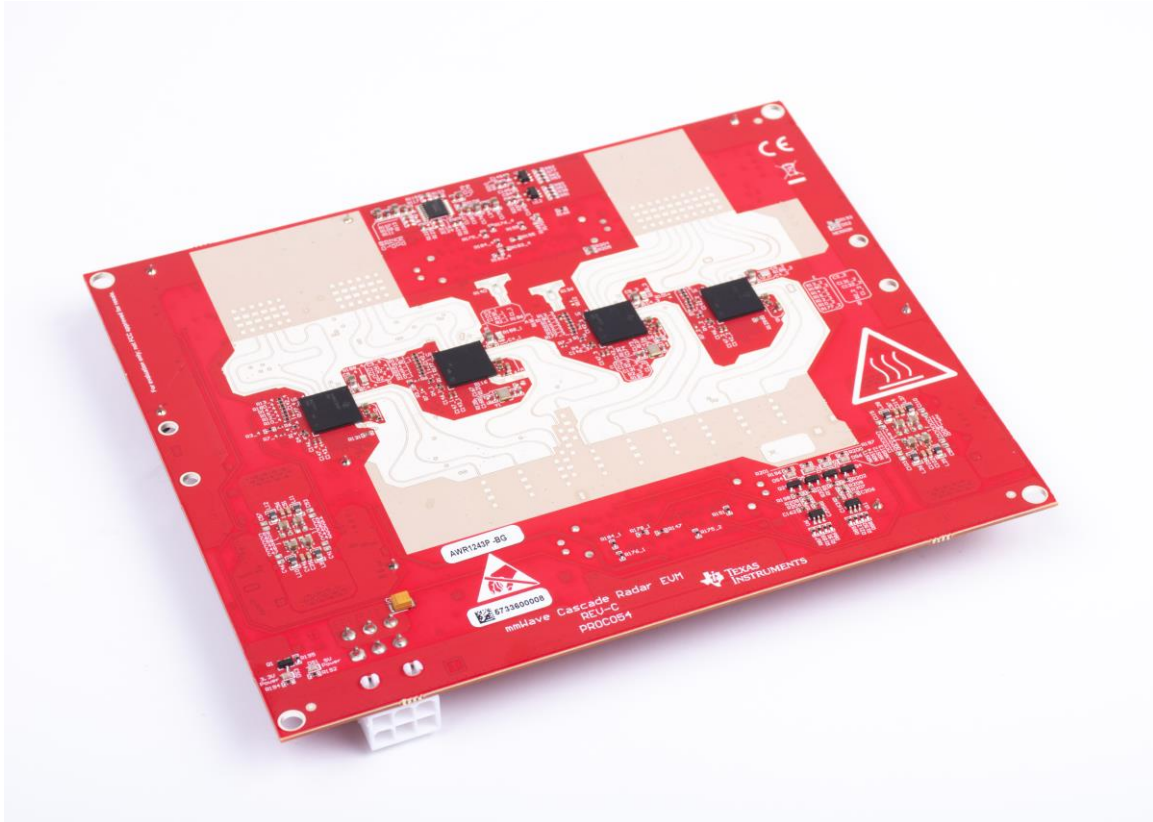


# ***AWRx Cascaded Radar RF Evaluation Module (MMWCAS-RF-EVM)***

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#### Trademarks

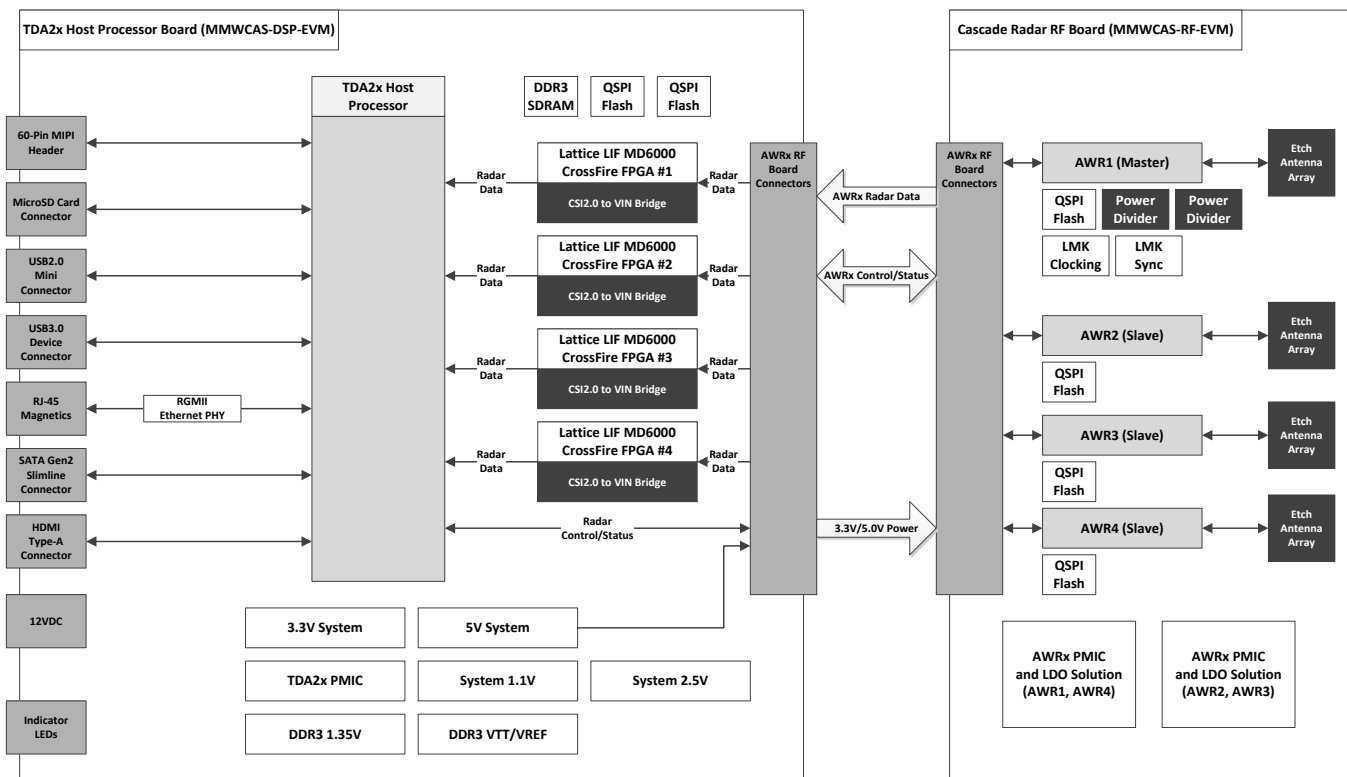
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# 1 Getting Started

## 1.1 Introduction

The AWRx Cascaded Radar RF evaluation board is an AWRx based mmWave sensing solution from TI implementing a 4-device, cascaded, array of AWRx mmWave devices. In this cascaded radar configuration, a single master device distributes a 20 GHz LO signal between all 4 devices, allowing these 4 devices to operate as a single RF transceiver. This enables support for up to 12 TX and 16 RX antenna elements. In TX beam-forming, beam-steering and MIMO/SIMO use-cases the larger number of antenna elements allows for higher SNR and higher angular resolution compared to a single-device system.

The Cascade Radar evaluation board interfaces to a companion TI TDA2x based Host/Data Capture board that is responsible for controlling the AWRx devices and receiving captured IF ADC samples. The TI TDA2x Host/Data Capture board includes SSD storage for supporting longer term data capture scenarios and 1Gigabit Ethernet connectivity for control and offloading captured data.



**Figure 1. Cascade RF EVM and companion TDA2x Host Processor Board Block Diagram**

The Cascade Radar evaluation board, when combined with a compatible host/data capture board, contains everything needed to start evaluating a single-device, or 2-device, 3-device or 4-device cascaded radar solution.

## 1.2 EVM Revisions

Multiple revisions of this EVM have been released. Please see below descriptions. This user guide is applicable to all of these EVM revisions. Usage of AWRx refers to either AWR1243P or AWR2243P throughout this document.

