PRM2141X Datasheet

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1. Introduction

1.1 Summary

The PRM2141X is a complete USB 3.0 to WiGig module with advanced features for long range, outdoor applications. It utilizes the Peraso X720 802.11ad 60 GHz phased array chipset which includes a baseband processor and a high-power mmWave beamforming transceiver RFIC.

The PRM2141X incorporates a 16-element phased array antenna which can be used with or without a dish reflector. The antenna is integrated into the PCB and provides uniform performance over the entire WiGig band from 57 to 71 GHz.

The Baseband processor is the PRS4601 B2E. This provides all MAC and PHY layer functionality necessary for 802.11ad operation and supports point-to-point or point-to-multipoint capability.

The PRS1165 RFIC provides 16 RF chains with high transmit power levels. It supports all 6 of the WiGig defined channels.

1.2 Features

- 57 to 71GHz operation
- 16-element PCB integrated antenna
- 38 dBm EIRP with 16-elements active
  (higher gains supported using a dish reflector)
- Total system DC power
  - Tx: 11.75W (at QPSK, 16 elements active)
  - Rx: 4.5W (at QPSK, 16 elements active)
  - Tx: 4.25W (at QPSK, 4 elements active)
  - Rx: 3.3W (at QPSK, 4 elements active)
- Automatic rate adaptation
- Dynamic beamforming
- Automatic calibrations
- FCC certified**
- 13 channels from 0.5 to 6.5
- ½-Channel*, Full-Channel BW
- Integrated power management
- 802.11ad MAC and PHY compliance
- -72dBm receive sensitivity @MCS1
- 3 Gbps maximum data rate*
- pi/2-BPSK, pi/2-QPSK modulation support
- AES 128 bit data encryption
- Peraso Directional Beam Scan and Connect (DBSC) for establishing long-range PtP links
- 1PPS synchronization support*
- A-MSDU, A-MPDU data aggregation

* Optional firmware enabled feature. Contact Peraso sales support for more information.
**PRM2141X-V-EGS is certified. FCC ID: 2A564141V40

1.3 Applications

- mmWave point-to-point small cell backhaul links
- PtMP fixed wireless access
- High performance 60 GHz access points and clients

1.4 Abbreviations and Acronym Definitions

Acronym	Definition
1PPS	One pulse per second
A-MPDU	Aggregated MAC protocol data unit
A-MSDU	Aggregated MAC service data Unit
BB	Baseband
BPSK	Binary phase shift key modulation
BW	Bandwidth
DBSC	Directional Beam Scan and Connect
DMG-TM / DMG	Directional Multi-Gigabit Test Mode
EIRP	Equivalent Isotropic Radiated Power
EVK	Evaluation kit
HPBW	Half power beamwidth
MIB	Management Information Base
PtMP	Point to multipoint
PtP	Point to point
QPSK	Quadrature phase shift key modulation
QAM	Quadrature Amplitude Modulation
RSSI	Received Signal Strength Indicator
SNR	Signal to Noise Ratio

1.5 Common RF Parameters

The PRM2141X can be tuned WiGig Channels 1-6, including half-channels.

Refer to Table 1-1 and Table 1-2 for the channels and center frequencies.

Table 1-1: IEEE 802.11ad/ay channels

Channel	Center Frequency (GHz)	Frequency Range (GHz) Full-channel Bandwidth	Frequency Range (GHz) Half-channel Bandwidth *
Channel 1	58.32	57.24 – 59.40	57.78 – 58.86
Channel 2	60.48	59.40 – 61.56	59.94 – 61.02
Channel 3	62.64	61.56 – 63.72	62.1 – 63.18
Channel 4	64.80	63.72 – 65.88	64.26 – 65.34
Channel 5	66.96	65.88 – 68.04	66.42 – 67.5
Channel 6	69.12	68.04 – 70.2	68.58 – 69.66

***Half-channel bandwidth is not supported in 802.11ad/ay**

Table 1-2: Half-channels

Channel	Center Frequency (GHz)	Frequency Range (GHz) Full-channel Bandwidth	Frequency Range (GHz) Half-channel Bandwidth *
Channel 0.5	57.24	56.16 – 58.32	56.7 – 57.78
Channel 1.5	59.4	58.32 – 60.48	58.86 – 59.94
Channel 2.5	61.56	60.48 – 62.64	61.02 – 62.1
Channel 3.5	63.72	62.64 – 64.8	63.18 – 64.26
Channel 4.5	65.88	64.8 – 66.96	65.34 – 66.42
Channel 5.5	68.04	66.96 – 69.12	67.5 – 68.58
Channel 6.5	70.2	69.12 – 71.28	69.66 – 70.4

***Half-channels are not supported in 802.11ad/ay**

Table 1-3:Modulation Code and raw PHY data rates

MCS Index	Modulation	Code Rate	PHY Data Rate (Mbps)
MCS0	DBPSK	1/2	27.5
MCS1	Π/2 BPSK	1/2	385
MCS2	Π/2 BPSK	1/2	770
MCS3	Π/2 BPSK	5/8	962.5
MCS4	Π/2 BPSK	3/4	1155
MCS5	Π/2 BPSK	13/16	1251.25
MCS6	Π/2 QPSK	1/2	1540
MCS7	Π/2 QPSK	5/8	1925
MCS8	Π/2 QPSK	3/4	2310
MCS9	Π/2 QPSK	13/16	2502.5

2. Product

2.1 General Description

The PRM2141X operates from a single 5V supplied through the connector. This module has programmable full and half BW channels. Refer to Table 1-1 and Table 1-2 for details. The PRM2141X provides all the functionality of a multi-gigabit wireless transceiver compliant with the 802.11ad standard, supporting the complete solution from SuperSpeed USB connectivity to 60GHz wireless functionality.

The integrated 16-element antenna performs beamforming. This module has two pre-set antenna configurations: one to be used in conjunction with a dish reflector and the other for use as a stand-alone antenna (i.e., for use without a dish reflector). This antenna can also operate with a quasi-omnidirectional antenna pattern.

No factory calibration is required, as all calibration is performed at run-time.

This module meets the compliance requirements of European Union Directive 2011/65/EU (RoHS).

3. Common Specifications

Unless noted otherwise, all specifications are under typical conditions, nominal VDD, 25 °C ambient, 65 °C junction temperature for the PRS4601 B2E and PRS1165.

3.1 Absolute Maximum Ratings

Table 3-1: Absolute maximum ratings

Parameter/Pin	Description	Conditions	Min	Max	Units
T_S	Storage temperature		-40	85	°C
Antenna	Maximum Device Incident Power			0.4	dBm
2.5V CMOS IO	Voltage on any 2.5-V CMOS IO pin		-0.25	2.75	V
VBUS_IN	used by the module to monitor the voltage level of the USB bus		0	5.25	V
VDD	Voltage rail supplied to the module		3.8	6	V
V3P3_OUT	voltage level of the PRM2141X's 3.3V regulator		-0.3	3.6	V
V2P5_OUT	voltage level of the PRM2141X's 2.5V regulator		-0.3	VDD+0.3	V
SSTX_M/_P, SSRX_M/_P,	USB3 data signals		0	1.21	V
DM,DP	USB2 data signals		0	3.6	V
DISABLE_N	Open-drain, active low			VDD	V
SYS_RESET_N	Open-drain, active low		-0.25	2.75	V
I_{VDD}	Supply current		2.25		A
T_j	Maximum junction temperature of PRS4601 B2E, PRS116	Module is connected to power		125	°C

1: This is maximum RF input power at any time including before power-on-reset sequence complete. Value is higher under specific configurations.

2: Die to ambient thermal resistance is not specified as this part is intended to be used with a heat sink.

3.2 Recommended Operating Conditions

Table 3-2: Recommended operating conditions

Parameter/Pin	Description	Conditions	Min	Typ	Max	Units
Tamb	Ambient operating temperature	See note 5	-40		85	°C
VDD			3.8	5	5.5	V
I_{VDD}	Min. current that the VDD needs to able to supply	At Min VDD of 3.8V	4			A
GPIO_0, GPIO_6,GPIO_1_14, GPIO_15, UM_PWM_0, UM_PWM_1, UM_PWM_2, UM_PWM_3, SYS_RESET_N, DISABLE_N	Voltage on any 2.5-V CMOS IO pin		0		V2P5_OUT	V
TWI_SDA, TWI_SCL			0		V2P5_OUT	V

5: The maximum ambient temperature depends on the complete thermal solution of the system. The maximum junction temperature of the PRS4601 B2E is limited to 110^0.therefore, the $T_{junction\text{-}ambient}$ is limited to 25C for +85C maximum ambient temperature.

The thermal resistance from junction to case for the PRM2141-V-EGS ($R_{\Theta JC}$) is 2.1^0 C/W. Refer to Section 11.1 for more details on thermal design

3.3 I/O Specifications

Unless otherwise noted, all specifications are at 25 °C.

Table 3-3 give the IO specifications of GPIO_0, GPIO_6, GPIO_15, GPIO_1_14, UM_PWM_0, UM_PWM_1, UM_PWM_2, UM_PWM_3, and SYS_RESET_N.

Table 3-3: CMOS IO (2.5V) specifications

Parameter	Description	Conditions	Min	Typ	Max	Units
V_{IL}	Low level input voltage				0.7	V
V_{IH}	High level input voltage		1.7			V
V_{HYST}	Schmitt trigger hysteresis		0.3			V
V_{OL}	Low level output voltage	I_{OL} = 8mA			0.20	V
V_{OH}	High level output voltage	I_{OH} = -8mA	VDD25 - 0.2			V

GPIO_6, GPIO_1_14, and GPIO_15 are Schmitt trigger inputs.

Table 3-4: Maximum Allowable Signal Levels

IO	Min	Max	Units
DISABLE_N	-0.3	6	V
V3P3_OUT	Can only source/sink 100mA maximum		

IO	Min	Max	Units
V2P5_OUT	Can only source/sink 100mA maximum		
TWI_SDA		V2P5	V
TWI_SCL		V2P5	V
VBUS_IN	0	5.25V	V

3.4 ESD

Table 3-5 shows the ESD ratings of the IO pins.

Table 3-5: ESD Ratings of I/O Pins

PIN	I/O	Model	Rating
1	DISABLE_N	HBM	2kV
2	V3P3_OUT	HBM	2kV
3	SYS_RESET_N	HBM	2kV
5	GPIO_1_14	HBM	2kV
6	V2P5_OUT	HBM	2kV
7	GPIO_15	HBM	2kV
10	SSTX_M	HBM	2kV
12	SSTX_P	HBM	2kV
13	GPIO_6	HBM	2kV
16	DP	HBM	2kV
18	DM	HBM	2kV
19	UM_PWM_3	HBM	2kV
22	SSRX_M	HBM	2kV
24	SSRX_P	HBM	2kV
25	UM_PWM_1	HBM	2kV
27	UM_PWM_2	HBM	2kV
28	TWI_SDA	HBM	2kV
29	UM_PWM_0	HBM	2kV
30	TWI_SCL	HBM	2kV
31	GPIO_0	HBM	2kV
34	VBUS_IN	HBM	2kV

4. Specifications for Dish Antenna Configuration

4.1 DC Specifications

Unless otherwise noted, all DC specifications are at 25 °C ambient, 65 °C junction, and channel 4 (64.80 GHz)

Table 4-1: DC Specifications when configured with the Dish Antenna Beam Table

Parameter/Pin	Description	Conditions	Min	Typ	Max	Units
Tx DC Power Consumption				4.25		W
Rx DC Power Consumption				3.3		W

4.2 Transmit Specifications

Table 4-2: Key performance parameters when configured with the Dish Antenna Beam Table

Parameter	Conditions	Min	Typ	Max	Units
Radiated Power	T_{amb}=25^{0}C, Not including any dish gain		18		dBm
Beamforming Parameters					
Predefined Beam Table Entries			9		
Maximum Beam Table Directions			64		
Azimuth Scan Range	See Note 1				
Elevation Scan Range	See Note 1				

Note 1: The different sectors use a subset of 4 elements. The beam is physically translated by selecting which 4 elements are enabled. The scan range is thus determined by the characteristics of the dish reflector. Refer to Section 9.2 for more details.

4.3 Receive Specifications

Table 4-3 lists the typical sensitivities at different MCS and channels.

Table 4-3: Sensitivity when configured with the Dish Antenna Beam Table (not including the gain of the dish)

Channel	MCS	Conditions	Min	Typ	Max	Units
Channel 1	MCS9	Boresight beam		-60		dBm
	MCS4	Boresight beam		-70		dBm
	MCS1	Boresight beam		-70		dBm
Channel 2	MCS9	Boresight beam		-63		dBm
	MCS4	Boresight beam		-71		dBm
	MCS1	Boresight beam		-71		dBm
Channel 3	MCS9	Boresight beam		-61		dBm
	MCS4	Boresight beam		-70		dBm
	MCS1	Boresight beam		-70		dBm
Channel 4	MCS9	Boresight beam		-60		dBm
	MCS4	Boresight beam		-70		dBm
	MCS1	Boresight beam		-72		dBm
Channel 5	MCS9	Boresight beam		-63		dBm

	MCS4	Boresight beam		-71		dBm
	MCS1	Boresight beam		-72		dBm
Channel 6	MCS9	Boresight beam		-61		dBm
	MCS4	Boresight beam		-71		dBm
	MCS1	Boresight beam		-72		dBm

4.4 Antenna Specifications

This section gives the specifications for the PRM2141X antenna when configured for use in a dish antenna. Unless otherwise noted, all specifications are at 25 °C ambient, with the PRS4601 B2E and PRS1165 junction temperature at 65 °C.

The different sectors in this configuration do not change the direction of the beam. Rather, the beam is translated such that it impacts the dish reflector slightly off center. The beam is then steered slightly, based on the dimension of the dish reflector. Figure 4-1 shows the elements that are active for each beam in the sector table.

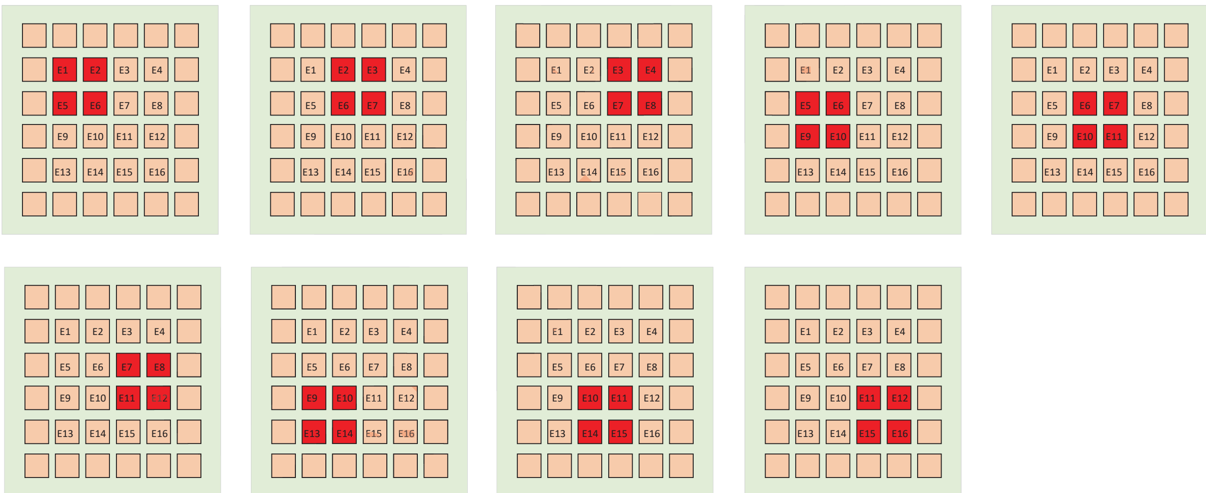


Figure 4-1: Showing activated elements for the sectors in the Dish Sector Table

5. Specifications for Stand-Alone Antenna Configuration

5.1 DC Specifications

Table 5-1: DC Power Consumption when configured with the Stand-Alone Beam Table

Parameter/Pin	Description	Conditions	Min	Typ	Max	Units
Tx DC Power Consumption				11.75		W
Rx DC Power Consumption				4.5		W

5.2 Transmit Specifications

Table 5-2 shows the key transmitter performance parameters.

