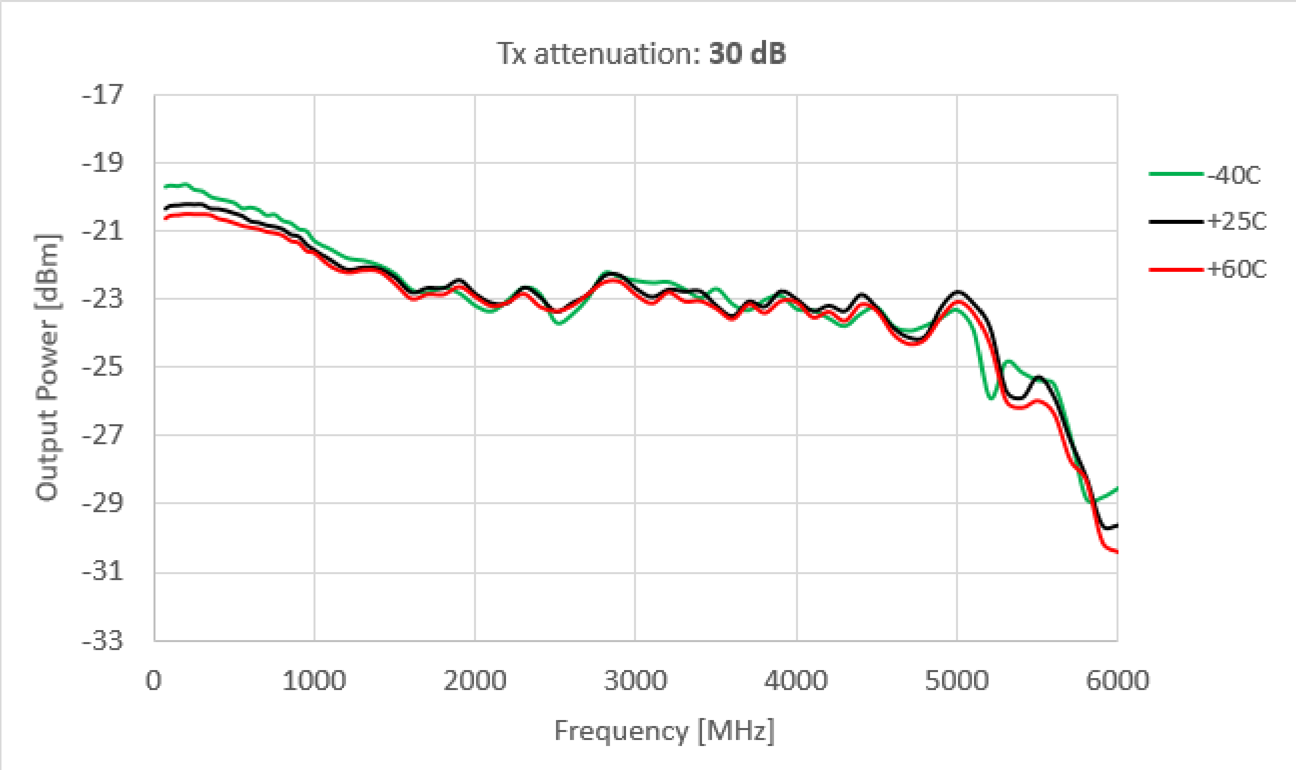


Figure 4: Tx output power at 30 dB attenuation.

The following subsection presents receiver performance.

9.2 Receiver

This section presents characteristics of the receiver, more specifically the measured and analyzed RF performance figures are input return loss, noise figure and intermodulation distortion.

9.2.1 Input Return Loss

Input return loss is expressed as the magnitude of S_{11}. In the case of full reflection the return loss would be 0 dB meaning that the reflected wave is 0 dB below incident wave. The opposite applies for the scenario of no reflection i.e. leading to infinite return loss.

The input return loss is measured as a function of Rx gain (MGC mode) and LO frequency. The input return loss is depicted in Figure 5 while operating at LO = 1 GHz and Rx gain index 1 & 70. Sweeping the LO frequency within supported range from 70 MHz to 6 GHz leads to similar input return loss characteristics as shown in Figure 5. Input return loss is not affected by LO frequency change due to the preceding LNA stage, which defines main impedance characteristics of Rx input.

