InfoSheet: PRA211-01 4×4-element Phased Array Antenna for the PRM2141X module

Revision 2211.3

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1. Introduction

1.1 PRA211-01 Antenna

The Information Sheet provides performance information for the PRA211-01 antenna design. This antenna design is instantiated as part of the Printed Circuit Board of the PRM2141X-V-EGx (x = S, F or N versions).

This antenna and module are intended for use in the unlicensed 60GHz band as defined by IEEE standard 802.11ad and 802.11ay.

Information provided within includes simulation data and laboratory measurements.

1.1.1 Antenna Source

The PRA211-01 antenna is designed and manufactured by Peraso Inc. The antenna is built into the Printed Circuit Board of the PRM2141X-V-EGx modules.

Peraso contact information:

Peraso Inc.
2309 Bering Dr.
San Jose, CA 95131

1.2 Abbreviations and Acronym Definitions

Acronym	Definition
PAA	Phased array antenna
UC	Unit cell
SLL	Side lobe level
HPBW	Half power beam-width
EIRP	Effective Isotropic Radiated Power
RFIC	Radio Frequency Integrated Circuit
RF	Radio Frequency
PCB	Printed Circuit Board

1.3 Test Engineer

The undersigned is the Test Engineer responsible for antenna measurements and providing the data presented in this InfoSheet.

Signature

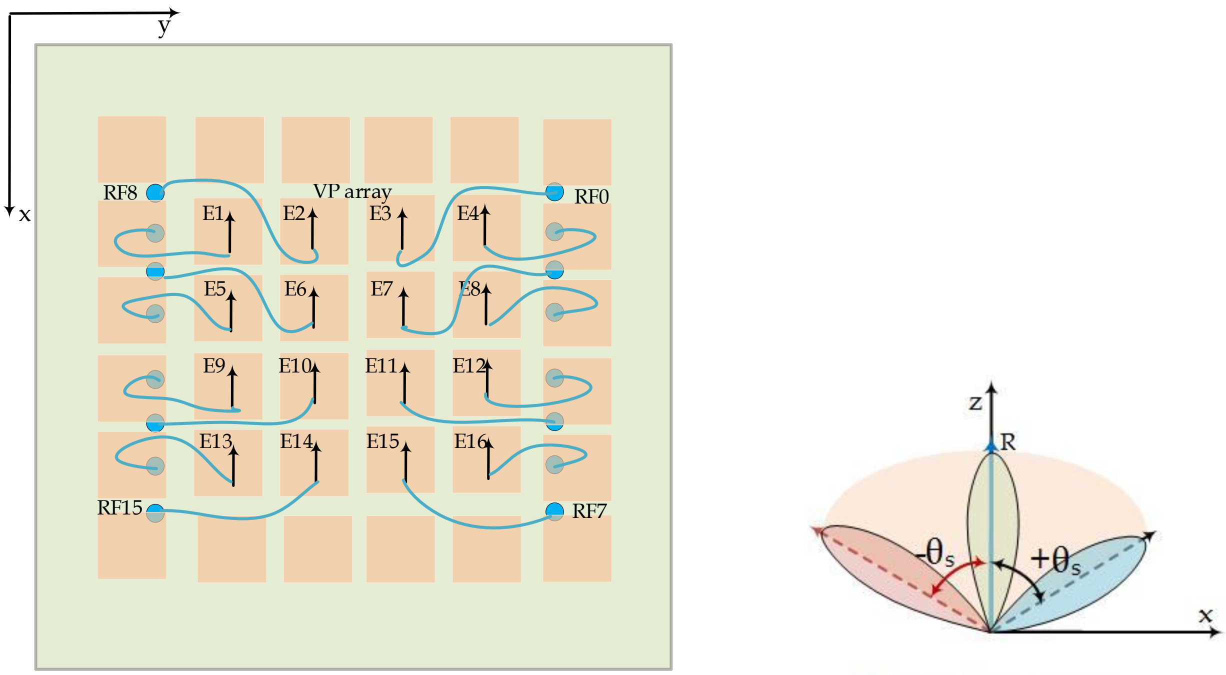
Intikhab Hussain
Printed name

2. Design

2.1 General Description

This 16-element Phased Array Antenna (PAA) is inteded to address the requirements of a high data rate long range wireless backhualing within the 56-71 GHz operating band. The radiation pattern of this reflector is vertically polarized. It covers 6 channels, and is integrated inside the PCB to reduce the fabrication cost.

The general block diagram of the vertically-polaried phased array antenna is shown in Figure 2-1. It consists of 4×4 active radiating elements surrounded with a row/collumn of dummy elements. Each element includes an innovative hybrid radiator, which is fed by an RF port of PRS1165 RFIC through a strip line. The antenna is integrated inside the multi-layer carrier board, where other RF circuitries and baseband chip reside.



Top view of Antenna array

Range and scan coverage

Figure 2-1. Single radio 4×4-element phased array antenna (antenna seen from top).

2.2 Feature Summary

- PCB integrated antenna array with 16 active elements
- 13mm x 13mm area
- Matched in the unlicensed 56 to 71 GHz band (better than -9 dB reflection coefficient bandwidth)
- -10 dB power beam-widths variation of radiation patterns (different sectors) over the six channels:
  E-plane: 79˚ -115 ˚
  H-plane: 79˚ -106 ˚
- Peak realized gain within the matched band when all/four-middle elements are on: 15.6/10 dBi
- 10 sectors were generated to switch the bean direction.

2.3 Specifications

Table 2-1 shows a summary of antenna performances. For further information about the designs' performances over the entire desired bandwidth, please refer to Section-4.