Table 5-2: Key performance parameters when configured with the Stand-Alone Beam Table

Parameter	Conditions	Min	Typ	Max	Units
EIRP	T_{amb}=25^{0}C, Channel 4, MCS9 without dish reflector		38		dBm
Beam Forming Parameters					
Predefined Beam Table Directions	Peraso provided beam table, # of directional beams		37		
Maximum Beam Table Entries			64		
Azimuth Scan Range			+/-45		degrees
Elevation Scan Range			+/-45		degrees
Max Side Lobe	Boresight beam		-13		dB
Beamwidth at Boresight	Half-power beamwidth. Changes across channels	25		37	degrees

Table 5-3: EIRP performance across scanning range for each channel

Channel	Description	Azimuth, Elevation (degrees)				
	EIRP at scan angle from boresight (dB)	**0,0**	**0,40**	**0,-40**	**40,0**	**-40,0**
Channel 1		38.1	37.36	35.34	37.33	35.32
Channel 2		37.6	38.57	36.24	35.83	34.2
Channel 3		38.6	39.63	36.76	36.98	35.41
Channel 4		39.9	39.17	37.33	37.96	36.01
Channel 5		36.2	37.03	36.38	36.77	34.18
Channel 6		36.4	35.23	32.57	35.04	31.79

5.3 Receiver Specifications

Table 5-4: Boresight Sensitivity

Channel	MCS	Conditions	Min	Typ	Max	Units
Channel 1	MCS9	Boresight beam		-60		dBm
	MCS4	Boresight beam		-69		dBm
	MCS1	Boresight beam		-69		dBm
Channel 2	MCS9	Boresight beam		-62		dBm
	MCS4	Boresight beam		-69		dBm
	MCS1	Boresight beam		-69		dBm
Channel 3	MCS9	Boresight beam		-61		dBm
	MCS4	Boresight beam		-69		dBm
	MCS1	Boresight beam		-69		dBm
Channel 4	MCS9	Boresight beam		-61		dBm
	MCS4	Boresight beam		-69		dBm
	MCS1	Boresight beam		-70		dBm
Channel 5	MCS9	Boresight beam		-64		dBm
	MCS4	Boresight beam		-70		dBm
	MCS1	Boresight beam		-70		dBm
Channel 6	MCS9	Boresight beam		-64		dBm
	MCS4	Boresight beam		-70		dBm
	MCS1	Boresight beam		-70		dBm

5.4 Antenna Specifications

Table 5-5 gives the direction of peak gain for each beam in the Antenna Sector Table. Figure 5-1 shows a plot of the peak gain directions for each beam.

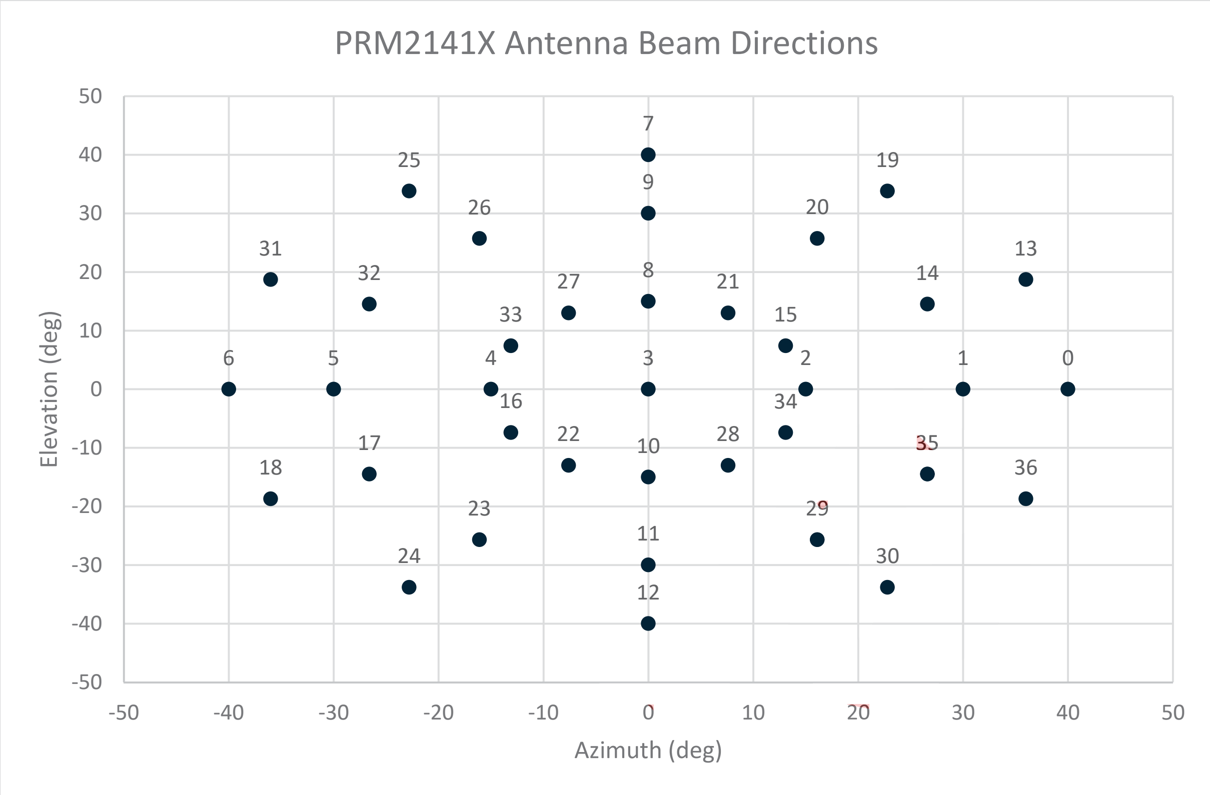


Figure 5-1: Direction of each beam in Stand-alone Antenna Sector Table

Table 5-5: Direction of each beam in Stand-alone Antenna Sector Table

Sector	Azimuth (degrees)	Elevation (degrees)	Sector	Azimuth (degrees)	Elevation (degrees)
0	40	0	**17**	-27	-15
1	30	0	**18**	-36	-19
2	15	0	**19**	23	34
3	0	0	**20**	16	26
4	-15	0	**21**	8	13
5	-30	0	**22**	-8	-13
6	-40	0	**23**	-16	-26
7	0	40	**24**	-23	-34
8	0	15	**25**	-23	34
9	0	30	**26**	-16	26
10	0	-15	**27**	-8	13
11	0	-30	**28**	8	-13
12	0	-40	**29**	16	-26
13	36	19	**30**	23	-34
14	27	15	**31**	-36	19
15	13	7	**32**	-27	15

Sector	Azimuth (degrees)	Elevation (degrees)	Sector	Azimuth (degrees)	Elevation (degrees)
16	-13	-7	**33**	-13	7
34	13	-7	**36**	36	-19
35	27	-15			

6. Signal Descriptions

6.1 Connector

This section describes the connector J3. This interface is a 34+2 pin connector. The mating connector is the Hirose BM28B0.6-34DP/2-0.35V(51).

The pin descriptions are found in Table 6-1 below. Section 9.3 gives more detailed description of these signals.

Table 6-1: Connector Pin Description

Pin	Signal Name	Level	Type	Active	Description
1	DISABLE_N	VDD	Input- Open drain. Pulled to VDD on module with 10K resistor.	Low	Pull to ground to turn off all regulators and disable module
2	V3P3_OUT	3.3V	Output- 3.3V power supply output (100mA maximum)		Voltage level of the 3.3V regulated voltage on the module
3	SYS_RESET_N	2.5V	Input- Open drain. Pulled to V2P5_BB on module with 10K resistor.	Low	Pull to ground to trigger module reset
4	GND				
5	GPIO_1_14	2.5V	IO- CMOS 2.5V signal	Configurable	Reserved. Must be left floating or pulled low during power-on / reset.
6	V2P5_OUT	2.5V	Output- 2.5V power supply output (100mA maximum)		Voltage level of the 2.5V regulated voltage on the module
7	GPIO_15	2.5V	IO- CMOS 2.5V signal	Configurable	External 1PPS clock input.
8	GND				
9	GND				
10	SSTX_M		Input		USB3 transmit data. Negative signal of the SSTX differential pair. AC coupled on the module.
11	GND				
12	SSTX_P		Input		USB3 transmit data. Positive signal of the SSTX differential pair.

Pin	Signal Name	Level	Type	Active	Description
					AC coupled on the module.
13	GPIO_6	2.5V	IO		Reserved. Must be left floating or pulled low during power-on / reset.
14	GND				
15	GND				
16	DP		IO		USB2 data. Positive signal of the differential pair.
17	GND				
18	DM		IO		USB2 data. Negative signal of the differential pair.
19	UM_PWM_3	2.5V	IO	Configurable	LED control (refer to Table 10-2for details). Must be left floating or pulled low during power-on / reset.
20	GND				
21	GND				
22	SSRX_M		Output		USB3 receive data. Negative signal of the SSRX differential pair.
23	GND				
24	SSRX_P		Output		USB3 receive data. Positive signal of the SSRX differential pair.
25	UM_PWM_1	2.5V	IO	Configurable	LED control. Must be left floating or pulled low during power-on / reset.
26	GND				
27	UM_PWM_2	2.5V	IO	Configurable	LED control (refer to Table 10-2 for details). Must be left floating or pulled low during power-on / reset.
28	TWI_SDA	2.5V	Open drain, pulled to V2P5_BB on module	Low	Two-Wire Interface data signal.
29	UM_PWM_0	2.5V	IO	Configurable	Reserved. Must be left floating or pulled low during power-on / reset.

Pin	Signal Name	Level	Type	Active	Description
30	TWI_SCL	2.5V	Open drain, pulled to V2P5_BB on module	Low	Two-Wire Interface Clock signal.
31	GPIO_0	2.5V	IO	Configurable	LED control (refer to Table 10-2 for details). Pull low during power-on / reset for normal boot. Pull high during power-on / reset to put in bootloader mode.
32	GND				
33	GND				
34	VBUS_IN	VBUS (5V)	Input		Used by the module to monitor the voltage level of the USB bus. May draw up to 100mA.
35,36	GND				
37,38	VDD				

A summary of the bootstrap functionality can be found in Table 9-1.

Figure 6-1 indicates the physical location of the signals on the connector. When looking at the component side of the module with module oriented such that the connector is in the left side, Pin 1 DISABLE_N is located on the edge of the board and on the upper end of the connector. This is the orientation shown in Figure 6-1.

7. Typical Performance for Dish Antenna Configuration

This section provides typical performance characteristics when the PRM2141X is configured to be used with a dish reflector.

7.1 Typical Antenna Performance

The PRM2145X antenna 10dB beamwidths are shown in Table 7-1. Figure 7-1 shows the axis directions. For reference as to how this antenna is oriented in the module, refer to Figure 9-1

Table 7-1: 3dB beamwidths when configured with the dish sector table (degrees)

	Ch 1		Ch2		Ch 3		Ch 4		Ch 5		Ch 6	
	Elev.	Azi.	Elev.	Azi.	Elev.	Azi.	Elev.	Azi.	Elev.	Azi.	Elev.	Azi.
E1, E2, E5, E6	77	53	85	53	70	55	55	54	53	56	46	47
E2, E3, E6, E7	51	71	79	67	64	68	54	62	54	69	47	51
E3, E4, E7, E8	77	53	85	53	70	57	57	55	54	56	46	47
E5, E6, E9, E10	63	51	48	53	39	55	62	54	54	49	50	51
E6, E7, E10, E11	55	67	44	67	32	66	59	68	51	66	53	56
E7, E8, E11, E12	64	52	49	54	40	56	64	55	54	50	48	50
E9, E10, E13, E14	72	52	78	52	57	54	56	56	52	58	49	50
E10, E11, E14, E15	46	66	68	67	57	66	44	75	50	74	51	55
E11, E12, E15, E16	70	50	78	53	59	55	56	57	52	58	49	50

Table 7-2: 10dB beamwidths when configured with the dish sector table (degrees)

	Ch 1		Ch2		Ch 3		Ch 4		Ch 5		Ch 6	
	Elev.	Azi.	Elev.	Azi.	Elev.	Azi.	Elev.	Azi.	Elev.	Azi.	Elev.	Azi.
E1, E2, E5, E6	112	105	113	98	108	95	91	88	97	88	84	81
E2, E3, E6, E7	115	106	115	106	103	101	88	97	93	94	79	89
E3, E4, E7, E8	113	106	114	99	107	95	91	88	97	88	83	80
E5, E6, E9, E10	99	107	103	100	102	94	102	89	85	88	95	85
E6, E7, E10, E11	99	109	95	105	98	101	95	99	79	103	95	96
E7, E8, E11, E12	99	107	103	100	102	94	103	90	86	88	95	85
E9, E10, E13, E14	114	108	112	95	104	93	102	95	91	91	86	86
E10, E11, E14, E15	113	102	106	97	96	105	96	104	90	100	79	92
E11, E12, E15, E16	113	108	114	95	104	94	102	94	90	91	86	87

7.2 Typical Transmit Performance

The transmit radiated power for each channel is given in Table 7-3.

To calculate the EIRP with the dish reflector, simply add the reflector gain to the value in Table 7-3.

Table 7-3: Tx Conducted Output Power when configured for use in a dish reflector (with 4-elements active)

Channel	Tx Output Power (dBm)
Channel 1	18.2
Channel 2	18.4
Channel 3	17.1
Channel 4	18.6
Channel 5	18.6
Channel 6	17.6

7.3 Typical Receive Performance

Figure 7-2Figure 8-26 and Table 7-4Table 8-2 give the sensitivity vs. MCS for each channel, when configured with the Dish Sector Table. It should be noted here that this sensitivity is measured at the power incident on the antenna of the PRM2141X. It does not include the gain of the dish. It does not include the array gain of the active elements. There are 4 active elements on the array.