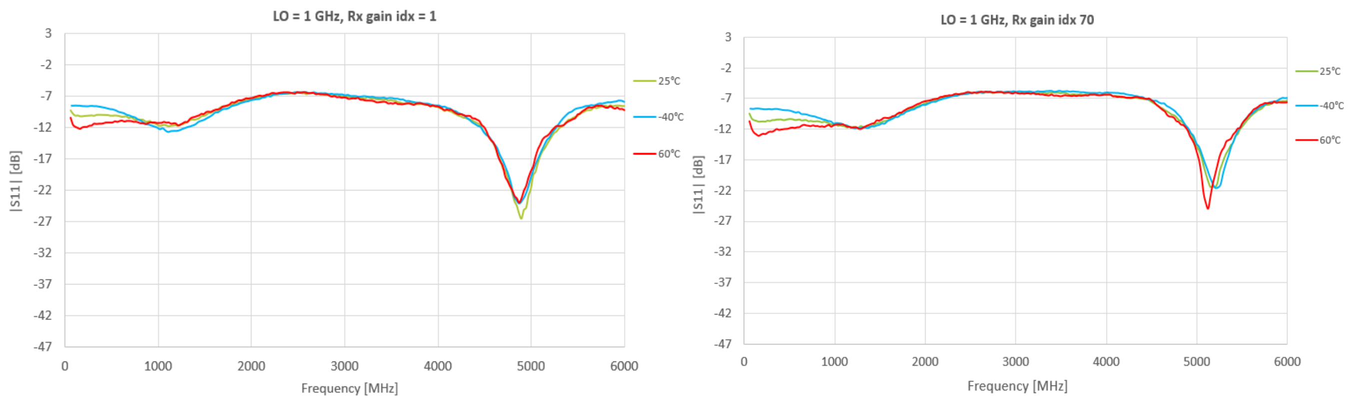


Figure 5: Return loss as a function of ambient temperature, LO = 1 GHz, Rx gain index 1 & 70.

Based on obtained results it is shown that Rx input return loss characteristics are subject to variation as a function of Rx gain. The worst-case return loss across frequency and gain setting is approx. -6 dB.

9.2.2 Noise Figure

The Noise Figure (NF) is measured using Y-Factor method. The analog filter bandwidth is set to 18 MHz and noise is measured at 2.5 MHz offset from LO frequency. The noise measurement bandwidth is 3 MHz. For detection of noise power at TR-600 receiver output, an RMS power meter has been implemented in GNU Radio.

The NF performance measured while operating at LO = 210 MHz is visualized in Figure 6.

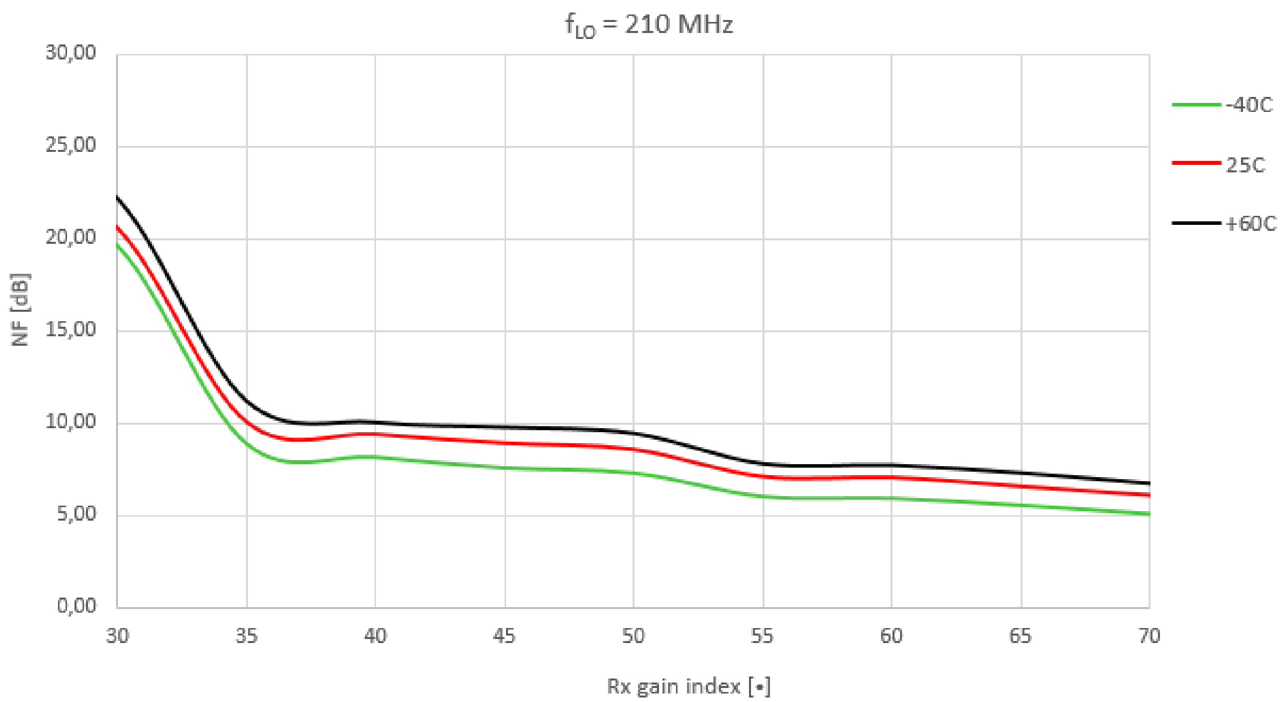


Figure 6: NF measurement while running with LO = 210 MHz, VHF applications.