- **MMWCAS-RF-EVM, PROC054C** - Release based on AWR1243P. AWR1243P is not recommended for new designs.
- **MMWCAS-RF-EVM, PROC054D** - Release based on AWR2243P. AWR2243P is recommended for new designs.



## 1.3 Key Features

**Table 1. Key Features**

<b>Cascade Radar RF Board</b>	
4x AWRx 76-81GHz Radar SoC	Integrated VCO, LO distribution, PA, LNA, ADC, 3 TX and 4 RX ARM MCU R4 Controller
<b>AWRx RF/LO Peripherals</b>	
12x TX, 16x RX Antennas	<ul style="list-style-type: none"> <li>• 12 total transmitters across all 4 AWRx devices</li> <li>• 16 total receivers across all 4 AWRx devices</li> <li>• 86 non-overlapping Azimuth virtual array (<math>\lambda/2</math>)</li> <li>• 4 minimum redundancy array (MRA) Elevation</li> </ul>
Embedded Antenna	<ul style="list-style-type: none"> <li>• 4-element series-fed patch antenna, 12dBi</li> <li>• <math>\pm 60</math> deg Azimuth 3dB</li> <li>• <math>\pm 30</math> deg Elevation 3dB</li> </ul>
20 GHz LO Star-Network Distribution	2x Wilkinson power dividers fed by the Master AWRx device LO output to Master and Slave AWRx devices
<b>AWR Digital Peripherals</b>	
CSI2.0 4-lane	600Mbps/Lane for 2.4 Gbps ADC IF data per device
QSPI Flash	16 Mbit QSPI flash for AWR firmware updates/deveopment
Serial Peripherals	SPI, I2C, UART, GPIO
System Temperature	TMP112 I2C Temperature Sensors
<b>Power</b>	
Radar Power Management IC (PMIC) Solution	<ul style="list-style-type: none"> <li>• 2x LP87524P Quad-Channel, Integrated FET, Buck Converters, secondary LC filtering solution powering all 4 AWRx devices</li> <li>• TPS73733 LDO generating 3.3V system power</li> </ul>

## 1.4 What is Included

### 1.4.1 Kit Hardware Contents

- MMWAVCAS-RF-EVM PCB assembly
- Mounting standoffs and screws

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**NOTE:** The MMWAVCAS-RF-EVM is designed to be mounted to the companion TI TDA2x Cascade Radar Host/Capture board (MMWAVCAS-DSP-EVM). The combination MMWAVCAS-RF-EVM and MMWAVCAS-RF-EVM kit is mastered through a host PC over Ethernet and USB and the mmWave Studio software suite.

For more information on assembling, powering and configuring the full two-board system, see the [mmWave Studio and MMWAVCAS-DSP-EVM](#) documentation. All necessary mounting hardware and peripheral cables are expected to be provided by the host board system.

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### 1.4.2 mmWave Studio and Matlab Post Processing