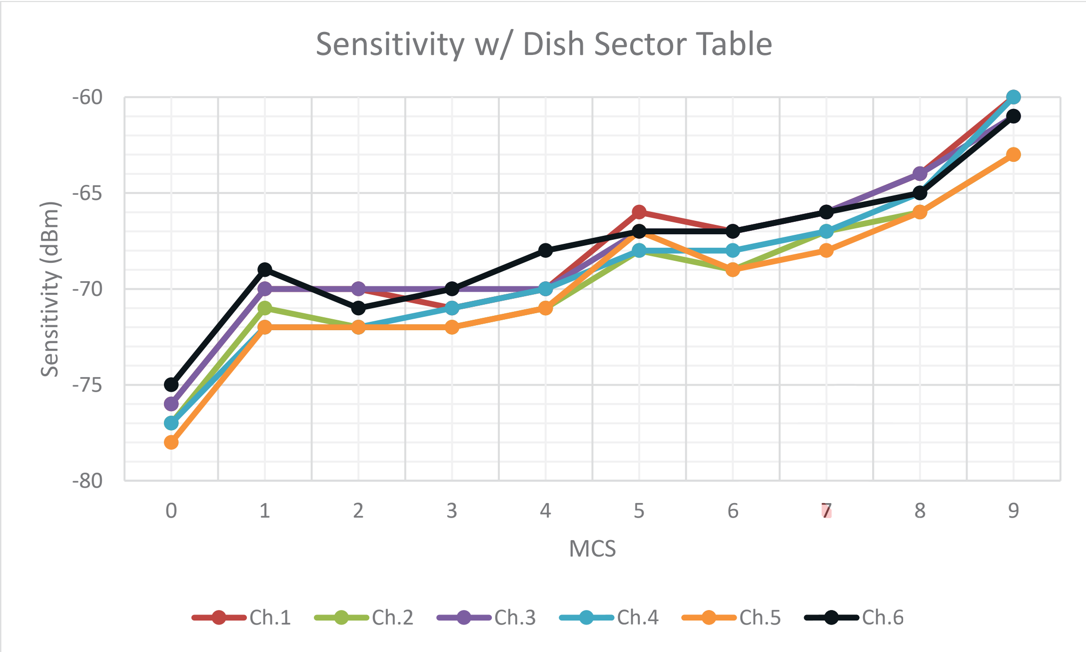


Figure 7-2: Sensitivity vs. MCS for all channels with Dish Sector Table

Table 7-4:Sensitivity vs. MCS with Dish Sector Table

Channel	MCS0	MCS1	MCS2	MCS3	MCS4	MCS5	MCS6	MCS7	MCS8	MCS9
1	-76	-70	-70	-71	-70	-66	-67	-66	-64	-60
2	-77	-71	-72	-72	-71	-68	-69	-67	-66	-63
3	-76	-70	-70	-70	-70	-67	-67	-66	-64	-61
4	-77	-72	-72	-71	-70	-68	-68	-67	-65	-60
5	-78	-72	-72	-72	-71	-67	-69	-68	-66	-63
6	-75	-69	-71	-70	-68	-67	-67	-66	-65	-61

8. Typical Performance for Stand-Alone Antenna Configuration

This section provides typical performance characteristics when the PRM2141X is configured to be used without a dish reflector (i.e., Stand-Alone Configuration).

Unless otherwise noted, all specifications are at 25 °C (65 °C junction).

8.1 Typical Antenna Performance

Figure 8-1 to Figure 8-12 show 2D plots of the antenna gain and the drop in gain from peak as it is scanned through the antenna sector table.

The antenna gain for each channel can be found in Table 8-1 below.

Table 8-1: Antenna Gain when configured in Stand-Alone mode

Channel	Boresight Gain (dBi)	Omni Gain (dBi)
Channel 1	14.6	9.7
Channel 2	14.4	9.9
Channel 3	15.6	10.6
Channel 4	16.2	11.4
Channel 5	16.0	12.3
Channel 6	16.1	11.7

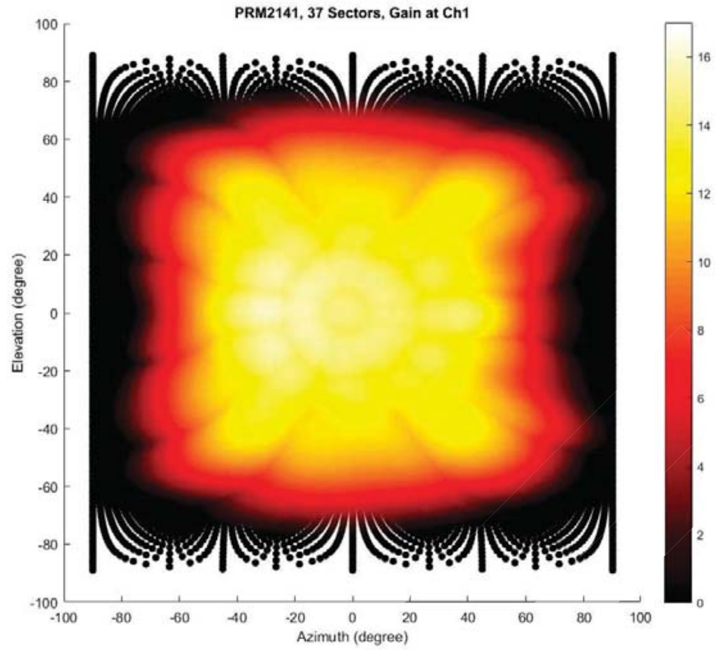


Figure 8-1: 2D surface plot of antenna gain for Ch. 1 (dBi)

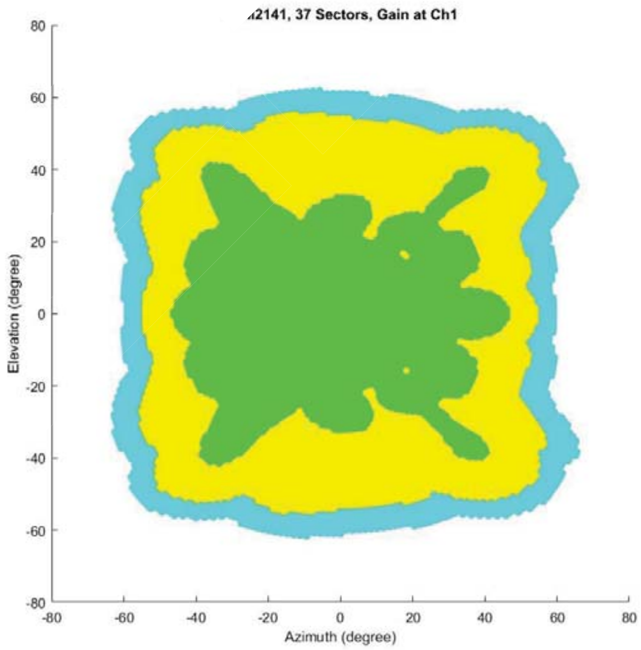


Figure 8-2: Surface plot showing gain drop from peak, Ch. 1. Green: 0-3 dB Yellow: 3-6 dB; Blue: 6-8 dB Drop.

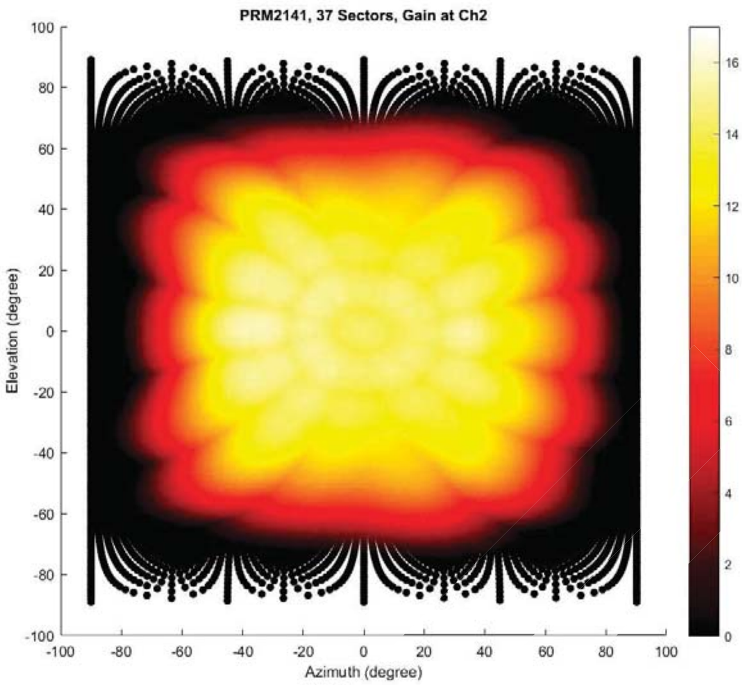


Figure 8-3: 2D surface plot of antenna gain for Ch. 2 (dBi)

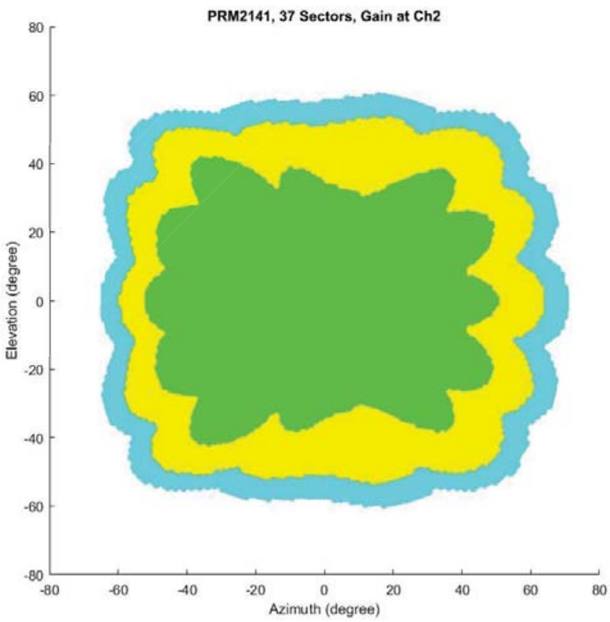


Figure 8-4: Surface plot showing gain drop from peak, Ch. 2. Green: 0-3 dB Yellow: 3-6 dB; Blue: 6-8 dB Drop.

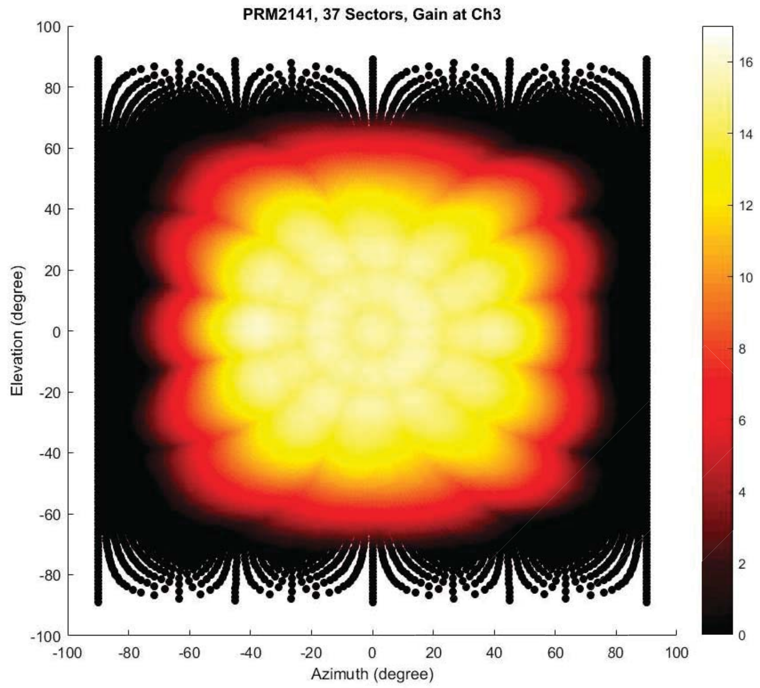


Figure 8-5: 2D surface plot of antenna gain for Ch. 3 (dBi)

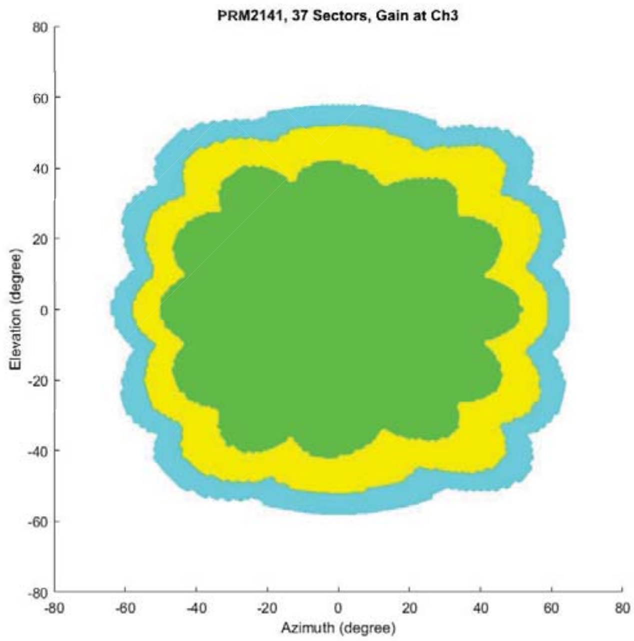


Figure 8-6: Surface plot showing gain drop from peak, Ch. 3. Green: 0-3 dB Yellow: 3-6 dB; Blue: 6-8 dB Drop.

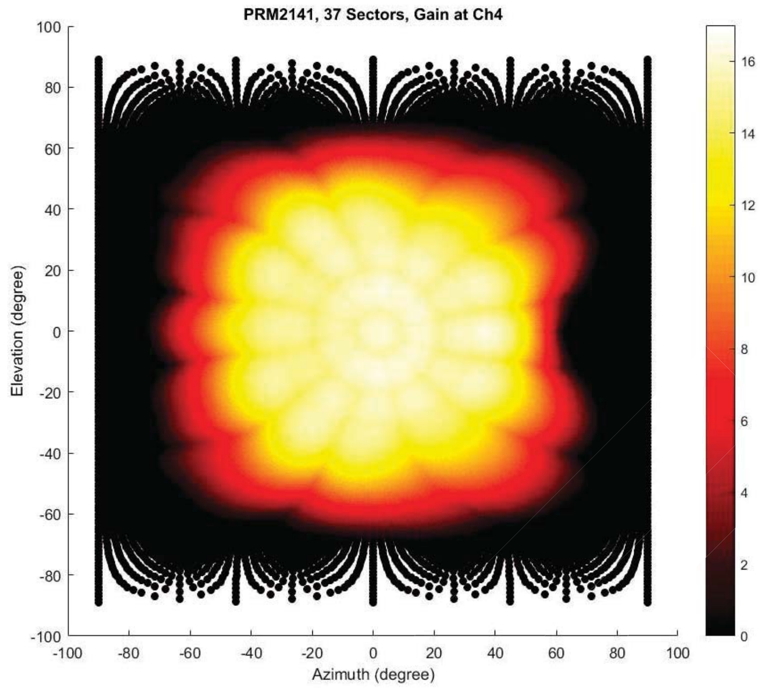


Figure 8-7: 2D surface plot of antenna gain for Ch. 4 (dBi)

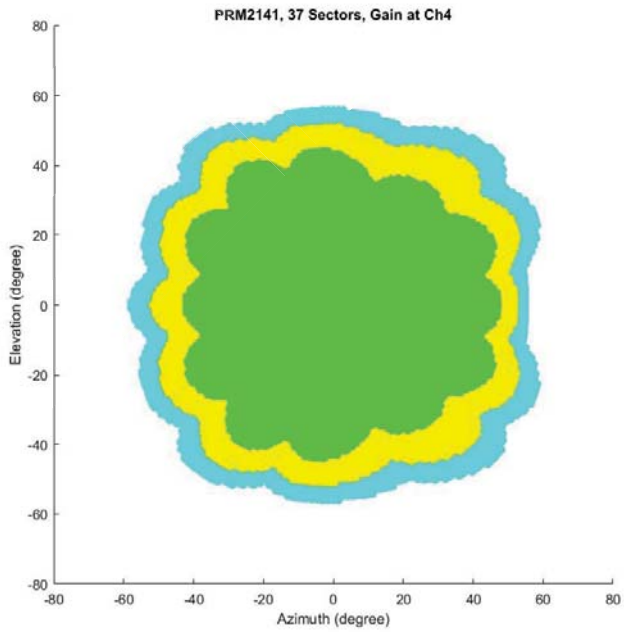


Figure 8-8: Surface plot showing gain drop from peak, Ch. 4. Green: 0-3 dB Yellow: 3-6 dB; Blue: 6-8 dB Drop.