Table 2-1: Electrical features of PER7211-01 phased array antenna

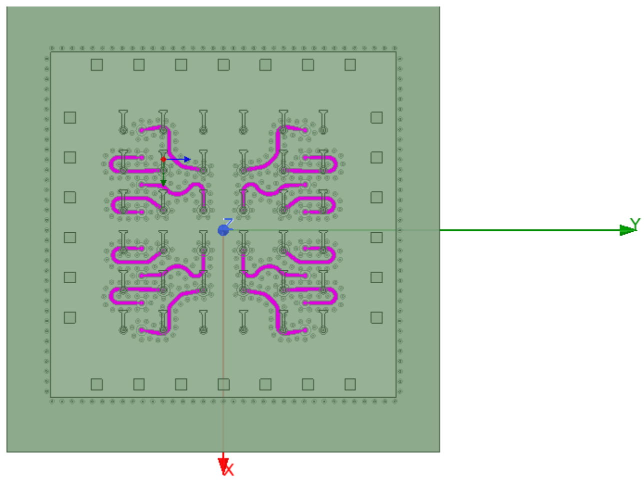
Characteristics	Value	Unit
Operating band (GHz)	56 – 71	GHz
Matched band (GHz) with S_{ii}< -9 dB	56-71	GHz
Maximum gain (dBi), all elements are ON	16.2	dBi
-10 dB beam-width E/H planes, range over different sectors over 6 channels	E: 79˚ -115˚ H: 79˚ -106˚	degrees
Gain drop at scan angles of ±1˚	> -3	dB

3. Antenna design and configuration

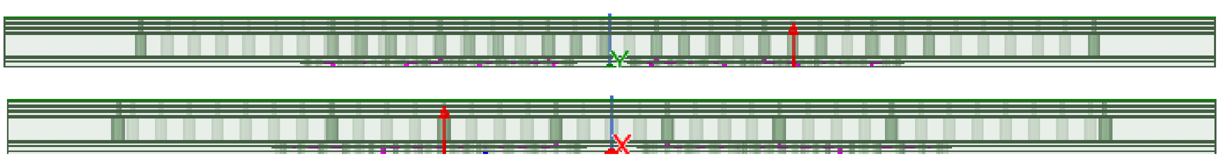
3.1 Antenna geometry

The dimensions of the active antenna area are 13 x 13 mm. This area covers the inner 16 active elements.

Figure 3-1 shows the geometry of designed antenna array.



(a) Front (left) and back (right) views.



(b) Two side views.

Figure 3-1. Antenna geometry.

3.2 Antenna Ports

3.2.1 Antenna port to RF port conversion table

In Table 3-1 given here, the relation between the antenna ports and RF port numbers defined in the application board are described. The port definitions are shown in Figure 3-2.

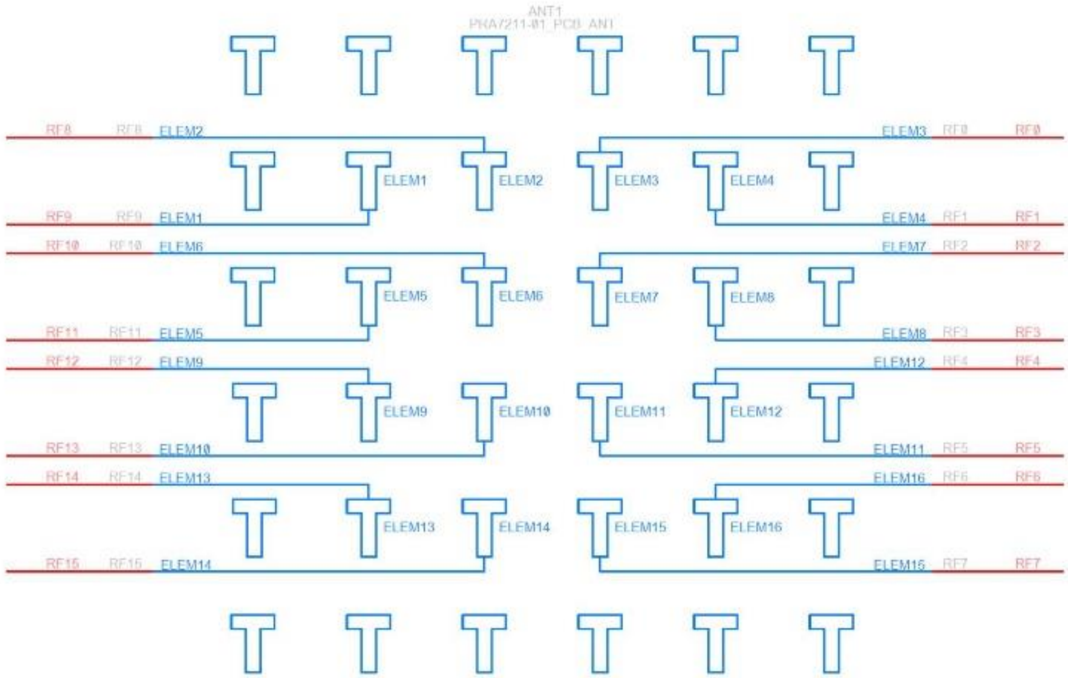


Figure 3-2. Antenna ports mapping diagrams

Viewed from top onto the PCB side where antenna is seen (where they are connected to antenna ports).

Table 3-1. Relations between the antenna ports and RF-ports.

	RFIC Port Map															
Antenna ports	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}	E_{16}
RF ports	RF9	RF8	RF0	RF1	RF11	RF10	RF2	RF3	RF12	RF13	RF5	RF4	RF14	RF15	RF7	RF6

4. Performance

This sections provides simulation and actual measured performance results.