As illustrated in Figure 6, increasing the Rx gain leads to improved NF performance, as expected. Furthermore, it is shown that lower operating temperature leads to improved NF, which is likewise expected behavior. Exact NF values at highest Rx gain indices are summarized in Table 1.

Temp./ Gain idx	55	60	65	70	Unit
60 °C	7.8	7.7	7.3	6.7	dB
25 °C	7.1	7.0	6.5	6.1	dB
-40 °C	6.0	5.9	5.4	5.1	dB

Table 1: NF values at upper Rx gain indices, f_{LO} = 210 MHz.

Corresponding NF behavior valid for UHF applications is shown in Figure 7.

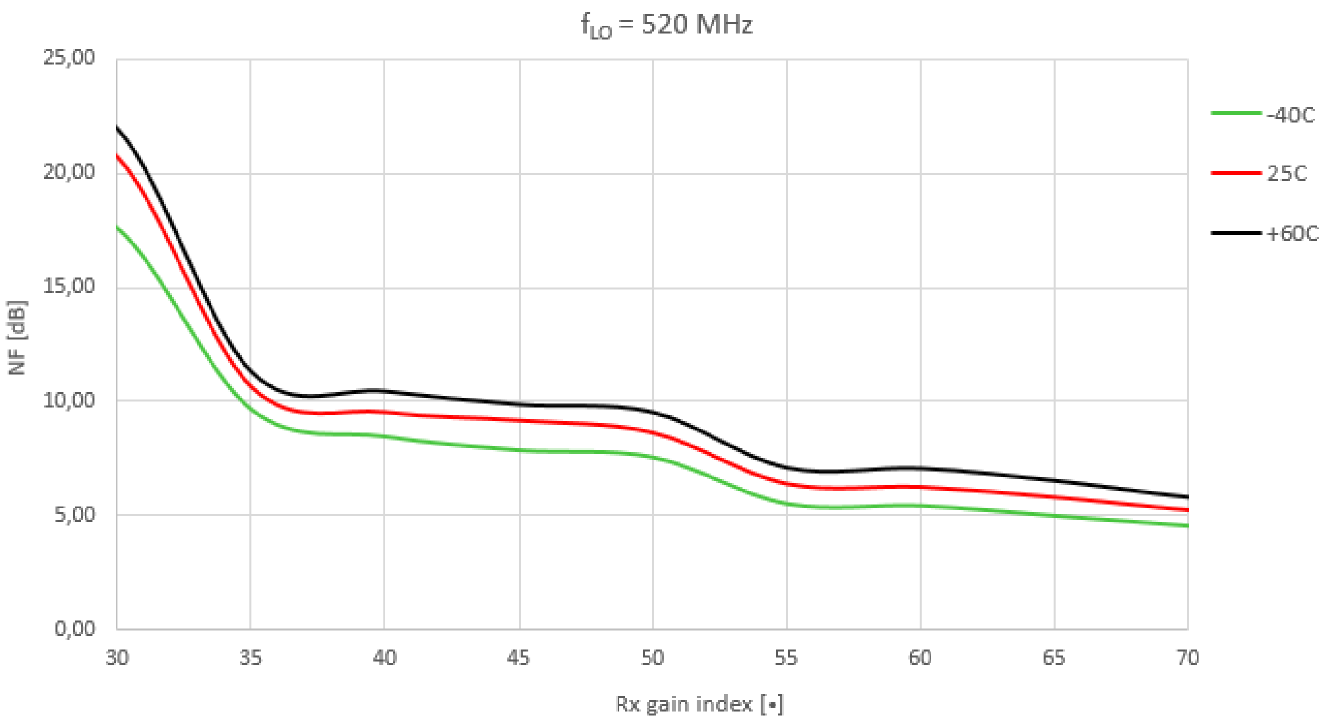


Figure 7: NF measurement while running with LO = 520 MHz, UHF applications.

Exact NF values at highest Rx gain indices are summarized in Table 2.

Temp./ Gain idx	55	60	65	70	Unit
60 °C	7	7	6.5	5.8	dB
25 °C	6.3	6.2	5.8	5.2	dB
-40 °C	5.5	5.4	5	4.5	dB

Table 2: NF values at upper Rx gain indices, f_{LO} = 520 MHz.

The measured NF characteristics at ADS-B frequency are presented in Figure 8.