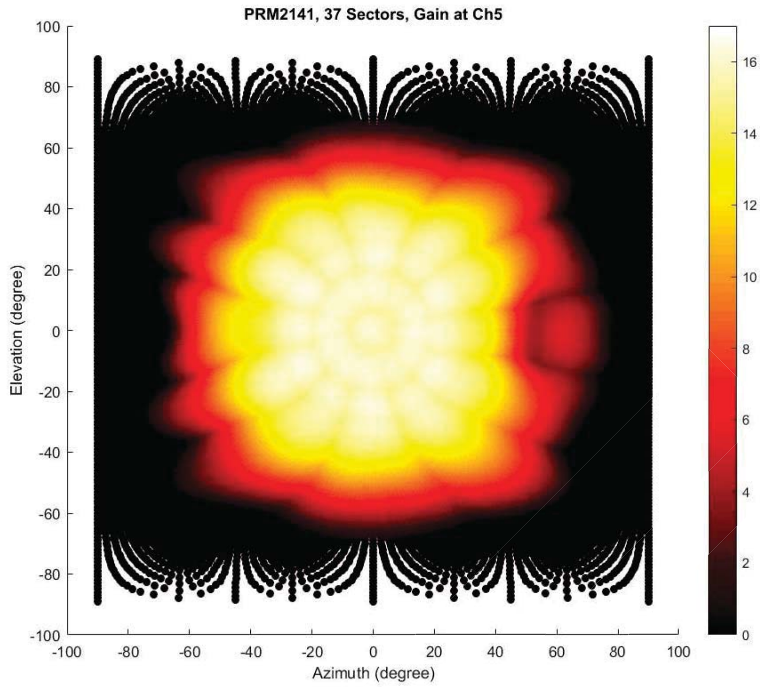


Figure 8-9: 2D surface plot of antenna gain for Ch. 5 (dBi)

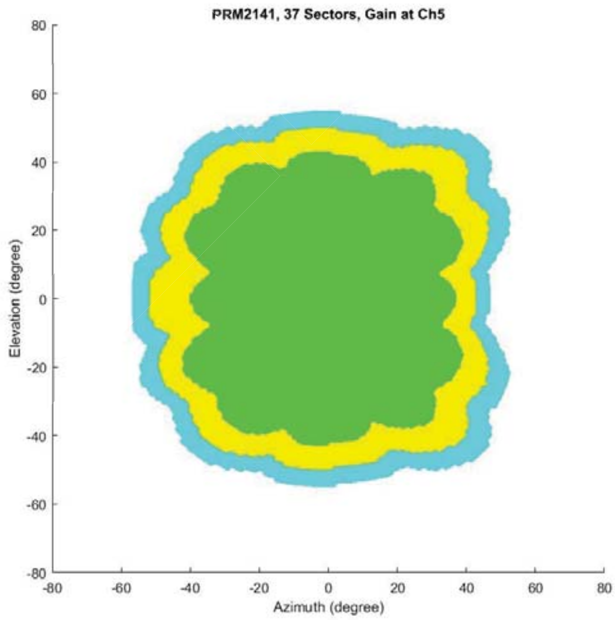


Figure 8-10: Surface plot showing gain drop from peak, Ch. 5. Green: 0-3 dB Yellow: 3-6 dB; Blue: 6-8 dB Drop.

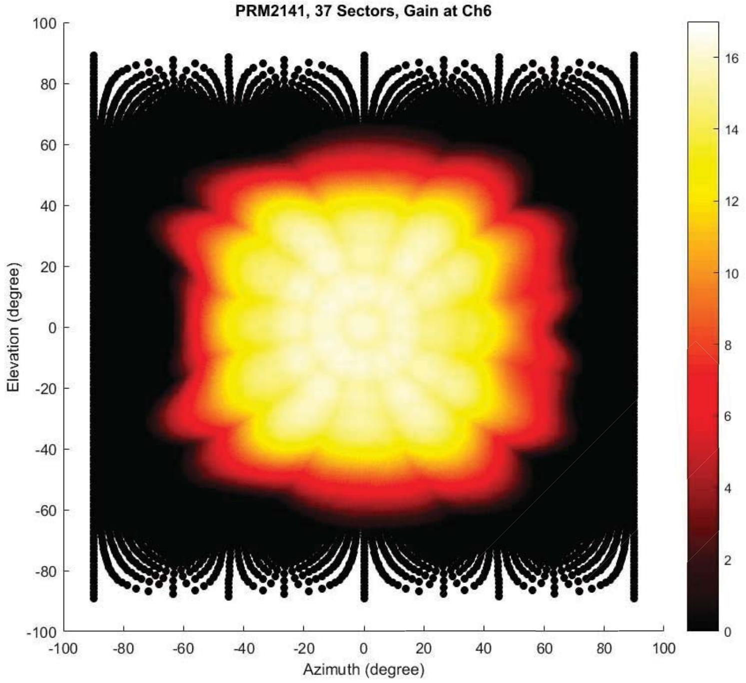


Figure 8-11: 2D surface plot of antenna gain for Ch. 6 (dBi)

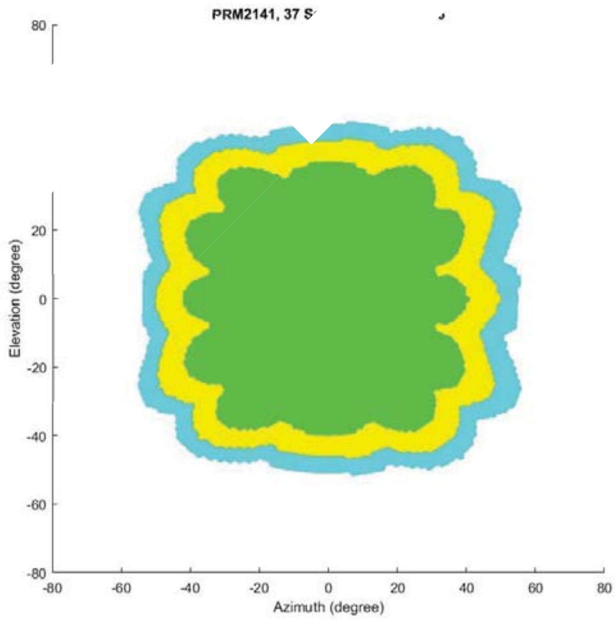


Figure 8-12: Surface plot showing gain drop from peak, Ch. 6. Green: 0-3 dB; Yellow: 3-6 dB; Blue: 6-8 dB Drop.