4.1 Simulation results

4.1.1 Reflection coefficient and transmission coefficient responses

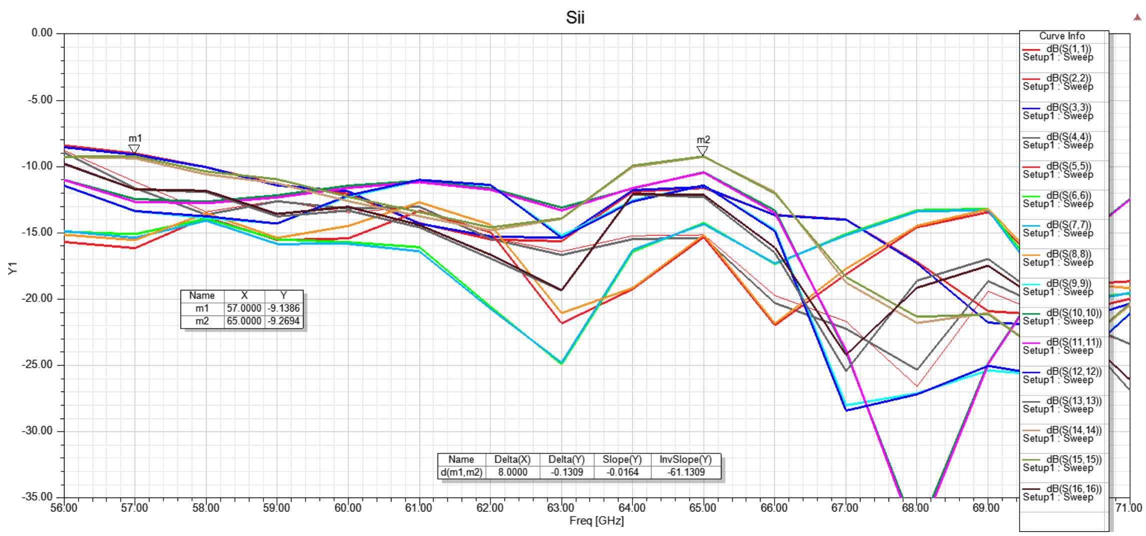


Figure 4-1. Antenna arrays reflection coefficients' responses.

4.1.2 Transmission coefficient responses

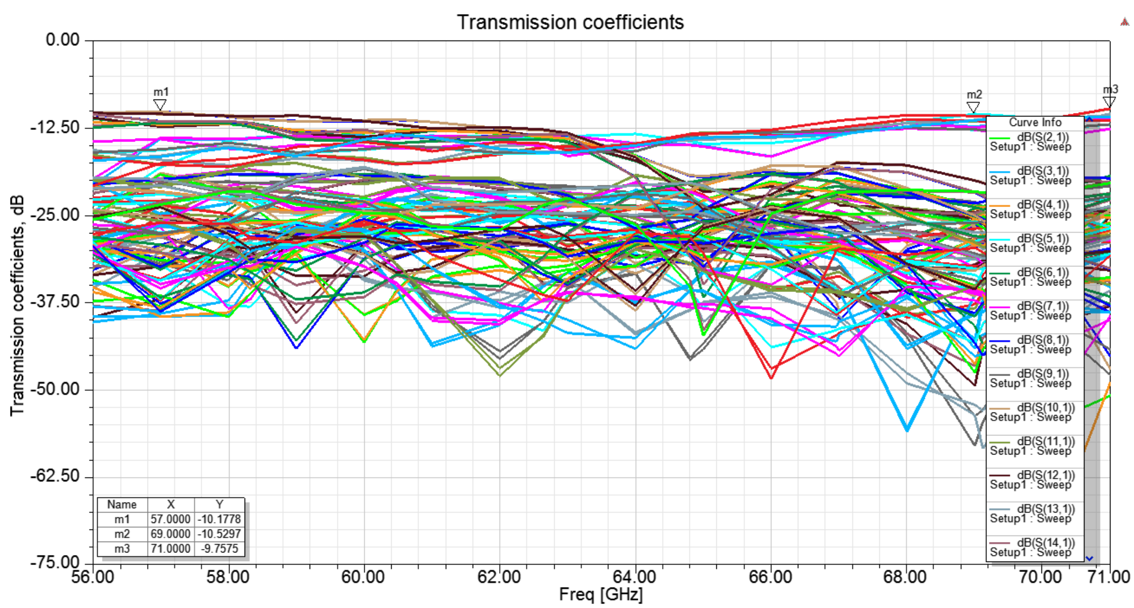


Figure 4-2. Antenna transmission coefficients' responses (elements' mutual couplings).

4.1.3 Antenna radiation efficiency

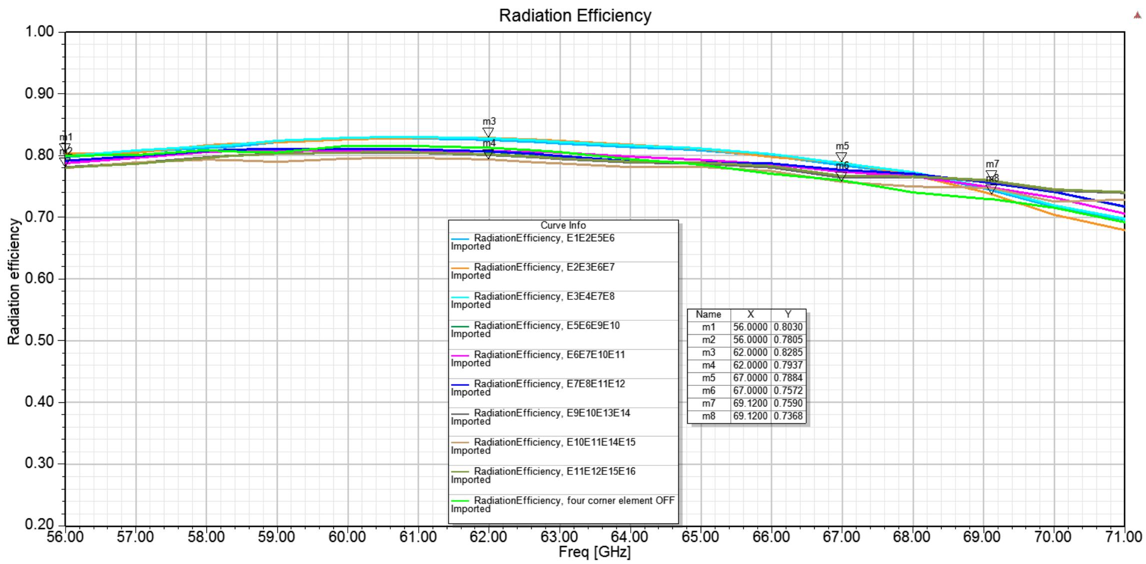


Figure 4-3. Antenna radiation efficiencies calculated for different sectors.

4.1.4 Beam Steering over the Channels

Based on the provided phase table for 37 sectors, the beam scanning performance at each channel are plotted in the following.