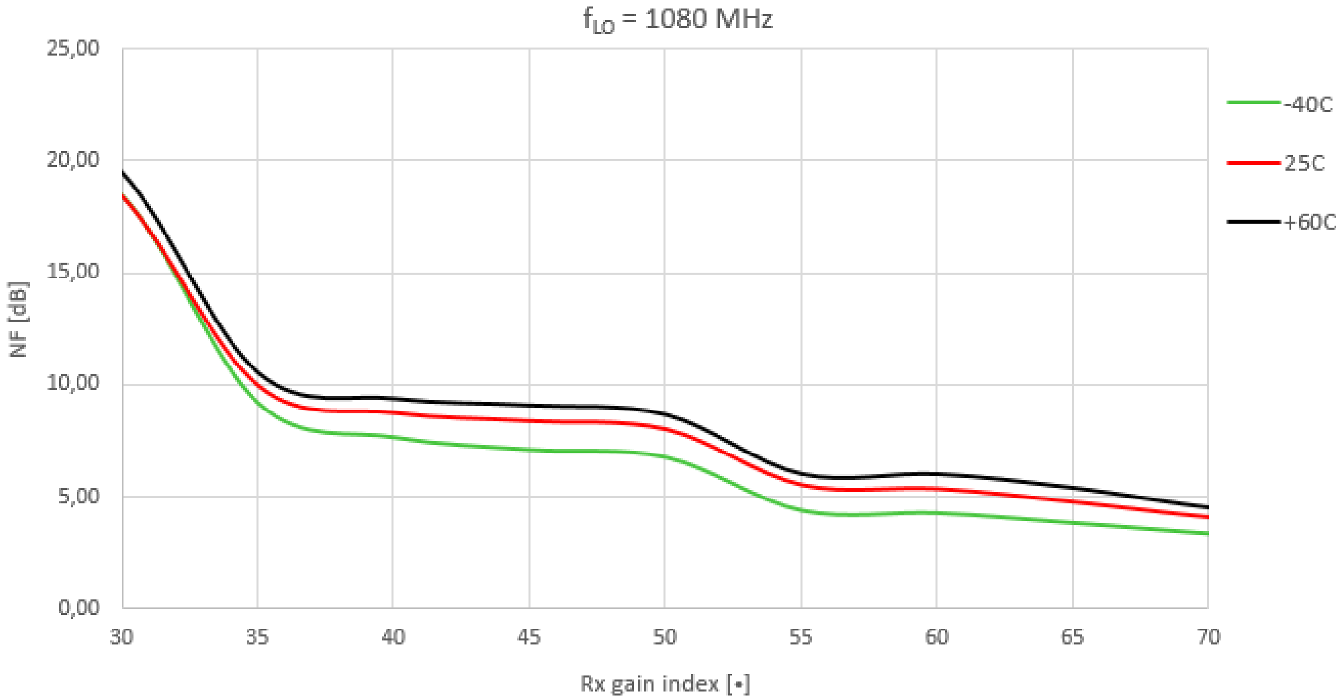


Figure 8: NF measurement while running with LO = 1080 MHz, ADS-B applications.

Exact NF values at highest Rx gain indices are summarized in Table 3.

Temp./ Gain idx	55	60	65	70	Unit
60 °C	6	6	5.4	4.6	dB
25 °C	5.5	5.3	4.7	4	dB
-40 °C	4.4	4.3	3.8	3.3	dB

Table 3: NF values at upper Rx gain indices, f_{LO} = 1080 MHz

Related results valid for operation at lower part of S-band are depicted in Figure 9.