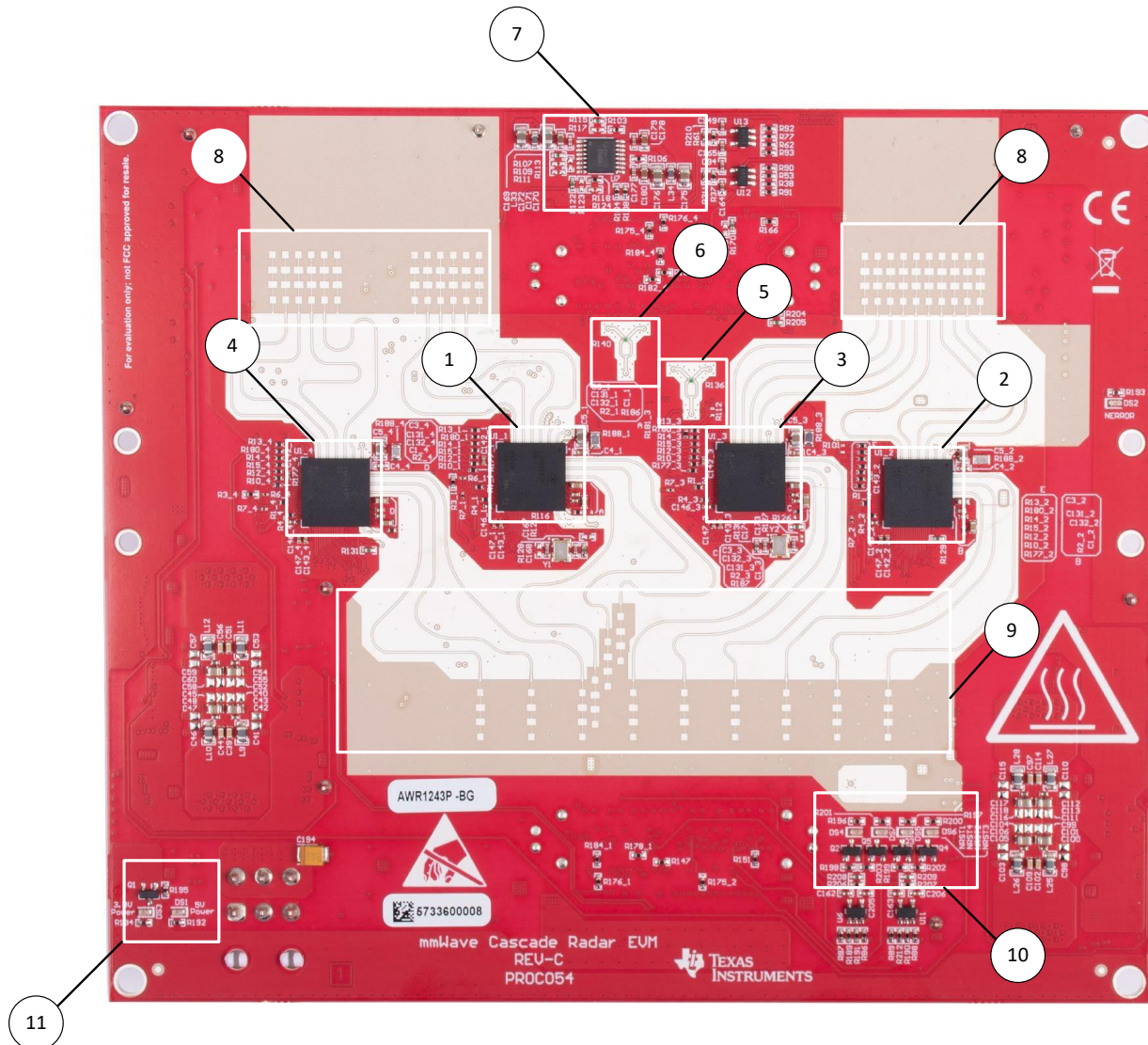
TI provides the following evaluation software to get started with the Cascade Radar evaluation module.

- mmWave Studio GUI and Lua scriptable configuration environment
- TDA2x ADC IF data capture application running on the MMWAVCAS-DSP-EVM
- Matlab post processing sample codes for reading captured ADC IQ sample datasets and example TDMA-MIMO and TX-Beamforming use modes

For details on getting started with these demos, see the [mmWave Studio User's Guide](#). This is part of the mmWave Studio 2.1 release (and later).

## 2 Hardware Description

Figure 2 and Figure 3 show the front and rear views of the evaluation board, respectively. The front (top layer) of the board primarily includes the AWRx devices and the embedded antenna arrays and 20 GHz LO splitters. The back (bottom layer) of the board primarily includes the host board connectors, power supplies (PMIC), most other support IC and most passives.