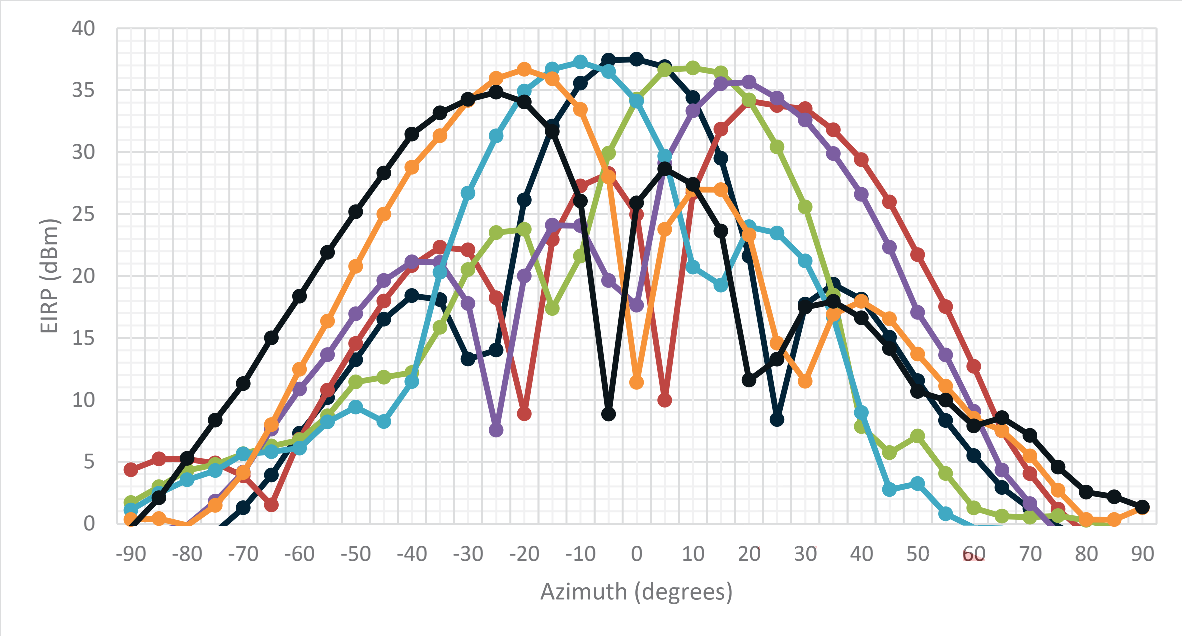


Figure 8-13: Azimuth-plane beam patterns, Ch. 1

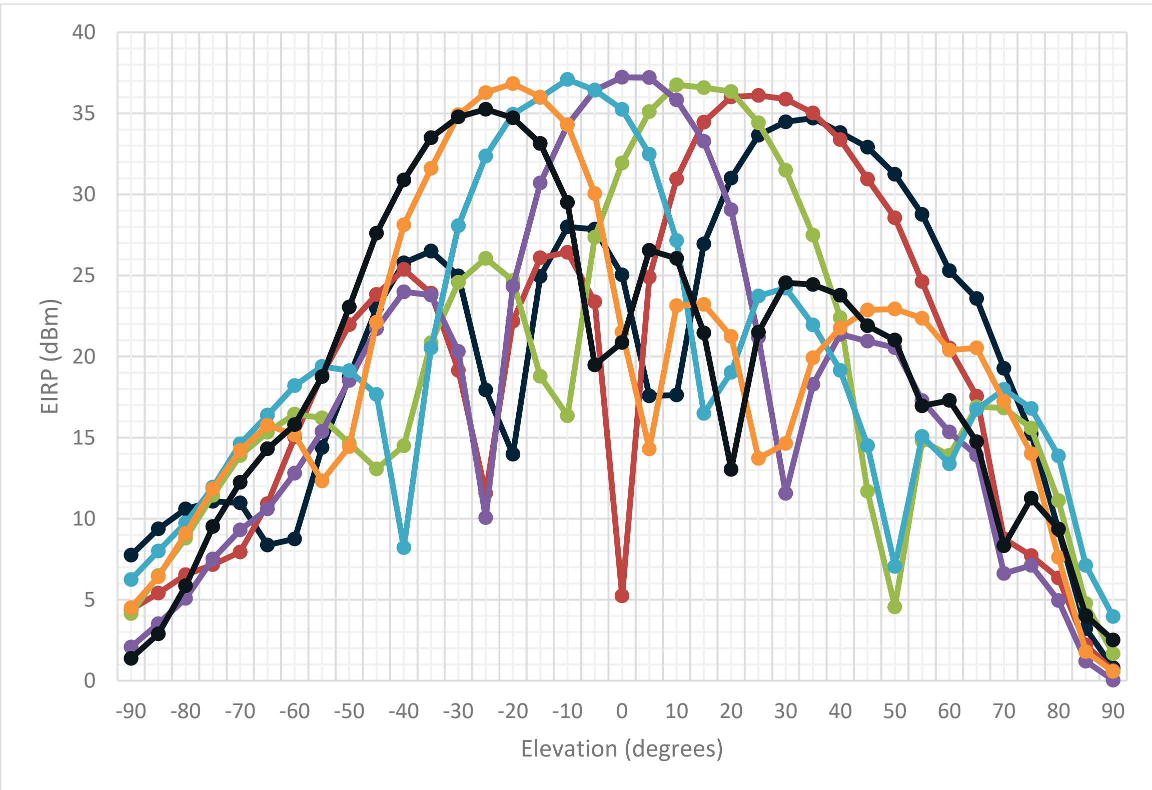


Figure 8-14: Elevation-plane beam patterns, ch.1

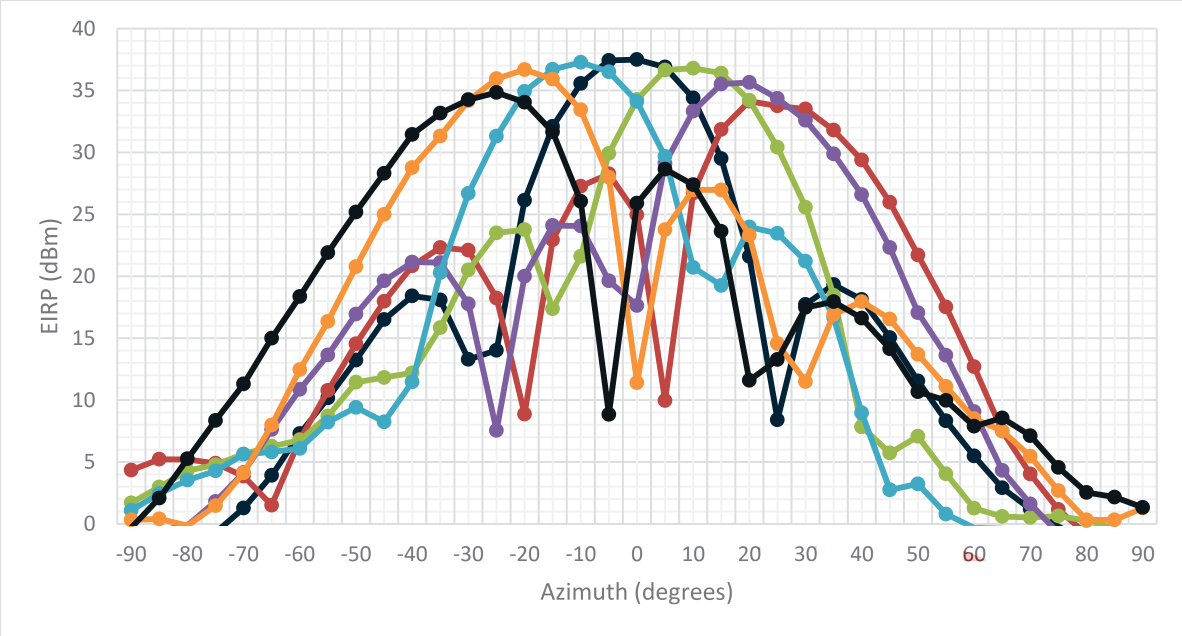


Figure 8-15: Azimuth-plane beam patterns, Ch. 2

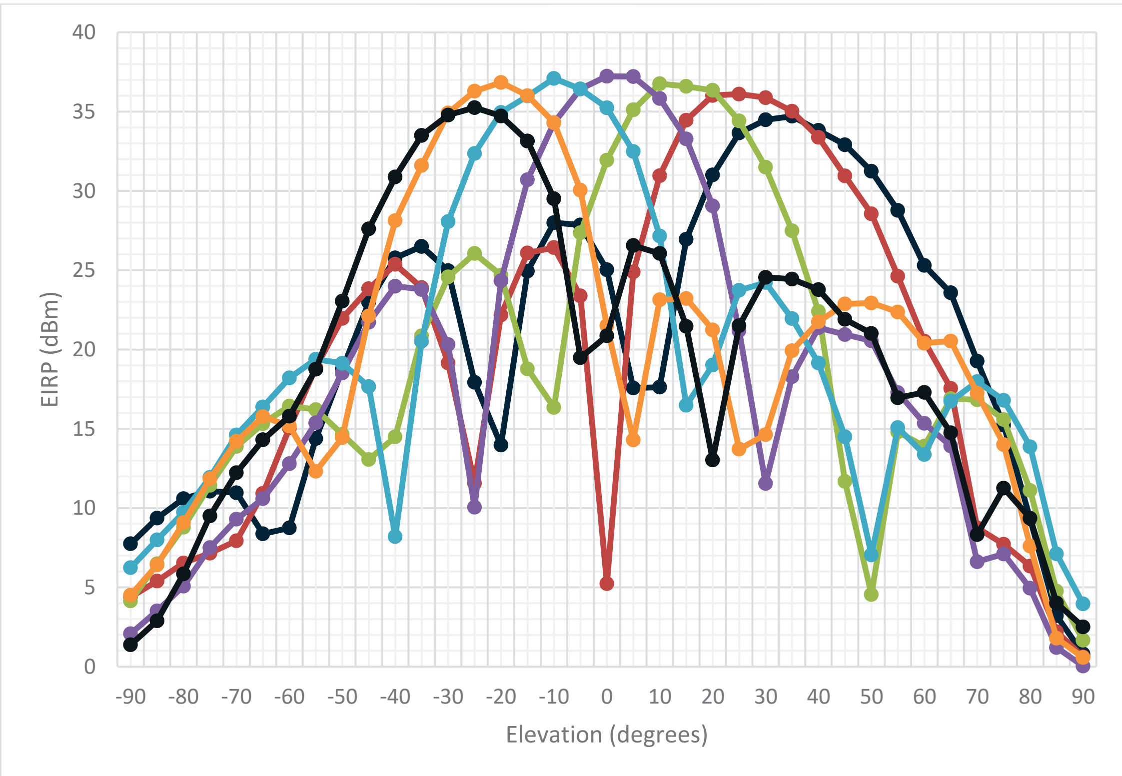


Figure 8-16: Elevation-plane beam patterns, ch.2

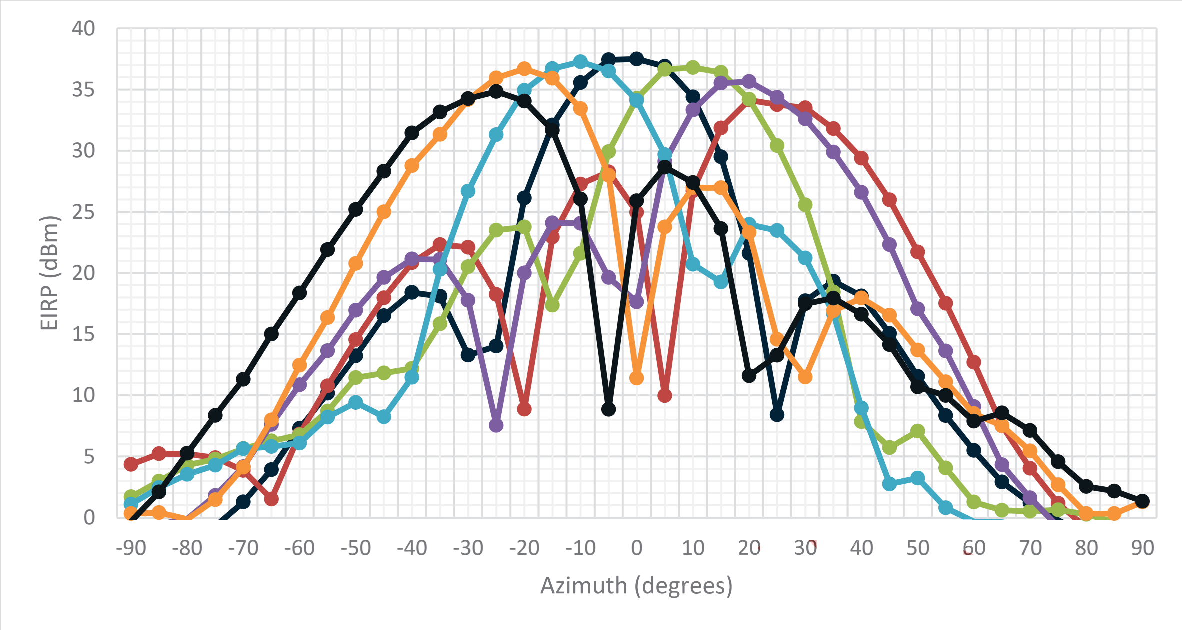


Figure 8-17: Azimuth-plane beam patterns, Ch. 3

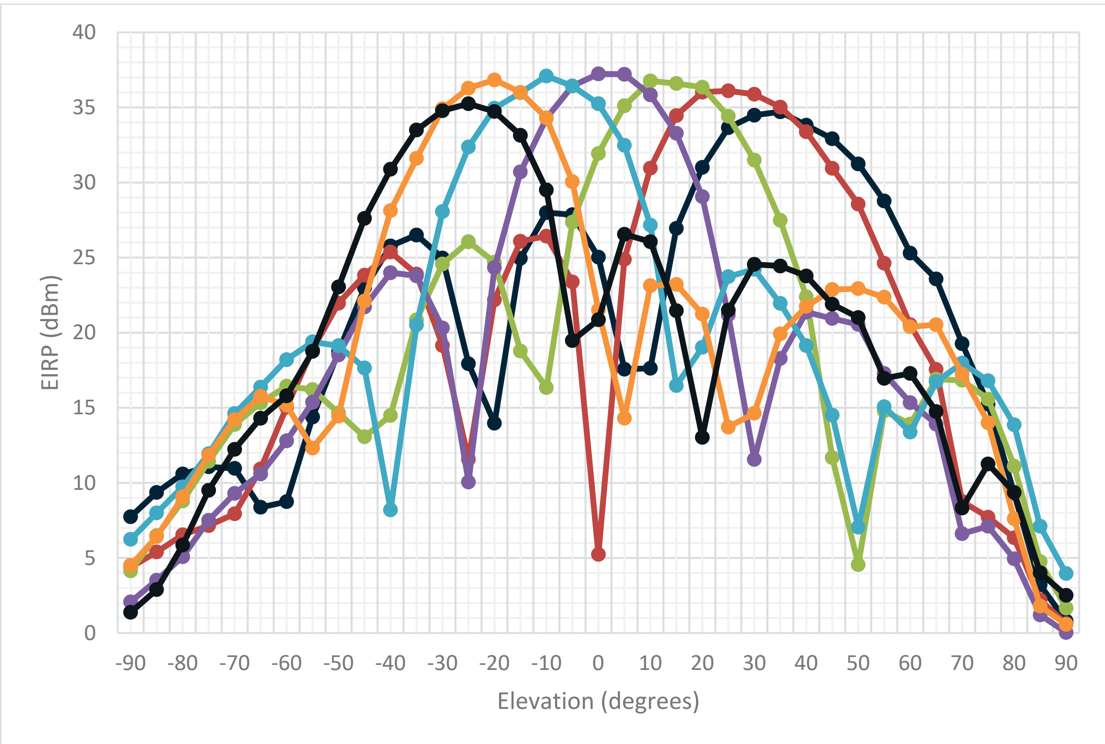


Figure 8-18: Elevation-plane beam patterns, ch.3

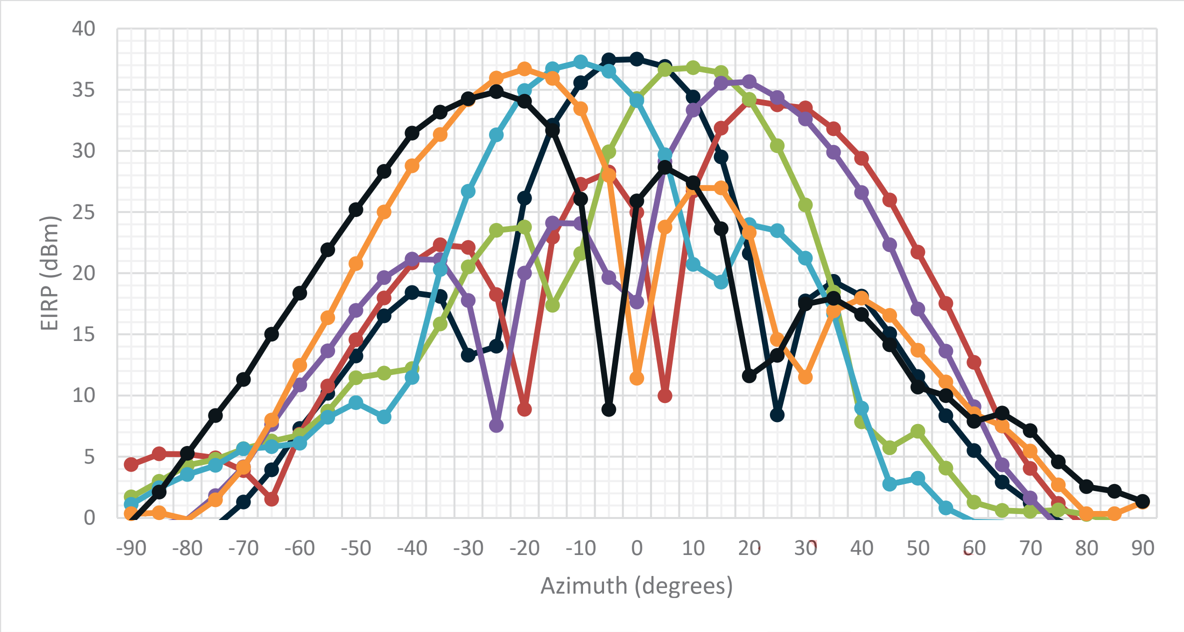


Figure 8-19: Azimuth-plane beam patterns, Ch. 4

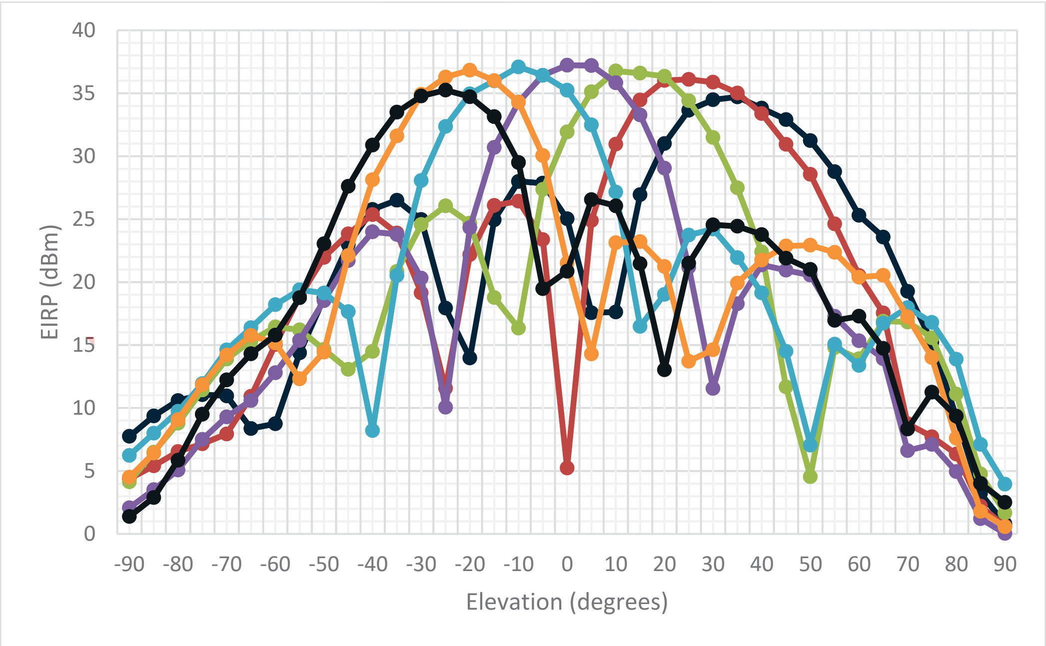


Figure 8-20: Elevation-plane beam patterns, ch.4

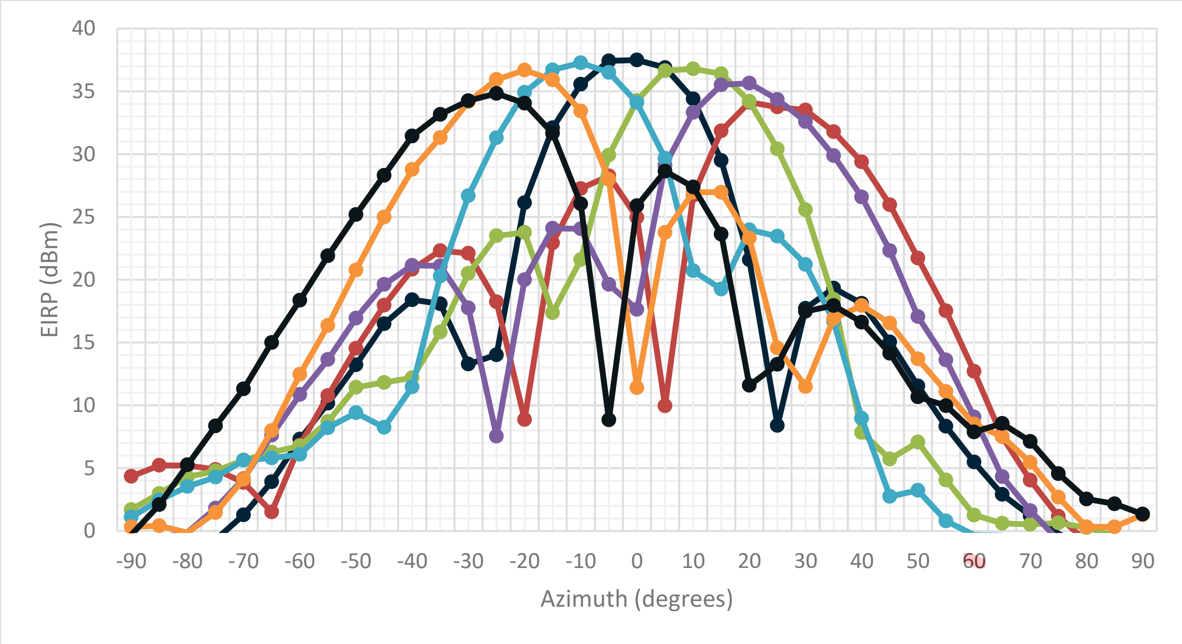


Figure 8-21: Azimuth-plane beam patterns, Ch. 5

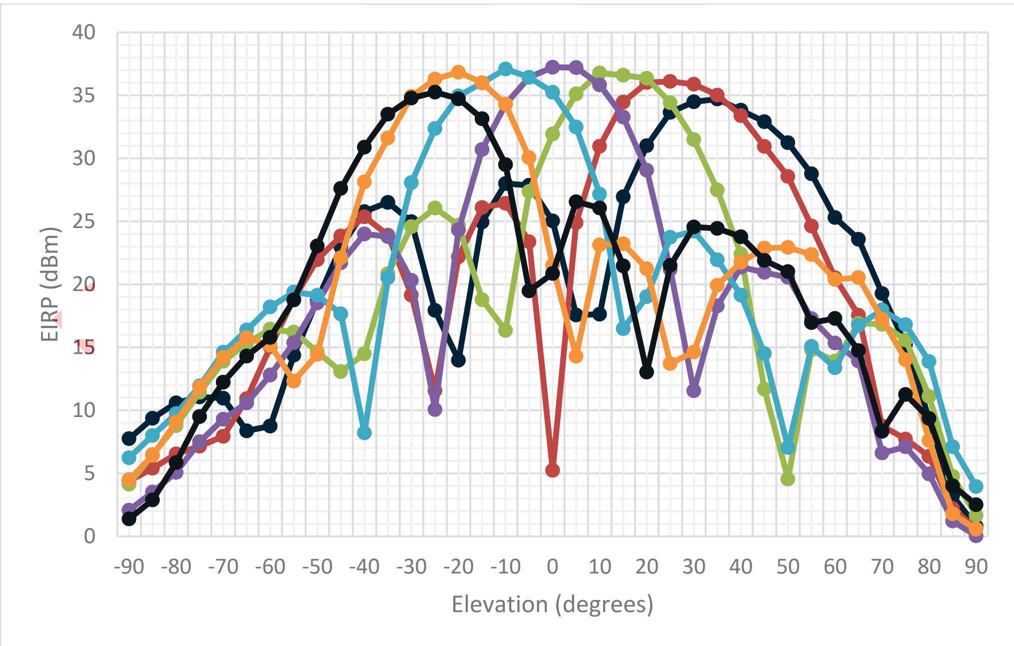


Figure 8-22: Elevation-plane beam patterns, ch.5

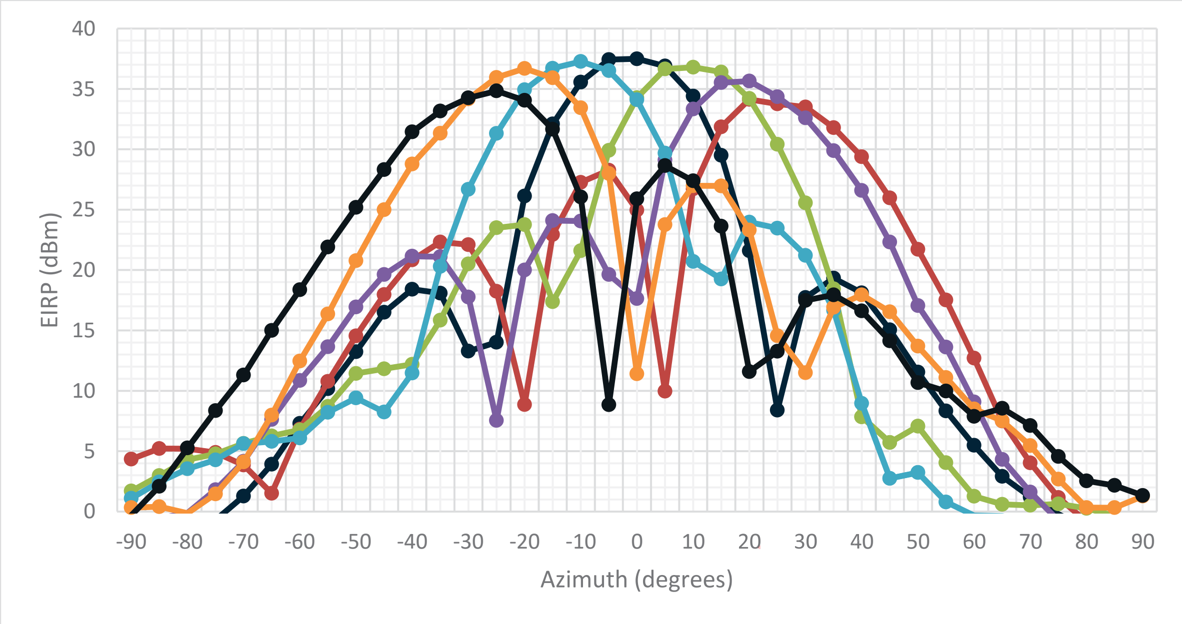


Figure 8-23: Azimuth-plane beam patterns, Ch. 6

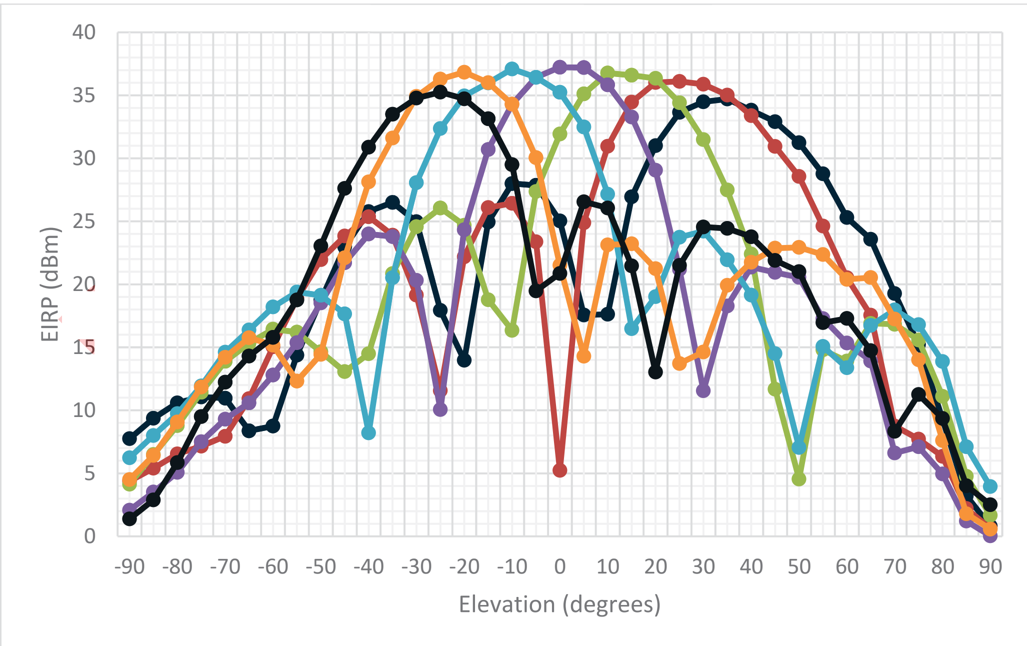


Figure 8-24: Elevation-plane beam patterns, ch.6

8.2 Typical Transmit Performance

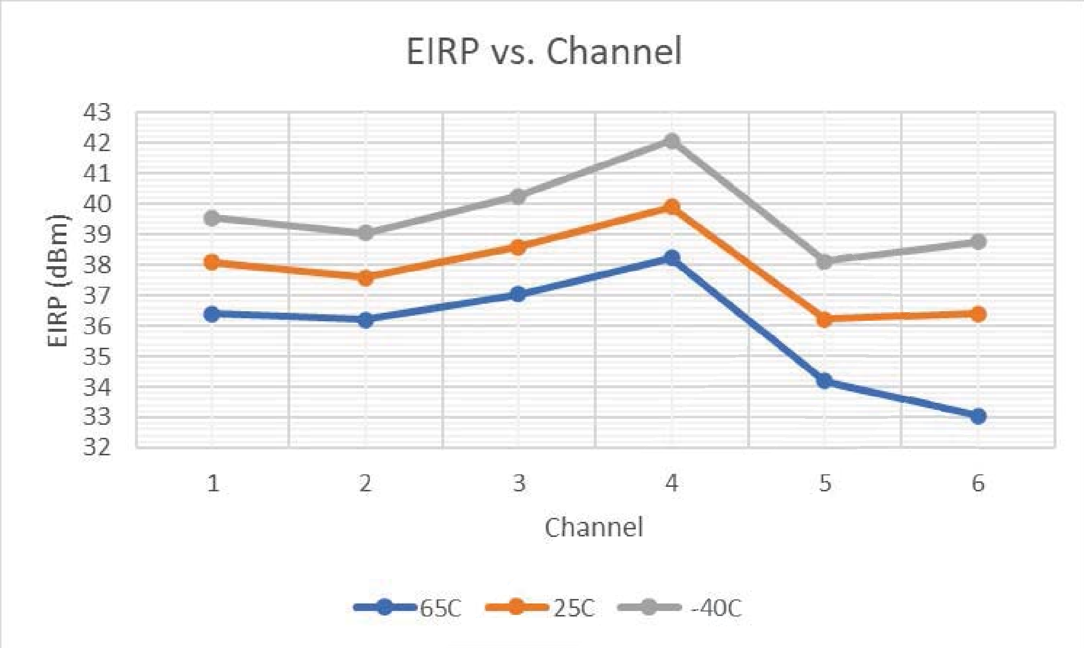


Figure 8-25: Boresight EIRP vs. Temperature

8.3 Typical Receive Performance

Figure 8-26 and Table 8-2 give the sensitivity vs. MCS for each channel. It should be noted here that this sensitivity is measured at the power incident on the antenna of the PRM2141X. The reference plain for the receive sensitivity is in between the antenna and the radio IC. It is not at the input to the module. Therefor, the antenna gain must be added to the link margin calculations. Refer to Section 10.3.