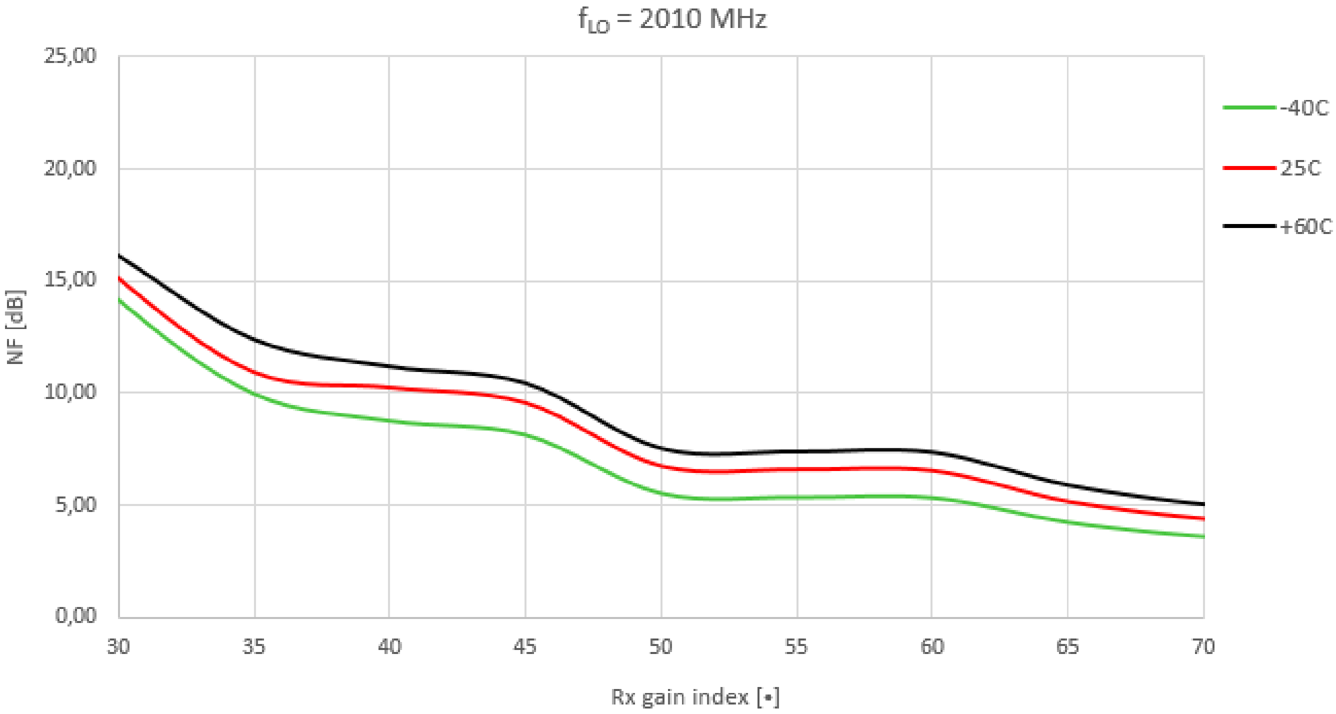


Figure 9: NF measurement while running with LO = 2010 MHz, S-band applications.

Exact NF values at highest Rx gain indices are summarized in Table 4.

Temp./ Gain idx	55	60	65	70	Unit
60 °C	7.3	7.3	5.9	5	dB
25 °C	6.6	6.5	5.2	4.4	dB
-40 °C	5.3	5.3	4.2	3.6	dB

Table 4: NF values at upper Rx gain indices, f_{LO} = 2010 MHz.

The measured NF characteristics at the upper part of S-band are visualized in Figure 10.

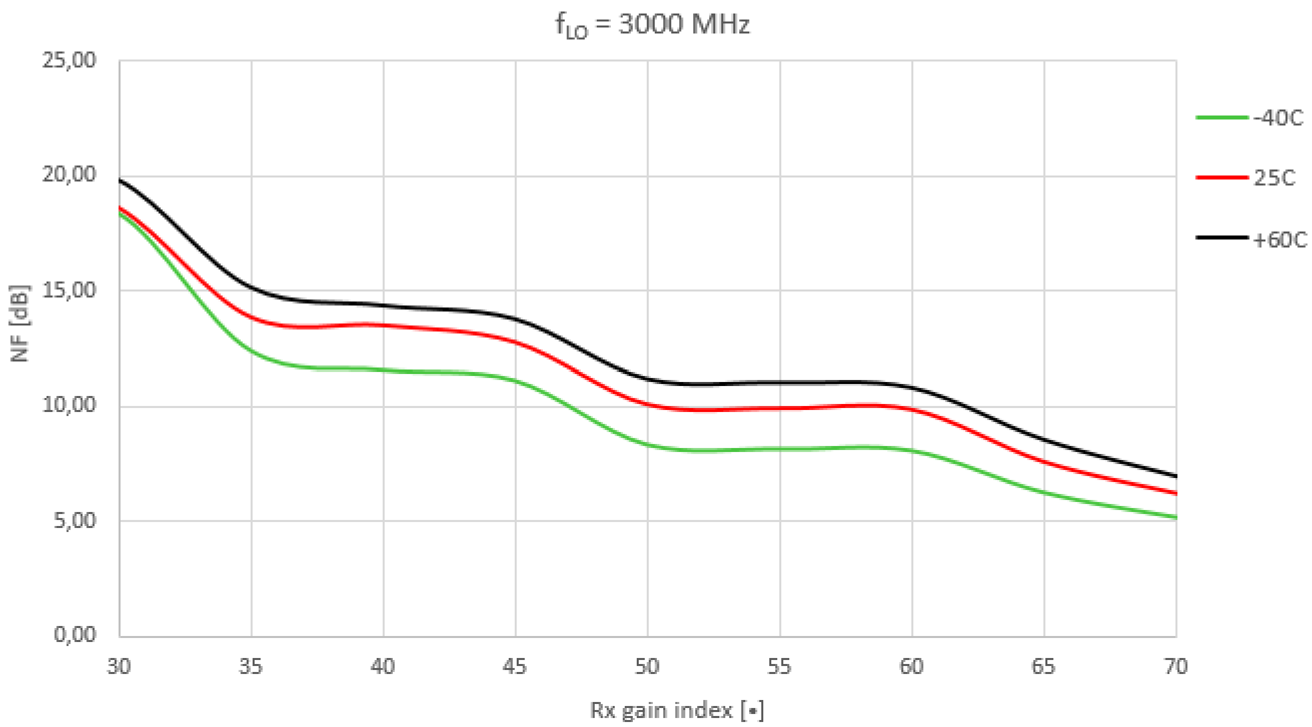


Figure 10: NF measurement while running with LO = 3000 MHz, S-band applications.

Exact NF values at highest Rx gain indices are summarized in Table 5.

Temp./ Gain idx	55	60	65	70	Unit
60 °C	11	10.8	8.5	7	dB
25 °C	9.9	9.8	7.6	6.2	dB
-40 °C	8.1	8.1	6.3	5.2	dB

Table 5: NF values at upper Rx gain indices, f_{LO} = 3000 MHz.