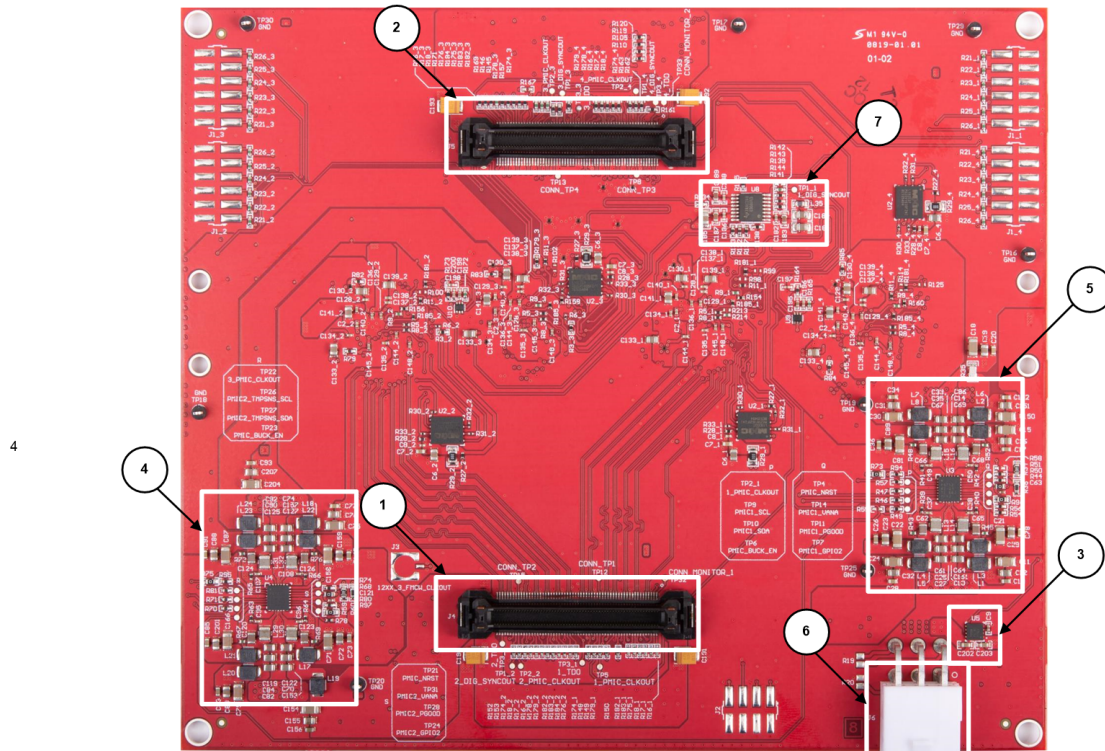


**Figure 2. MMWAVCAS-RF-EVM Front View**

Front View Callouts:

1. AWRx #1 "Master" (U1\_1)
2. AWRx #2 "Slave 1" (U1\_2)
3. AWRx #4 "Slave 3" (U1\_4)
4. AWRx #3 "Slave 2" (U1\_3)
5. 20 GHz LO Wilkinson Power Divider #1 (FMCW\_CLKOUT) AWR #1 and AWR #2
6. 20 GHz LO Wilkinson Power Divider #2 (FMCW\_SYNCOUT) AWR #3 and AWR #4
7. LMK00804B (U4) AWRx 40 MHz clock distribution buffer
8. Receive antenna array
9. Transmit antenna array

- 10. AWRx reset LED indicators
- 11. System 5.0 V and 3.3 V power status indicators



**Figure 3. MMWAVCAS-RF-EVM Back View**

Back View Callouts:

1. Host Board Connector #1 (J4) 5.0 V power, interfaces for AWRx #1, AWRx #2
2. Host Board Connector #2 (J5) 5.0 V power, interfaces AWRx #3, AWRx #4
3. LP87524P PMIC #2 (U4) powers AWRx #2 and AWRx #3
4. LP87524P PMIC #1 (U3) powers AWRx #1 and AWRx #4
5. TPS73733 5.0V to 3.3 V LDO (U5) provides system 3.3 V power
6. Bench 5.0 V power connector (J6)
7. LMK00804B (U8) AWRx digital synchronization distribution buffer

## 2.1 Block Diagram

The MMWAVCAS-RF-EVM consists of four AWR mmWave SoC and their associated power, clocking, synchronization, LO and RF TX and RX circuits. Each AWRx RF TX and RX port is routed to an etched, series-fed, patch antenna element. Each AWRx on the RF board has a 4-port CSI2.0 transmitter which is used for sending radar IQ ADC data samples to an attached host processor CSI2.0 receiver set. All of the AWRx configuration, control and reset lines are made available on two host interface connectors (J4 and J5) implemented with Hirose FX23-120 connectors.