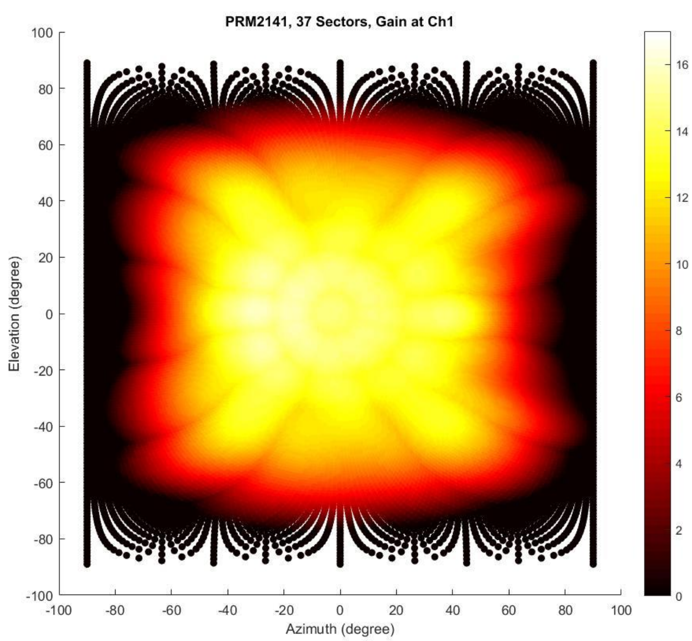


Figure 4-4. Beam Steering of 37 Sectors at Ch1.

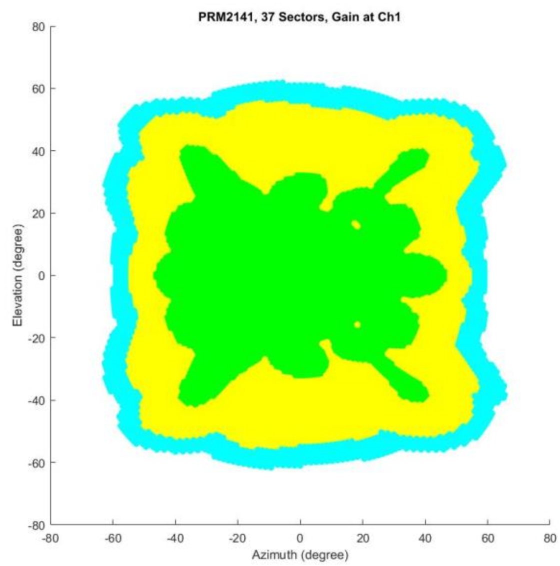


Figure 4-5. Beam Steering of 37 Sectors at Ch1 with gain drop levels.

Green: 0-3 dB Drop; Yellow: 3-6 dB Drop; Blue: 6-8 dB Drop.

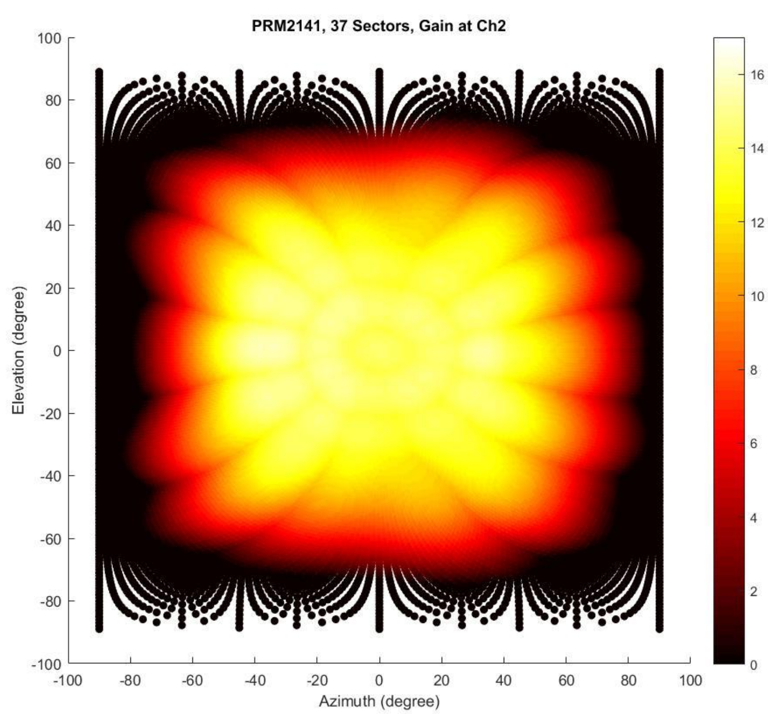


Figure 4-6. Beam Steering of 37 Sectors at Ch2.

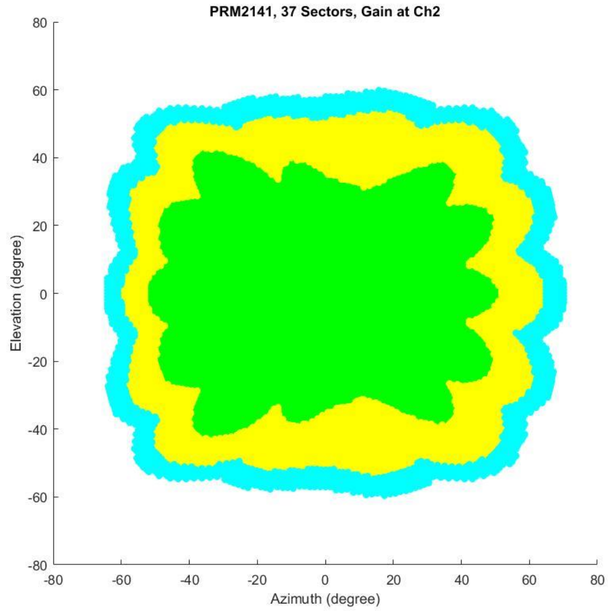


Figure 4-7. Beam Steering of 37 Sectors at Ch2 with gain drop levels.

Green: 0-3 dB Drop; Yellow: 3-6 dB Drop; Blue: 6-8 dB Drop.