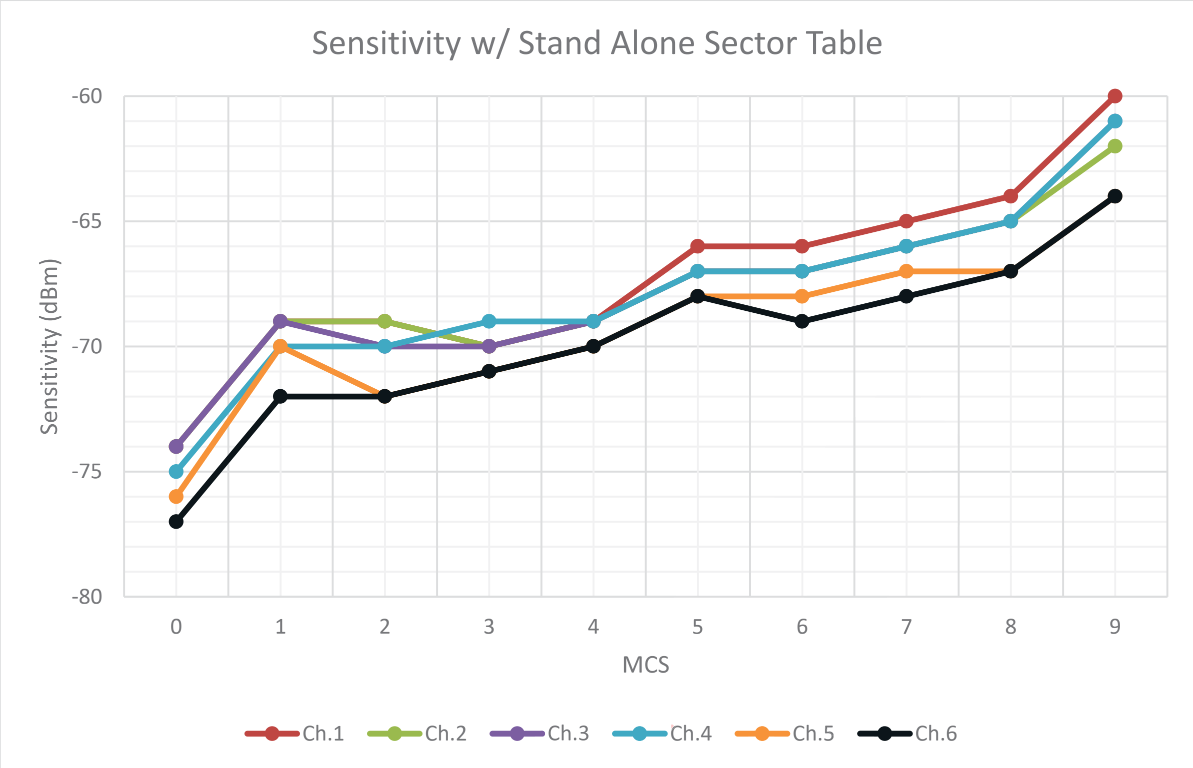


Figure 8-26: Sensitivity vs MCS for all channels with Stand-alone Sector Table

Table 8-2: Measured Sensitivity (dBm) for each MCS

Channel	MCS0	MCS1	MCS2	MCS3	MCS4	MCS5	MCS6	MCS7	MCS8	MCS9
1	-74	-69	-69	-70	-69	-66	-66	-65	-64	-60
2	-74	-69	-69	-70	-69	-67	-67	-66	-65	-62
3	-74	-69	-70	-70	-69	-67	-67	-66	-65	-61
4	-75	-70	-70	-69	-69	-67	-67	-66	-65	-61
5	-76	-70	-72	-71	-70	-68	-68	-67	-67	-64
6	-77	-72	-72	-71	-70	-68	-69	-68	-67	-64

9. System Level Interfaces

This section describes the system level interfaces to the module.

9.1 GPIOs used for Bootstraps

Bootstrap settings are shown in Table 9-1

Table 9-1: Bootstraps

IO	Power-on /Reset State
GPIO_1_14	Must be left floating or pulled low during power-on / reset.
GPIO_0	Pull low during power-on / reset for normal boot.
GPIO_6	Must be left floating or pulled low during power-on / reset.
UM_PWM_0	Must be left floating or pulled low during power-on / reset.
UM_PWM_1	Must be left floating or pulled low during power-on / reset.
UM_PWM_2	Must be left floating or pulled low during power-on / reset.
UM_PWM_3	Must be left floating or pulled low during power-on / reset.

9.2 Antenna

The PRM2141X has a PCB integrated antenna. This antenna design allows for a broad frequency response that encompasses WiGig channels 1 to 6.

The antenna is designed with 16 elements, and is capable of beamforming in both the elevation and azimuth axes.

This antenna has been designed for use as a stand-alone antenna, or to be used with a dish reflector.