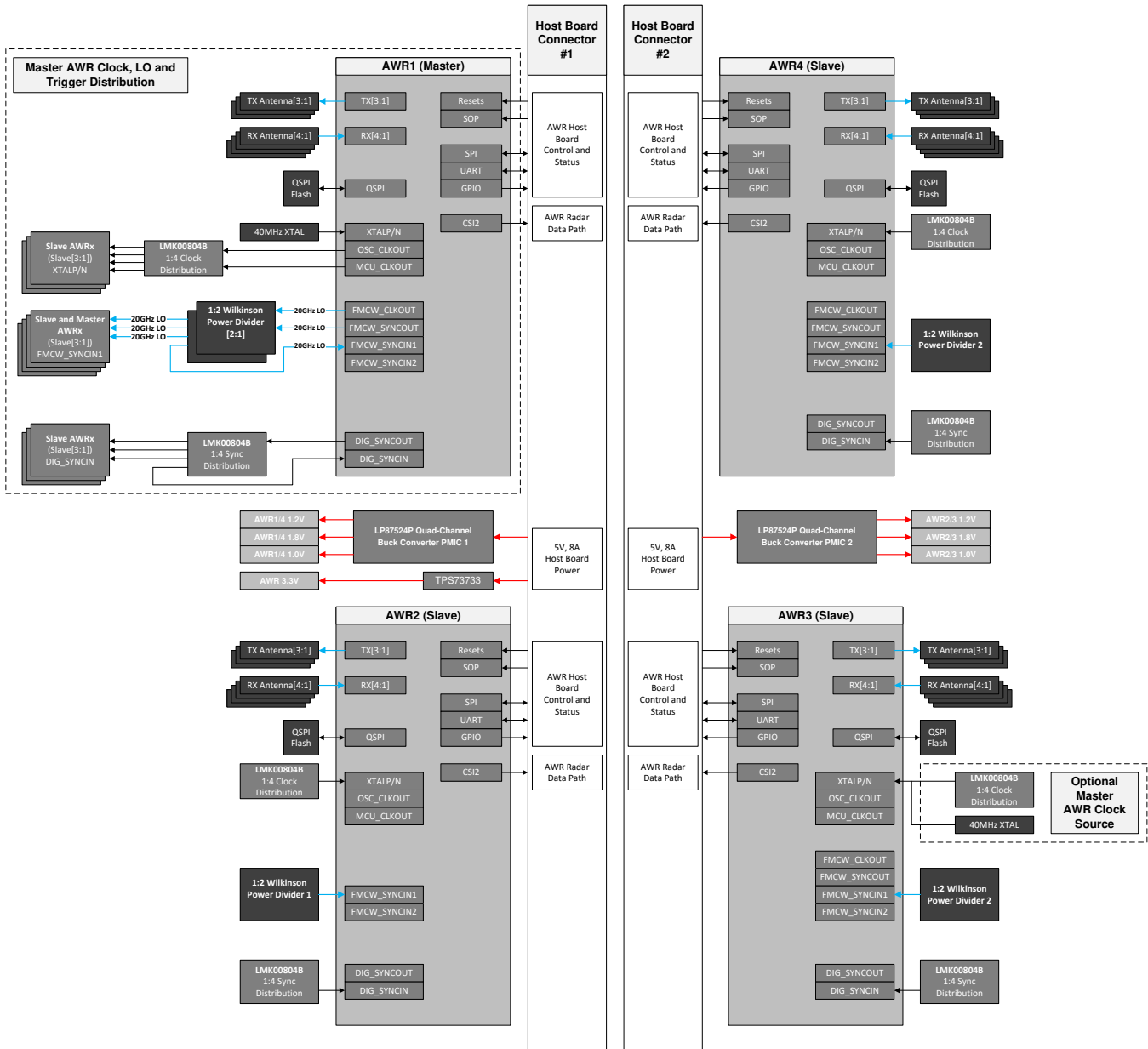


Figure 4. MMWAVCAS-RF-EVM System Block Diagram

The AWR devices are separated into Master and Slave classes of devices. AWRx #1, the Master device, utilizes the AWRx architecture built in VCO, LO distribution, clock distribution and frame synchronization distribution to provide 40 MHz clock, 20 GHz LO and frame synchronization to the other three Slave devices – AWRx #2, AWRx #3 and AWRx #4. This allows the system to generate and receive synchronous FMCW chirps across the four device AWRx array of transmitters and receivers.