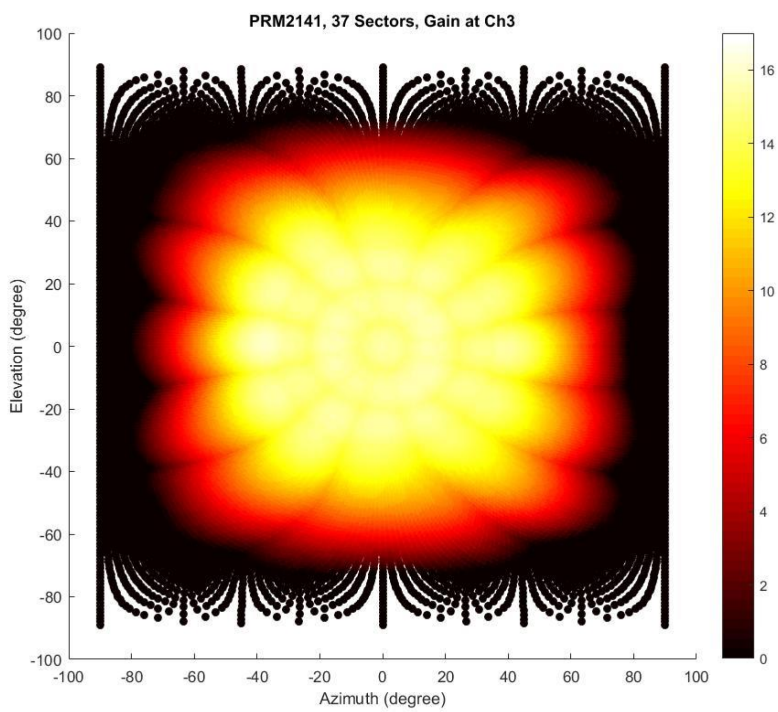


Figure 4-8. Beam Steering of 37 Sectors at Ch3.

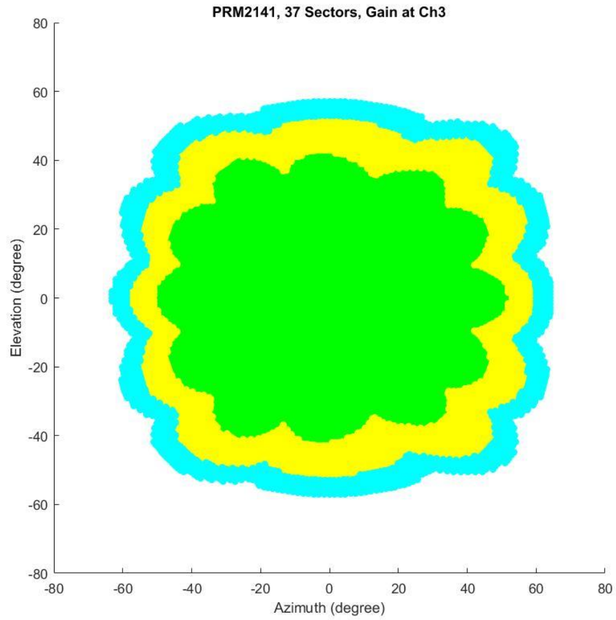


Figure 4-9. Beam Steering of 37 Sectors at Ch3 with gain drop levels.

Green: 0-3 dB Drop; Yellow: 3-6 dB Drop; Blue: 6-8 dB Drop.

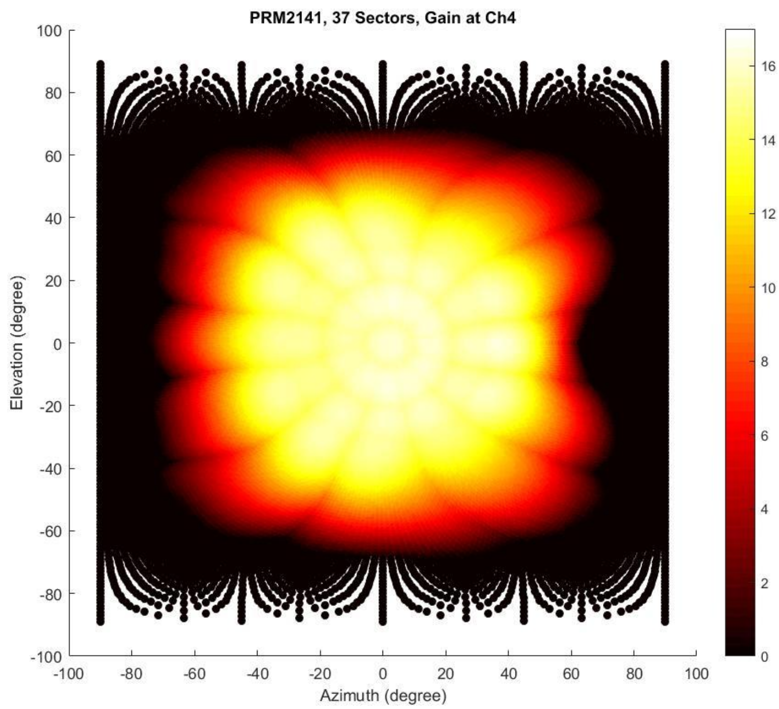


Figure 4-10. Beam Steering of 37 Sectors at Ch4.

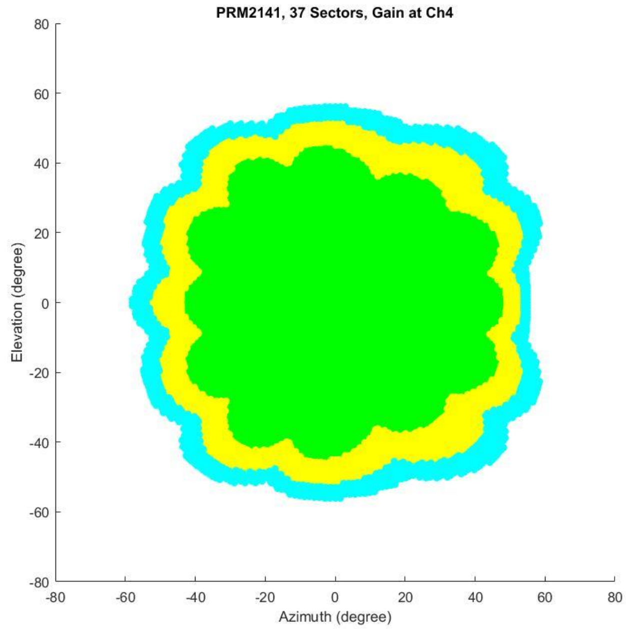


Figure 4-11. Beam Steering of 37 Sectors at Ch4 with gain drop levels.