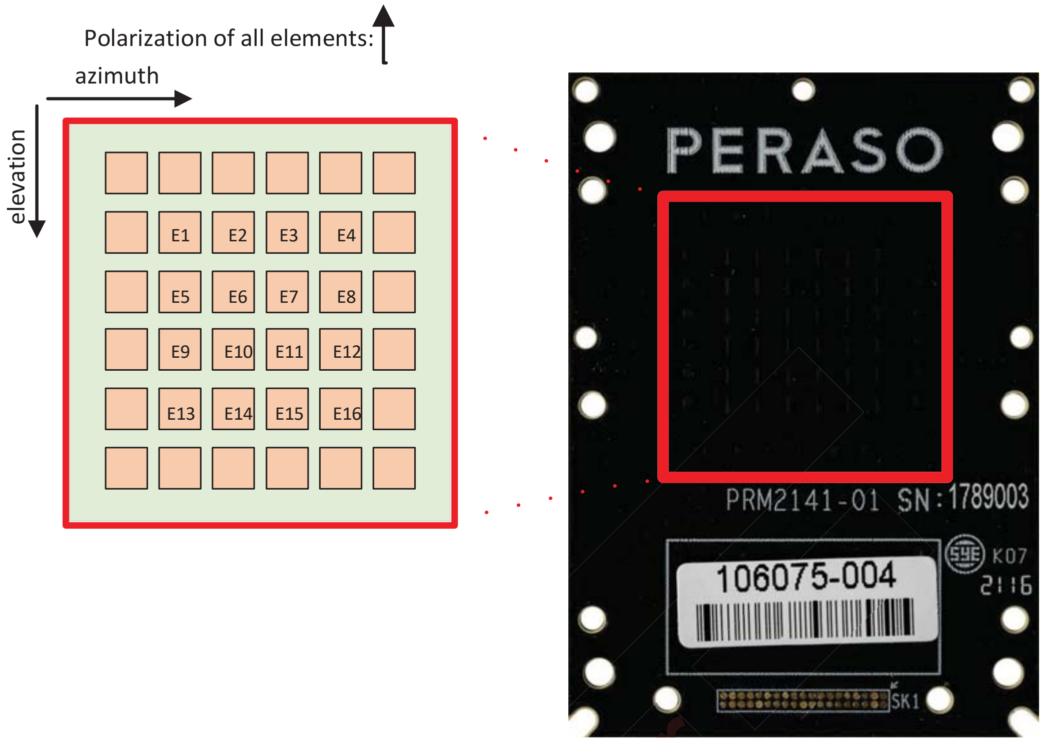


Figure 9-1: Diagram of the PRM2141X 16-element antenna and position on the module

9.3 I/O Signal Descriptions

This section provides more details on the pins and signals listed in the Section 6.1.

9.3.1 DISABLE_N

This signal is active low. When this signal is active the regulators are disabled, and the module is disabled.

This signal is an open drain signal. It is pulled to 2.5V Vdd with a 10kΩ resistor.

9.3.2 SYS_RESET_N

This signal is active low. When this signal is asserted, the module will reset.

This signal is an open drain signal. It is pulled to 2.5V Vdd with a 10kΩ resistor.

9.3.3 GPIO_0

This is a 2.5V CMOS signal. It can be used to control an LED.

9.3.4 GPIO_1_14

When pulled low during reset the module will boot from flash memory. This signal has a weak pulldown on the module. This signal should be left floating or pulled down for normal operation. This signal is a CMOS 2.5V signal.

9.3.5 V3P3_OUT, V2P5_OUT

These are output signals. These signals are the voltage level of the 3.3V and 2.5V regulated voltages on the module. These can be used by the system to detect/monitor the voltage levels on the module.

9.3.6 GPIO_15

This signal can be used for the 1PPS clock input.

This signal is a CMOS 2.5V signal.

9.3.7 GPIO_6

This signal can be used to force USB2 operation. If this signal is high during power-on/reset, the module will boot in USB2 operation. If this signal is low during power-on/reset the module will autodetect USB3, or USB2 operation.

For normal operation, this signal has a weak pulldown on the module and should be pulled low, or left floating, during power-on/reset.

This signal is a CMOS 2.5V signal.

9.3.8 UM_PWM_0,_1, _2, _3

During power-on/reset, UM_PWM_0,_1,_2,_3 can affect the state of the module.

UM_PWM1, UM_PWM2, UM_PWM_3 must be left floating or pulled low during power-on/reset.

UM_PWM_0 should be pulled low, or left floating, during power-on/reset to power the module from the USB bus.

UMPWM_0,_1,_2, and _3 can be used to control an LED.

These signals are CMOS 2.5V signals.

9.3.9 TWI_SCL, TWI_SDA

These are Two-Wire Interface signals. TWI_SCL is the Two-Wire Interface Clock signal. TWI_SDA is the Two-Wire Interface data signal.

9.3.10 VBUS_IN

This is an input signal. It is used by the module to monitor the voltage level of the USB bus.

9.3.11 SSTX_M/_P, SSRX_M/_P

These are the USB3 data signals. The same care should be taken to the layout of these signals as with any USB3 interface. Care should be taken to match the routing and length of the positive and negative signals. The impedance should be controlled to 90 Ω.

The SSTX_M/P signals have AC coupling capacitors on the module.

9.3.12 DM, DP

These are the USB2 data signals. The same care should be taken to the layout of these signals as with any USB3 interface. Care should be taken to match the routing and length of the positive and negative signals. The impedance should be controlled to 90 Ω.

10. Theory of Operation

This section describes the theory of operations of several key elements of the PRM2141X.

10.1 Beamforming

The PRM2141X performs beamforming to ensure that that RF link is optimized. There is a table of different beams that cover the full scanning range. The FW uses a proprietary algorithm to select the best sector (i.e., beam) from the antenna sector table.

The antenna sectors are contained in the onboard flash and may be updated as part of the FW update.

10.1.1 Sector Control

The antenna sector can also be manually selected. This is only recommended for testing.
This can be done via MIB commands.

10.2 RF Quality (RSSI, SNR)

Receive Signal Strength Indicator (RSSI), and Signal-to-Noise ratio (SNR), are available through the CLI interface of the module.

The SNR is measured at the baseband demodulator (i.e., PRS4601 B2E) output.

The RSSI value is taken at the interface between the antenna and the input pins to the PRS1165. It does not include the gain of the antenna. It does include the gain of adding the signal of each enabled input pin. Figure 10-1 shows where this reference plane lies.

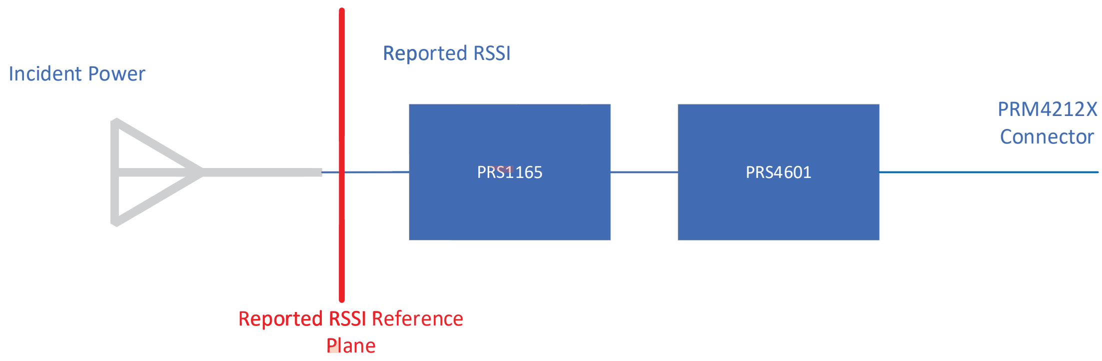


Figure 10-1: Diagram showing the reference plane for the reported RSSI

10.3 Reference Plane for Sensitivity and Link Margin

The reference plane for the sensitivity numbers provided in this datasheet is in between the module antenna and the input to the PRS1165 radio IC in the module. Refer to Figure 10-2.

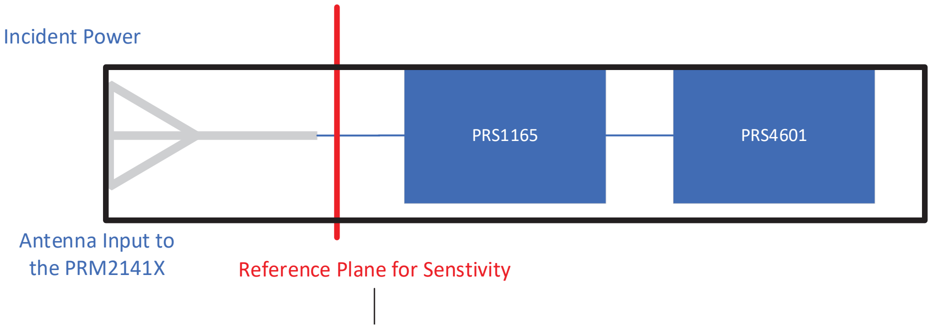


Figure 10-2: Reference Plane for Sensitivity

The gain of the antenna needs to be included when calculated link margins. The sensitivity of the module is then

$$Rx_{sens\_module\_mcsX} = Rx_{sens\_mcsX} - G_{ant}$$

Where G_{ant} is the gain of the antenna, Rx_{sens_mcsX} is the quoted sensitivity number for a specific MCS, and $Rx_{sens\_module\_mcsX}$ is the sensitivity of the PRM2141X at the input of the antenna.

When the PRM2141X is configured in stand-alone mode, the values given in Table 8-1 can be used for G_{ant}. When configured for use in a dish, the gain of the dish antenna can be used for G_{ant}.

10.4 LED and Device Status

The PRM2141X connector includes several signals that can be connected to LED status indicators. Typically, these signals are connected to either a tri-color LED, or three individual colored LEDs. Table 10-1 below shows the default LED connections. Applications schematics can be found in Section 11. Table 10-2 shows the definitions of the LED status indicators.

Table 10-1:Default Connections to Status LEDs

PRM2141X Signal Name	Connection
GPIO_0	Red LED
UM_PWM_0	Green LED
GPIO_1_14	Yellow LED

Table 10-2: Meaning of LED Status Indicators

LED	PRM2141X Status
Solid Red	1.Initializing (Initializing should be complete within 2 seconds. 2. If >2 seconds, the module is in an error state. Power cycle reset is needed.
Blinking Red	The module is in bootloader mode. This may be caused by: a) the firmware image is not valid. b) the firmware and host driver are not from the same release package.
Solid Yellow	The USB host interface is not at Super Speed and is limited to USB2 throughput speeds. The PRM2141X is idle, and not associated
Solid Green	The USB host interface is at Super Speed. The module is idle and not associated.
Solid Blue	The PRM2141X is associated with another 60GHz unit.
Blinking Blue	The PRM2141X is transmitting/receiving data to/from another 60GHz unit.

10.5 Overheat Protection

If the radio or baseband processor reaches 110^{0}C the module will power down. It will power on when the temperature drops below 110^{0}C.

10.6 Clock Synchronization

Clock synchronization is possible through GPIO_15. Typically, A 1PPS signal is used as the clock synchronization signal.

10.7 Power Management

Power management is handled through the FW.

10.8 Firmware Upgrade (PDB and firmware)

The PRM2141X contains non-volatile memory that is used to store the firmware image, and a persistent database (PDB) of configuration and other settings data.

The PDB consists of two sections; (1) a HW Configuration section, and (2) a device specific One-Time-Programmable (OTP) section. The PDB is structured as a Management Information Base (MIB) format.

The HW Configuration section contains settings that are specific to the module HW. It is not recommended to overwrite this section of the PDB. Overwriting this section of the PDB may make the module inoperable.

The One-Time-programmable (OTP) section contains unit specific information (e.g., MAC Address, serial number). These entries are meant to be written at the final assembly stage of production. Refer to the ***Falcon-X-MIB-definitions*** document included with every SW release for the complete set of entries available for the OTP section of the PDB.

10.9 DMG Test Mode

Directional Multi-Gigabit Test Mode (DMG-TM) is a physical layer test mode available in the PRM2141X's firmware. It uses CLI commands to control the PHY layer directly to transmit or receive data across a wireless link.

This can be used in development, and in production line final testing. Refer to ***Peraso-an0072-DMG_test_mode_user_guide*** for detailed instructions on how to use this test mode.

10.10 Firmware and USB Enumeration

USB enumeration occurs as the final step in the initialization sequence. If initialization is successful, the device exposes the NDIS and ACM (COM port) interfaces through USB descriptors, as well as other information such as the PID/VID. The host is able to fetch the USB descriptors through USB Get Descriptor requests. Based on the information provided in the descriptors, the host can then make a decision to load the correct Peraso driver for the given device. The Peraso driver will then query the device for Peraso specific information, such as the channels the device supports and the feature capabilities of the device. As well, the host may contain an ini file consisting of a list of MIBs to set, which will be sent to the device during the driver-up process. The driver may also send some initial commands based on driver params. After this, the driver is fully loaded, and the device is ready for normal operation.

11. Applications Information

11.1 Thermal Considerations

A heatsink is needed to remove the heat from the PRM2141X. This section is meant to aid in the design of such a heatsink.

PRM2141-V-EGS

The thermal resistance from junction to case for the PRM2141-V-EGS ($R_{\Theta JC}$) is 2.1^0 C/W.

PRM2141-V-EGN

The PRM2141X-EGN has two Peraso ICs on it. The PRS1165, and the PRS4601 B2E. These ICs have an exposed die on the top of the case. This exposed die is specifically to help aid in heat flow. It greatly reduces the thermal resistance of the case.

The heatsink for the PRM2141X-EGN needs to make contact with the exposed die of the PRS1165, and the PRS4601 B2E.

This creates the dominant path of heat flow to be through the exposed die, the heat paste that contacts the die to the heatsink, and the heatsink to the ambient air.

Thermal adhesive or thermal paste is critical in this application. It is imperative that the thermal paste contacts both the exposed die and the heatsink.

There is an area around the perimeter of the module that has bare copper exposed. This bare copper has been left exposed to provide another path of heat transfer. The heat sink should also contact as much of this exposed copper as possible.

Table 12-1 gives the coordinates of the PRS4601 B2E, the PRS1165 on the module.

The PRM2141X-EVK includes a heatsink. A step file for the heatsink that is included in the PRM2141X-EVK is available as a reference.

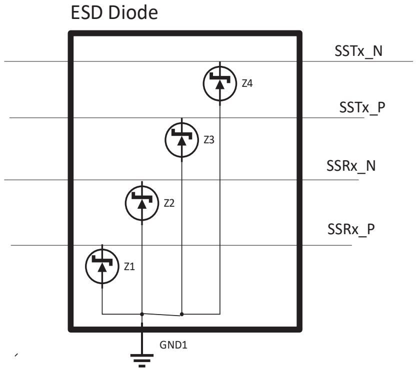
The thermal resistance for the PRM2141-V-EGN is established by the PRS1165. This device has a $R_{\Theta JC}$=1.8^0 C/W.

11.2 Temperature Sensor

The temperature for the radio and baseband ICs can be monitored via MIBs. Refer to the **Falcon-X-MIB-definitions** document for details.

11.3 USB Connections and General Circuit Considerations

The signals DP, DM, SSTX_P/_M, and SSRX_P/_M should all be routed as differential pairs with a characteristic impedance of 90 ohms. Care should be taken to match the routing and length of the positive and negative signals.



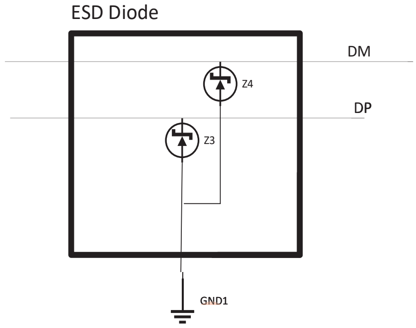


Figure 11-1: Primary ESD Protection for data signals

11.4 USB-C Support

When connecting to a USB-C connector using a CC logic chip and a Mux suitable for USB3 signals will allow for polarity detection. Polarity detection and signal multiplexing are not supported on the PRM2141X without these components. Refer to Figure 11-2.