The measured NF characteristics at the upper part of S-band are visualized in Figure 15.

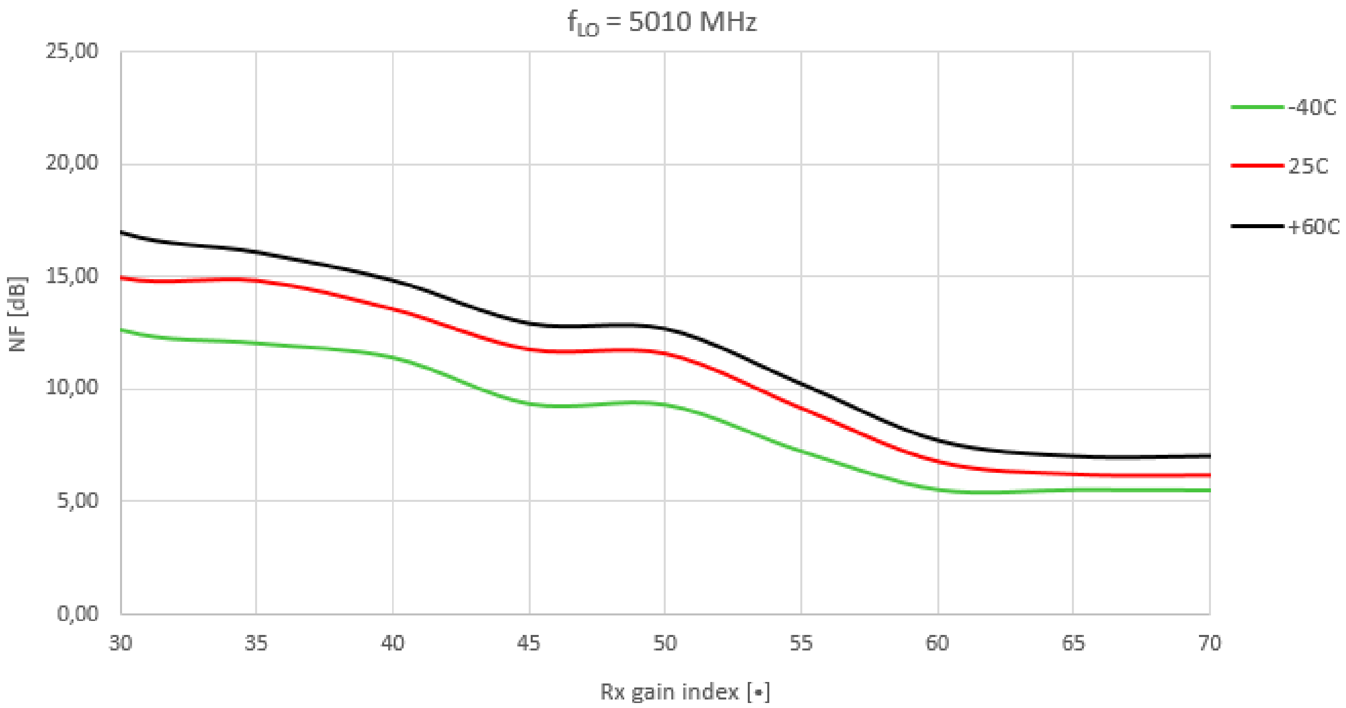


Figure 11: NF measurement while running with LO = 5010 MHz, C-band applications.

Exact NF values at highest Rx gain indices are summarized in Table 6.

Temp./ Gain idx	55	60	65	70	Unit
60 °C	10.2	7.7	7	7	dB
25 °C	9.1	6.7	6.2	6.1	dB
-40 °C	7.2	5.5	5.5	5.5	dB

Table 6: NF values at upper Rx gain indices, f_{LO} = 5010 MHz

Based on obtained results it is observed that lowest NF is achieved by operating at highest receiver gain levels, which is a valid statement for all considered center frequencies. Table 7 serves for NF comparison when operating at different LO frequencies – valid for T_{amb} = 25°C.

Freq./ Gain idx	55	60	65	70	Unit
210 MHz	7.1	7	6.5	6.1	dB
520 MHz	6.3	6.2	5.8	5.2	dB
1080 MHz	5.5	5.3	4.7	4	dB
2010 MHz	6.6	6.5	5.2	4.4	dB
3000 MHz	9.9	9.8	7.6	6.2	dB
5010 MHz	9.1	6.7	6.2	6.1	dB

Table 7: Summarized NF results, T_{amb}=25°C.

Conclusively, it is advisable to deploy highest gain possible for given input signal with the scope to enhance receiver sensitivity.

9.2.3 Intermodulation Distortion – IIP3

The IIP3 is measured using a two-tone (CW) test where interfering tones RF_1 and RF_2 are applied at receiver input. The measurement is executed in two scenarios i.e. while interfering tones are inside RF channel bandwidth (in-band) and while being out-of-band, as visualized in Figure 12.