\Green: 0-3 dB Drop; Yellow: 3-6 dB Drop; Blue: 6-8 dB Drop.

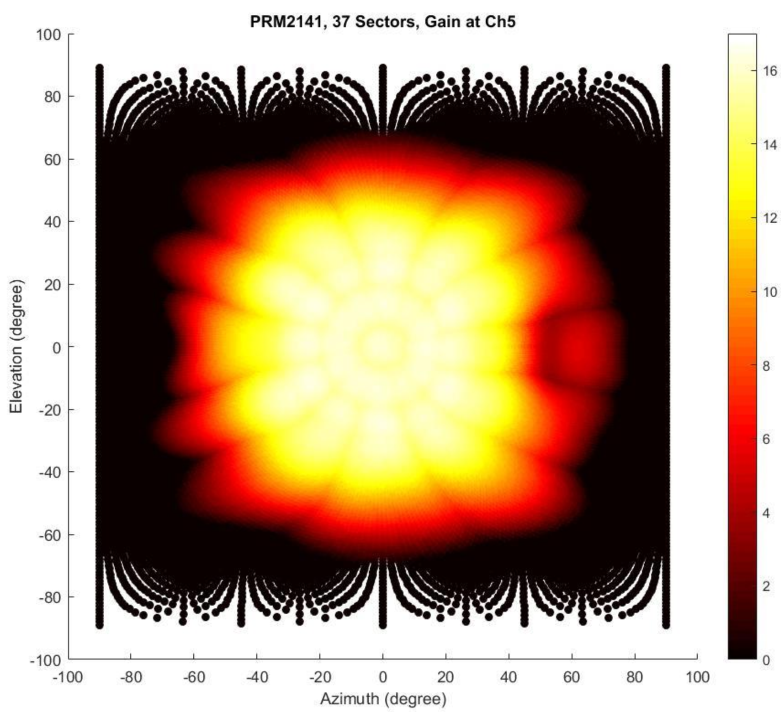


Figure 4-12. Beam Steering of 37 Sectors at Ch5.

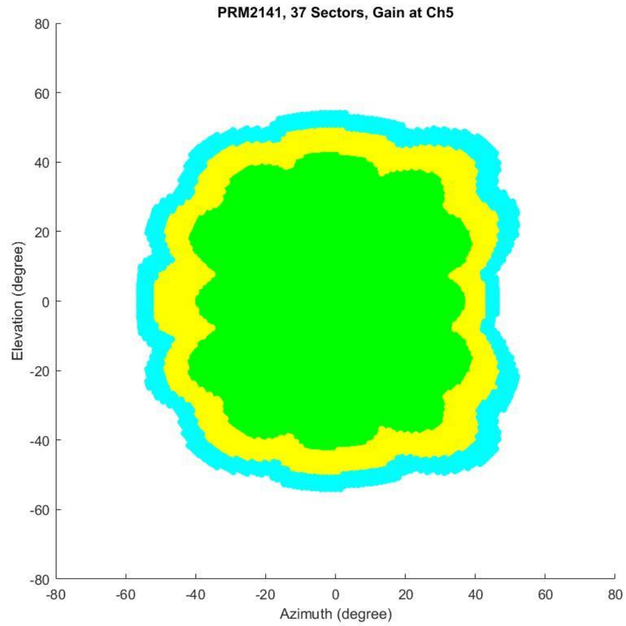


Figure 4-13. Beam Steering of 37 Sectors at Ch5 with gain drop levels.

Green: 0-3 dB Drop; Yellow: 3-6 dB Drop; Blue: 6-8 dB Drop

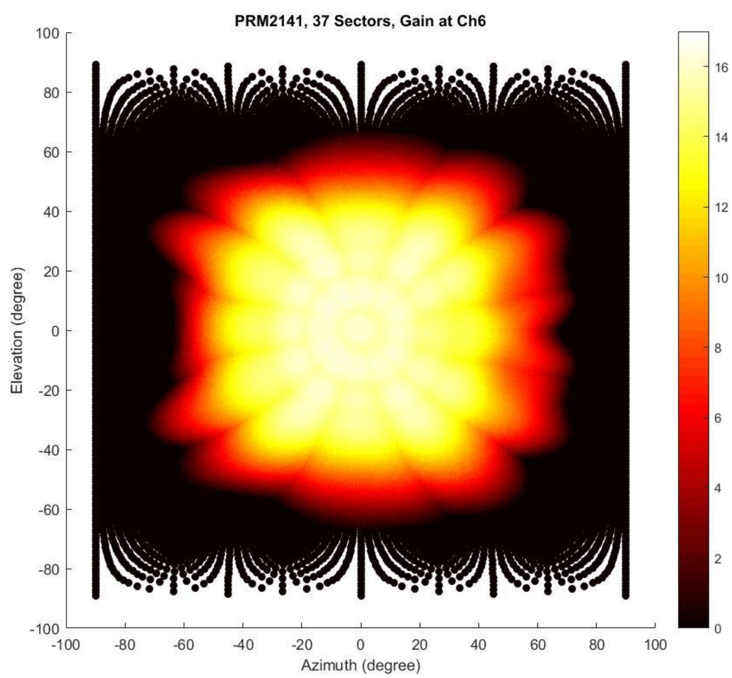


Figure 4-14. Beam Steering of 37 Sectors at Ch6.