The LO distribution follows the star-network configuration described in [AWR2243 Cascade](#). The master AWRx feeds a network of two Wilkinson power dividers, which in turn provide synchronous LO for the Master and Slave PA and mixer subsystems. All clock distribution, synchronization distribution and LO distribution requirements are documented in this referenced application note.

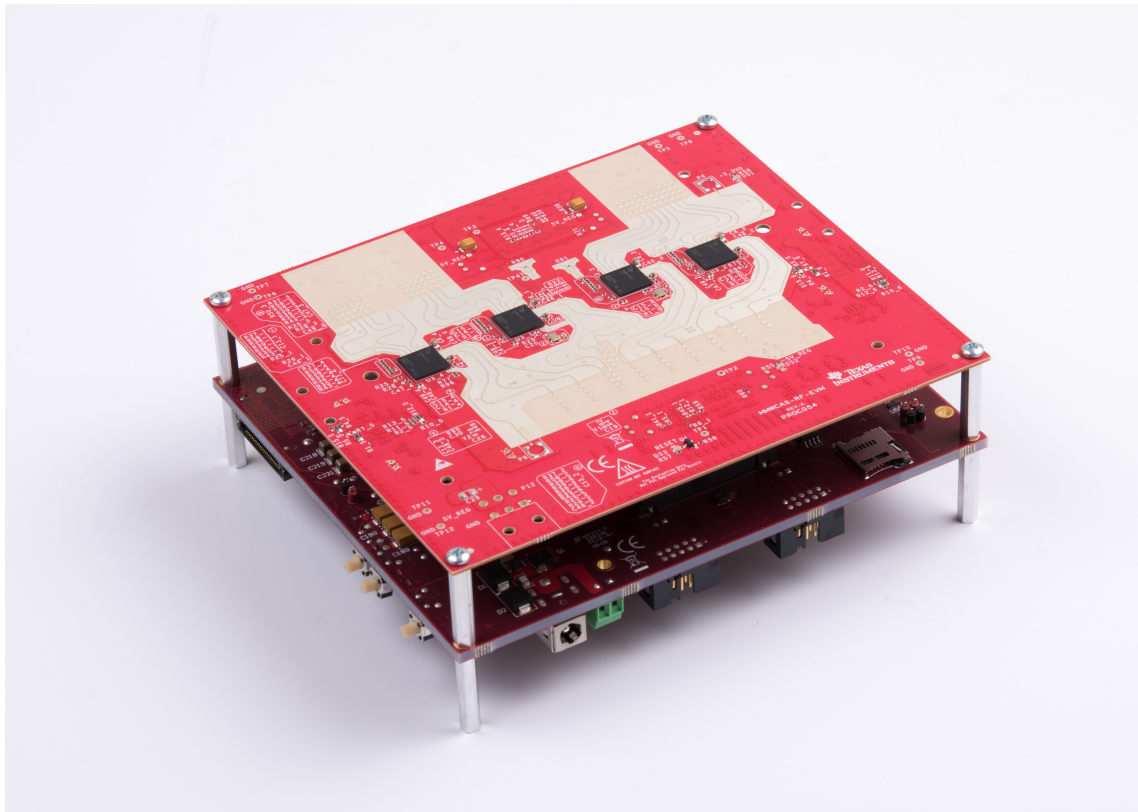
The Cascade RF board accepts 5V DC, 8A (max) power primarily through the host board connectors J4 and J5. A separate 6-pin power connector (J6) is available as an alternate power path. The primary 5V system rail provided by the host board is converted into the various AWRx device rails by the LP87524P quad-channel, monolithic, buck-converter.

## 2.2 Attaching the MMWAVCAS-RF-EVM to the MMWAVCAS-DSP-EVM

The MMWAVCAS-RF-EVM is designed to operate attached to the companion MMWAVCAS-DSP-EVM host board. The MMWAVCAS-DSP-EVM host board provides 5.0 V power and all necessary control signals to reset, boot and load AWRx firmware.