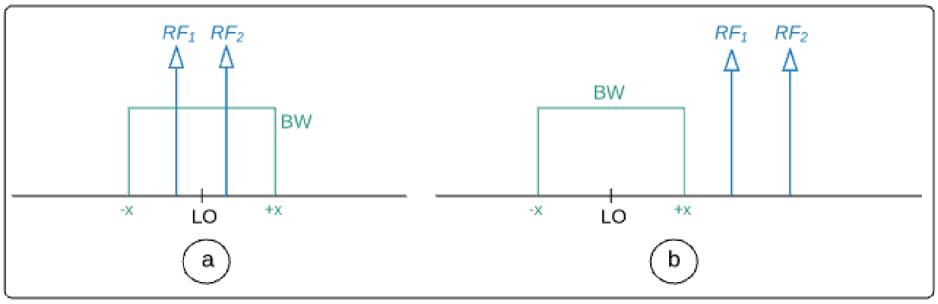


Figure 12: IIP3: a) interfering tones are in-band, b) interfering tones are out-of-band.

The obtained results for respectively in-band and out-of-band cases are presented in the following.

9.2.3.1 In-band IIP3

This measurement is applied at three LO frequencies, namely 524 MHz, 1095 MHz & 2008 MHz and using two Rx gain indices i.e. 30 and 50. The RF channel bandwidth is set to ±9 MHz.

The interfering tones RF_1 and RF_2 are applied at ±1 MHz offset from LO frequency, which entails that the resulting IM3 products are located at ±3 MHz offset from LO frequency.

The obtained in-band IIP3 results are shown in Table 8.

	LO = 524 MHz	LO = 1095 MHz	LO = 2008 MHz	Unit
RX gain index 30	0.5	2.1	-1.8	dBm
RX gain index 50	-18.1	-15.2	-15.3	dBm

Table 8: In-band IIP3 results.

9.2.3.2 Out-of-band IIP3

This measurement is applied for three different LO frequencies, namely 525 MHz, 1095 MHz & 2008 MHz and using three Rx gain indices i.e. 30, 50 and 70. The RF channel bandwidth is set to ±3 MHz.

While operating with LO = 525 MHz, the applied interfering tones are RF_1 = 532 MHz and RF_2 = 537 MHz. Based on this configuration, the created in-band IM3 product is computed as follows: IM3 = (2 * 532 – 537) – 525 = 2 MHz. The corresponding IIP3 is derived based on the magnitude of this IM3 product and the out-of-band tone RF_1.

While operating with LO = 1095 MHz, the applied interfering tones are RF_1 = 1102 MHz and RF_2 = 1107 MHz. Based on this configuration, the created in-band IM3 product is computed as follows: IM3 = (2 * 1102 – 1107) – 1095 = 2 MHz. The corresponding IIP3 is derived based on the magnitude of this IM3 product and the out-of-band tone RF_1.

While operating with LO = 2008 MHz, the applied interfering tones are RF_1 = 2015 MHz and RF_2 = 2020 MHz. Based on this configuration, the created in-band IM3 product is computed as follows: IM3 = (2 * 2015 – 2020) – 2008 = 2 MHz. The corresponding IIP3 is derived based on the magnitude of this IM3 product and the out-of-band tone RF_1.

The out-of-band IIP3 results are summarized Table 9.

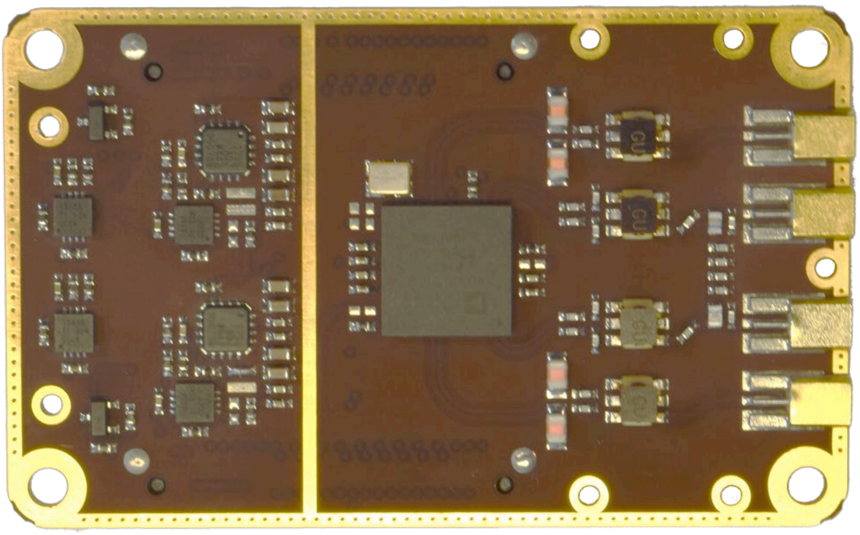
	LO = 525 MHz	**LO = 1095 MHz**	**LO = 2008 MHz**	**Unit**
RX gain index 30	5	3.3	-3.2	dBm
RX gain index 50	-7.2	-8.5	-11.8	dBm
RX gain index 70	-17.6	-19.2	-19.6	dBm

Table 9: Obtained out-of-band IIP3 results.