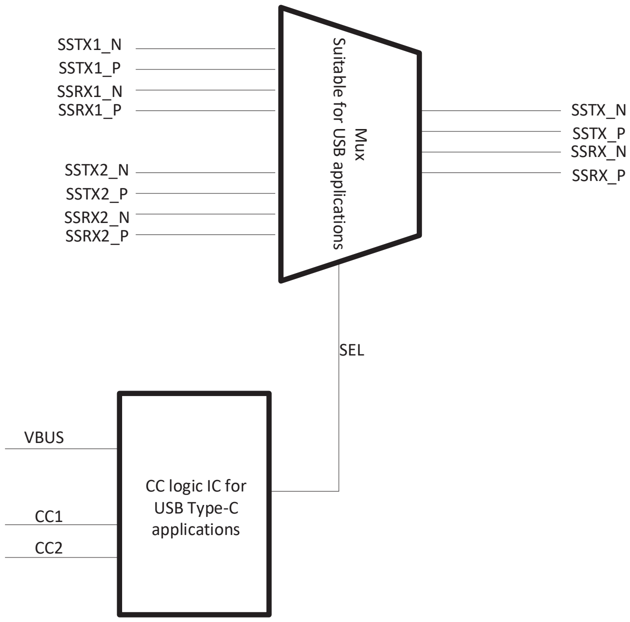


Figure 11-2:USB-C connections

11.5 Connections to LED Signals

The PRM2141X provides signals that can be used as Status and Signal Strength indicators. Refer to 10.4 for details on the status indicators. Figure 11-3 shows the connection details.

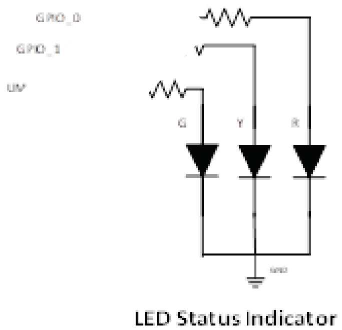


Figure 11-3: LED Status Connections

11.6 Connector Details

The connector of the module mates with the Hirose BM28B0.6-34DP/2-0.35V(51) connector. The specifications of this connector can be found here: https://www.hirose.com/product/p/CL0673-5064-0-51.

Details of the connector placement can be found in Section 9.

11.7 Dish Antenna Applications

In high gain applications, the PRM2141X can be used to feed a dish reflector. The dish antenna sector table that is preloaded with the PRM2141X is designed to be used with a f/D=0.45, where f is the focal length and D is the diameter of the dish reflector. Refer to Figure 11-4.

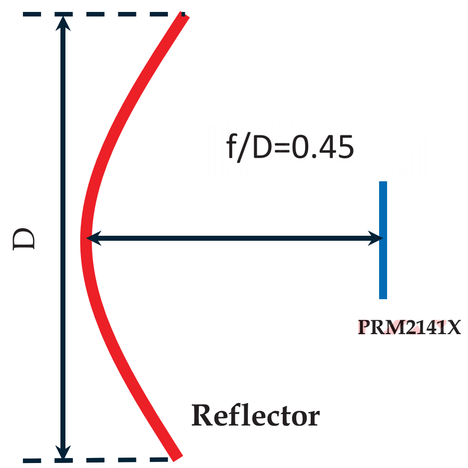


Figure 11-4: General dimensions of the Dish Reflector

11.8 Transmission Emissions Spectra

Figure 11-5 to Figure 11-16 show the transmission spectra for full channels at MCS5, and MCS9.

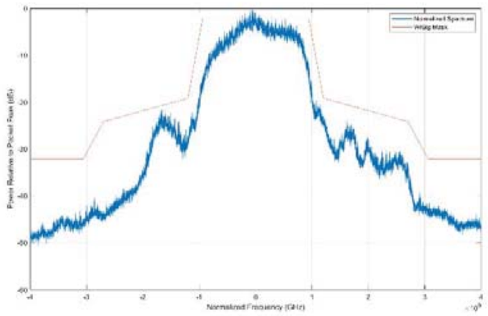


Figure 11-5: Tx spectral mask, MCS 4, channel 1

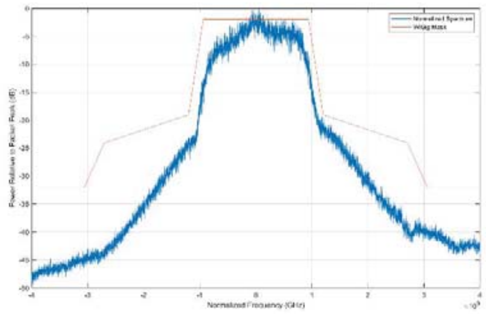


Figure 11-6: Tx spectral mask, MCS 9, channel 1

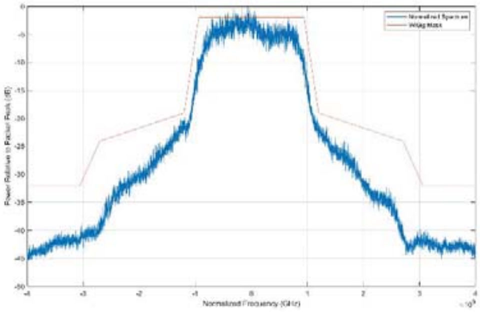


Figure 11-7: Tx spectral mask, MCS 9, channel 2

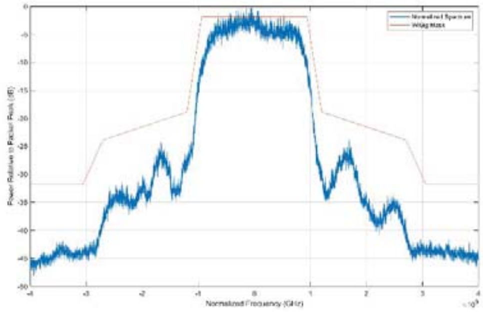


Figure 11-8: Tx spectral mask, MCS 4, channel 2

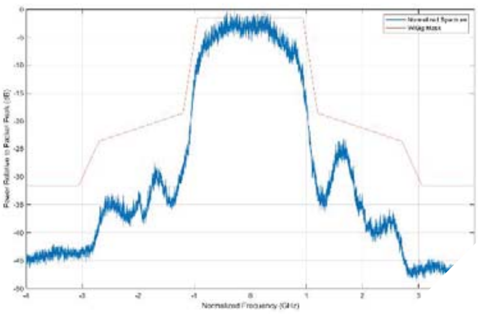


Figure 11-9: Tx spectral mask, MCS 4, channel 3

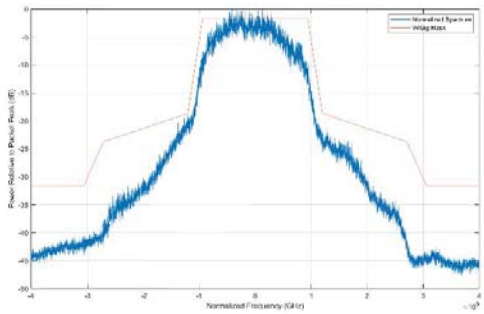


Figure 11-10: Tx spectral mask, MCS 9, channel 3

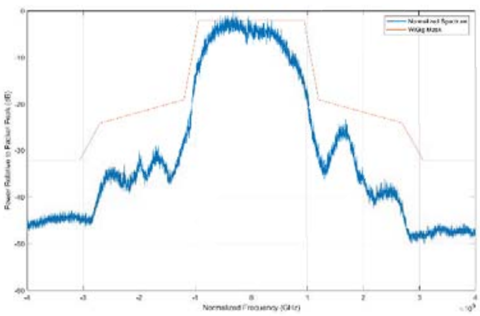


Figure 11-11: Tx spectral mask, MCS 4, channel 4

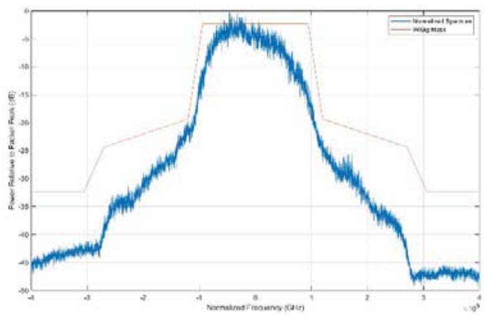


Figure 11-12: Tx spectral mask, MCS 9, channel 4

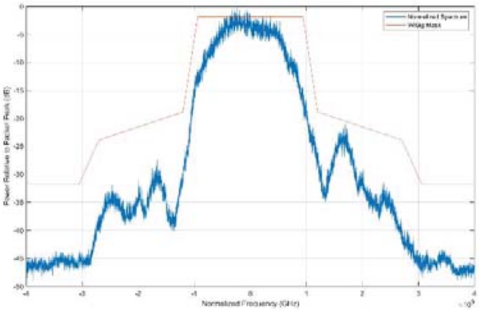


Figure 11-13: Tx spectral mask, MCS 4, channel 5

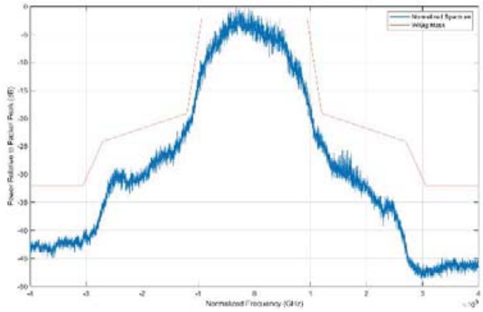


Figure 11-14: Tx spectral mask, MCS 9, channel 5

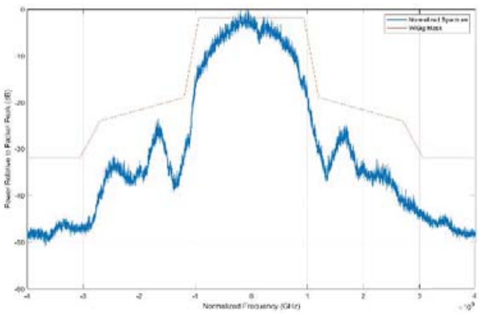


Figure 11-15: Tx spectral mask, MCS 4, channel 6

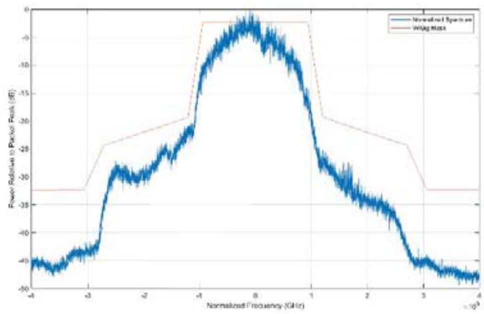


Figure 11-16: Tx spectral mask, MCS 9, channel 6

12. Mechanical Specifications

12.1 PRM2141X-V-EGS with an EMI Shield

This section describes the mechanical details of the PRM2141X-V-EGS. This version of the module contains a full EMI shield.

12.2 PRM2141X-V-EGN without EMI Shield

The centre of the connector is located 3mm from the bottom edge and 17.5mm from the side of the module.

Using the centre of the **"M2 screw (4x)" mounting hole as a reference point**, the centre of the connector is located 15mm away and 2mm toward the board edge (refer to Figure 12-2).

The connector on the module is the Hirose BM28B0.6-34DS/2-0.35V(51).

The mating connector for this module is the Hirose BM28B0.6-34DP/2-0.35V(51).

Table 12-1: Position of key components

Component	X (mm)	Y (mm)
"Reference Point"	0	0
Connector	-15	-2
PRS4601 B2E	-15	10
PRS1165	-15	25

12.3 Antenna Center

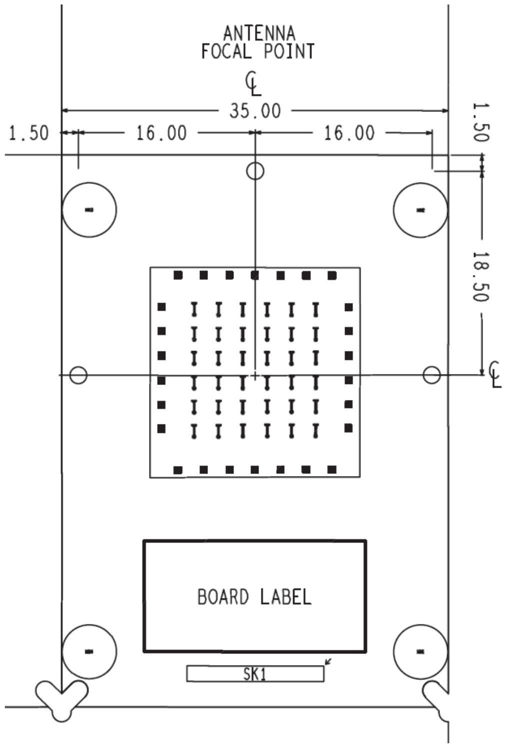


Figure 12-3: Board Layout showing the antenna centre point

The antenna centre is located 18.5mm from the top alignment hole, and 16 mm from either of the side alignment holes of the PCB. Refer to Figure 12-3.

Referenced to the M2 mounting holes, the antenna center is located 15mm down from the top mounting holes and 15mm to the centre from the mounting holes.

Referenced to the board edges, the antenna center is located 17.5mm form either side edge, and 20mm from the top board edge.

The distance between each element is 2.2mm center-to-center.

13. Ordering Information

Table 13-1 shows the different part numbers and ordering codes.

Table 13-1: Part Numbers

Part Number	Description
PRM2141-V-EGS (mm) (-Frnn)	PRM2141X module with EMI shield mm= module revision (optional) - F FW version code (optional)
PRM2141X-V-EGN (mm) (-Frnn)	PRM2141X module without EMI shield. mm= module revision (optional) - F FW version code (optional)
EVK2141X-V-EWUB5V-PN	Evaluation kit that includes heatsink, power supply, and adapter board to accommodate power and USB connection

14. Appendix

14.1 Revision History

Revision	Date	Comments
0.8.2104	2021/4/30	First Created
0.8.2107	2021/6/00	Updated plots for more consistent look. Added connector placement details.
0.8.2108	2021/8/00	Labels changed from E-beam to Elevation, H-beam to Azimuth. Updated Figure 7-1.
0.8.2111	2021/11/23	Updated all references to PRM2141 to PRM2141X. Text in Section 10 and Section 4 was changed to make clear the connector used on the module and the mating connector needed.
0.8.2206	2022/06/20	Added 2D plots of antenna gain. Updated the Section 10, 11. Separated the specification and performance sections into Stand-Alone and Dish. Updated the Sensitivity plots and tables. Reorganized the sections into two distinct configurations: Stand-Alone and Dish. Updated Company address. Added 10.3.Updated figure 2-1.
0.8.2209	2022/09/14	Updated DC power consumption numbers. Added max sidelobe.
0.8.2211	2022/11/2	Updated Table 8-1. Added the EVK, fence, and fence+lid options to Table13-1.
1.0.2212	2022/12/6	Removed the -EGF product offering from Table 13-1. Updated Section 10, 11-2. Added FCC information in Features. Added -EGS mechanical drawing in Section 11. Updated title page tagline. Rotated the orientation of Fig 6-1. Updated Table 6-1. Updated Section 11.1.