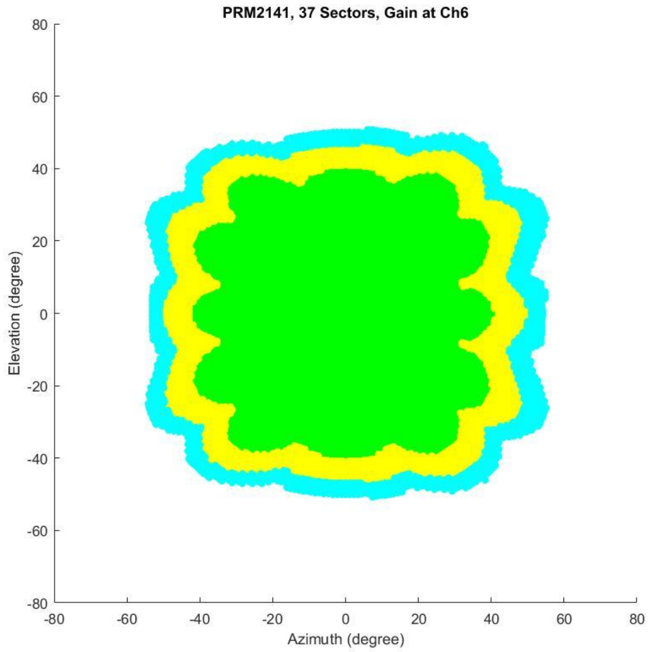


Figure 4-15. Beam steering of 37 sectors at Ch6 with gain drop levels.

Green: 0-3 dB Drop; Yellow: 3-6 dB Drop; Blue: 6-8 dB Drop.

4.2 Antenna Measurements

4.2.1 Test Setup

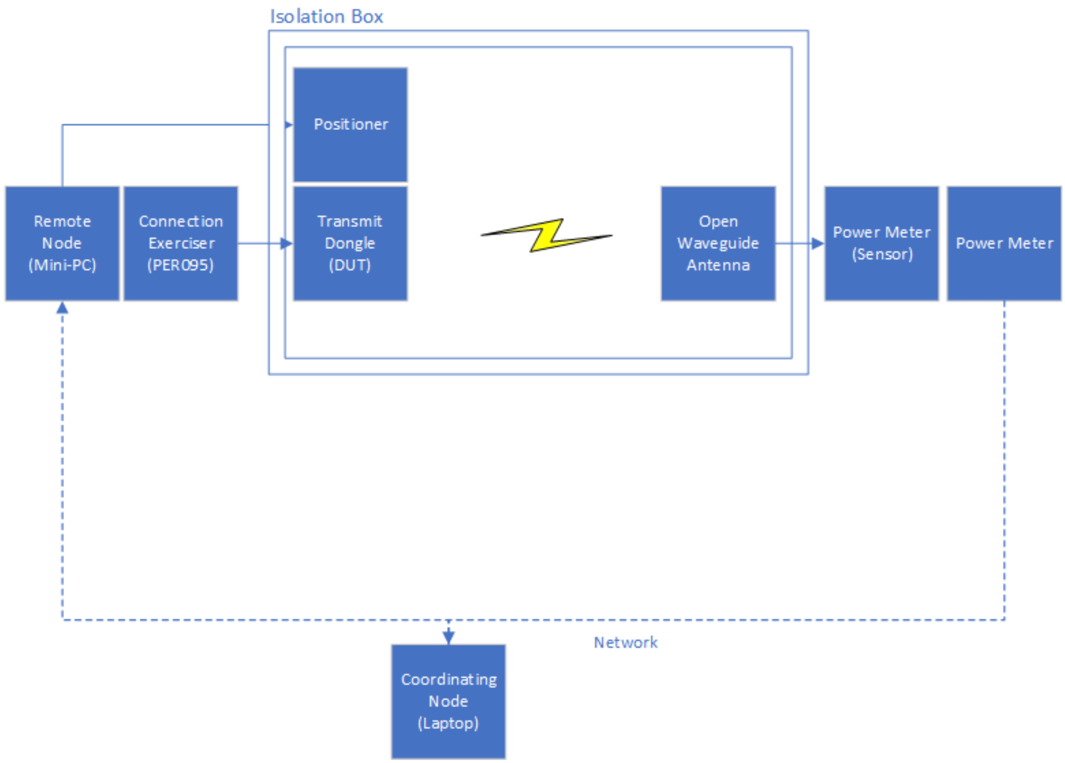


Figure 4-16. Antenna measurement setup

Table 4-1. Test Equipment

Qty.	Vendor	Part No.	Description
1	HD Supply	52000	Metal test chamber
6	TelePro	C-RAM FAC-1.5	RF absorber foam, 24in x 24in / velcro, unpainted
1	Lenovo	ThinkPad E490	Laptop, used as the coordinating node.
2	Dell	OptiPlex 7060	TX workstations
2	Any	N/A	USB cable (A-Male to A-Female)
2	Any	N/A	USB cable (A-Male to B-Male)
2	Any	N/A	USB cable (A-Male to Micro-B)
2	Any	N/A	RJ45 CAT6 ethernet cable
1	Keysight	N1914A or any other	Power Meter
1	Keysight	V8486A H02	Power Sensor
1	Quinstar	QAP-V01038500	Open wave guide, WR-15, antenna. V-Band.

Qty.	Vendor	Part No.	Description
2	Sage Millimeter	SWC-15VF-E1	wave guide to-cable adapter
1	HASCO	HLL125-VP-VP-36	Cable, V-connection from open wave guide to power meter
1	Newmark Systems	RT-2-2D-22	Motorized rotary stage with Step 17 MDrive intelligent stepper motor
1	Newmark Systems	250138	USB adapter for MDrive intelligent stepper motor
1	Newmark Systems	9000055	Switching Adapter 100-240 V 50/60 GHz 1.2 A, power source for RT-2-2D-22
2	Peraso	PER095	Exerciser
1	Peraso	PER711-03	Golden reference dongle

4.2.2 Beam Table Configuration

Test for Stand Alone Sector Table is configured with following parameters

- Channels: 1-6
- MCS: 1
- Scan angle: -90 deg to +90 deg with 5 deg increments
- Sectors:
  - Azimuth: 3, 7-12, 255 (omni)
  - Elevation: 0-6, 255 (omni)

4.2.3 Measurement plane

The patterns are measured along azimuth E-plane, (Azimuth) as shown:

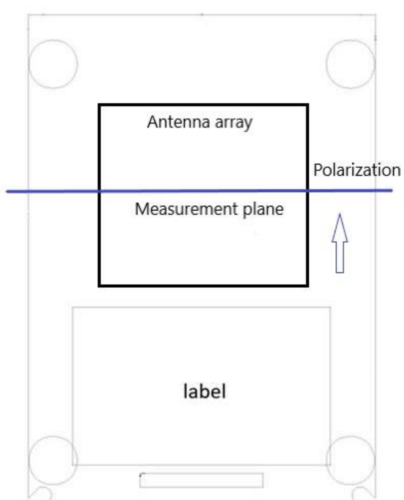


Figure 4-17. E-Plane measurement reference

4.2.4 Antenna Gain Calculation

The PRS1165 RFIC is directly connected to the antenna array without any connectors. In order to characterize the realized antenna gain, the conducted output power of the RFIC must be measured independently.