10 Physical Layout

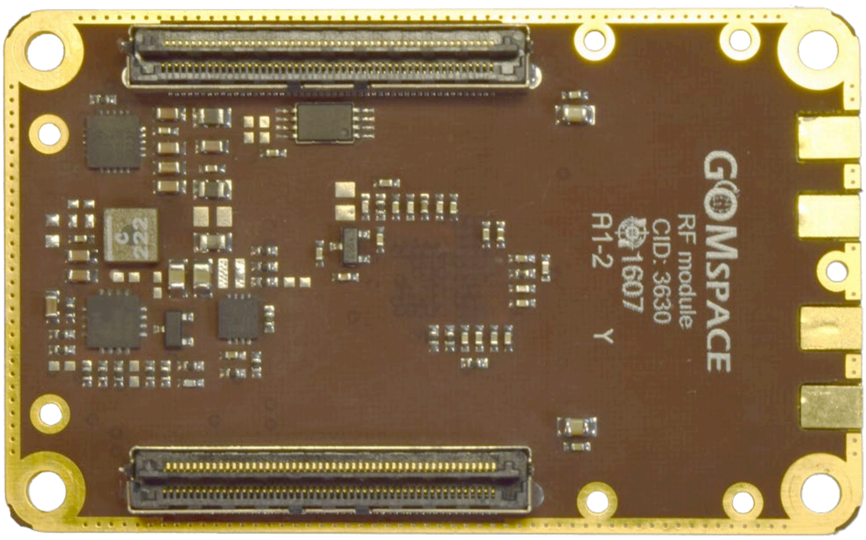
10.1 Top

On the right edge are the 4 Molex SSMCX EDGE 73415-4670 connectors. The left third part is the PSU and the current and voltage measurements. In the middle is the transceiver.



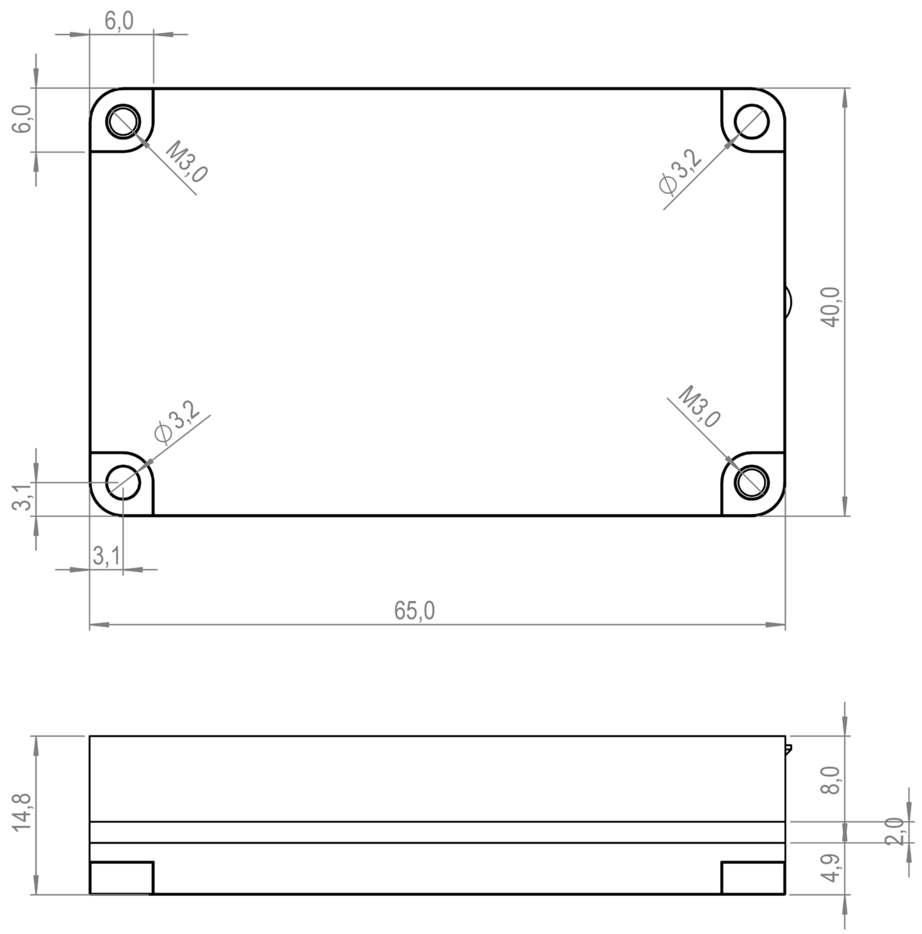
10.2 Bottom

The bottom part of the PCB contains the two connectors to the motherboard Samtec LSHM-150-04.0-L-DV-A-S-K-TR. The top left corner is the ADC and lower left PSU. Just below the top connector is the EEprom.



11 Mechanical Drawing

All dimensions in mm



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