The output power of the RFIC is measured using a connectorized evaluation board. Each RF front end is independently routed to a surface-mount connector. A network analyzer measures the output powers at different frequency channels, while the required biasing was provided through different voltage sources. The output power is extracted after de-embedding all the losses associated with the transmission lines, traces, and connectors.

The antenna gain (G) is calculated from EIRP measurements. EIRP is measured in an anechoic chamber as explained above. The gain is extracted in each frequency channel as follows:

$$G = EIRP - [10*\log10(16FE) - L]$$

EIRP and Pout are measured under the same output level condition of Psat (saturation).

4.2.5 Antenna Gain Summary

Peak gain for each channel is found in following table.

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

Figure 4-18. Peak gain measurements

4.2.6 Measured Gain Patterns

The device has at least ±40° conical scan coverage over the entire six channels with about 4 dB drop at the extreme scanned angles (compared to the broadside pattern at the corresponding frequency).

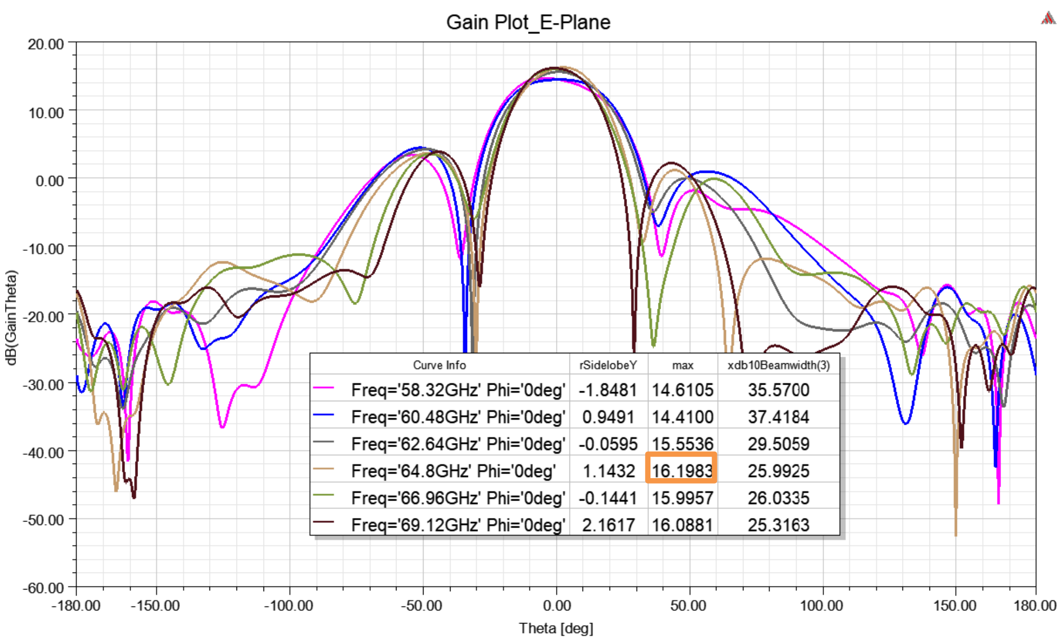


Figure 4-19. E-Plane radiation pattern over the channels. All elements phase set to zero

Note: Peak gain found on 64.8GHz measurement.

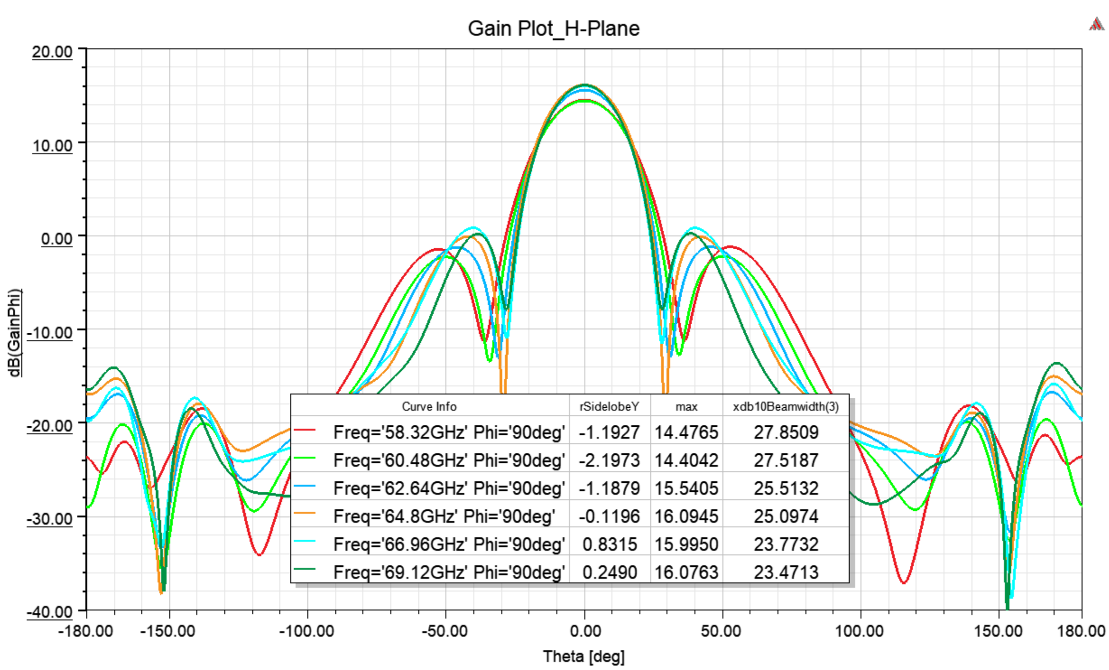


Figure 4-20. H-Plane radiation pattern over the channels. All elements phase set to zero