The two boards are attached and aligned through the the Host Board Connector #1 (J4) and Host Board Connector #2 (J5). These two connectors are keyed to prevent incorrect, 180°, opposite orientation. Also, the four corner mounting holes and the overall board outlines match between the MMWAVCAS-RF-EVM and MMWAVCAS-DSP-EVM host board. Simply depressing the J4 and J5 connectors into their opposing connector pairs on the MMWAVCAS-DSP-EVM will connect the two EVM. Additional 25 mm mounting stand-offs and screws should be used to secure the two boards together into a single assembly.

[Section 2.5.1](#) discusses the host board connectors.

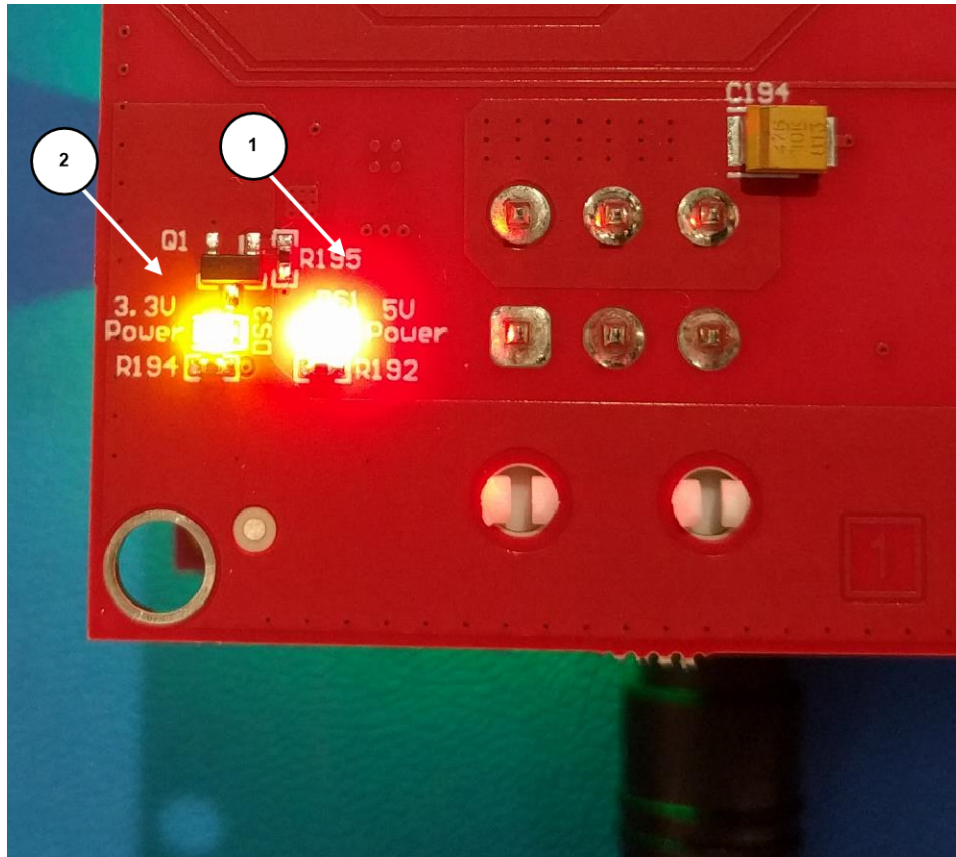


**Figure 5. MMWAVCAS-RF-EVM (top) attached to the MMWAVCAS-DSP-EVM (bottom)**

For additional information on the MMWAVCAS-DSP-EVM, see the [MMWAVCAS-DSP-EVM User's Guide](#) on the associated technical documents collateral.

### 2.3 Power Status LED Indicators

The MMWAVCAS-RF-EVM board provides two LED for visually evaluating 5.0 V and 3.3 V system power status. The 5.0 V LED will be enabled as soon as 5 V power is provided to the system through either the primary host connectors (J4, J5) or through the bench power connector J6. The 3.3 V LED will be enabled as soon as the TPS73733 LDO (U5) output is enabled. TPS73733 3.3 V power is enabled through the GPIO2 output of LP87524P PMIC #1 (U3) as the last stage of the PMIC power on sequence.



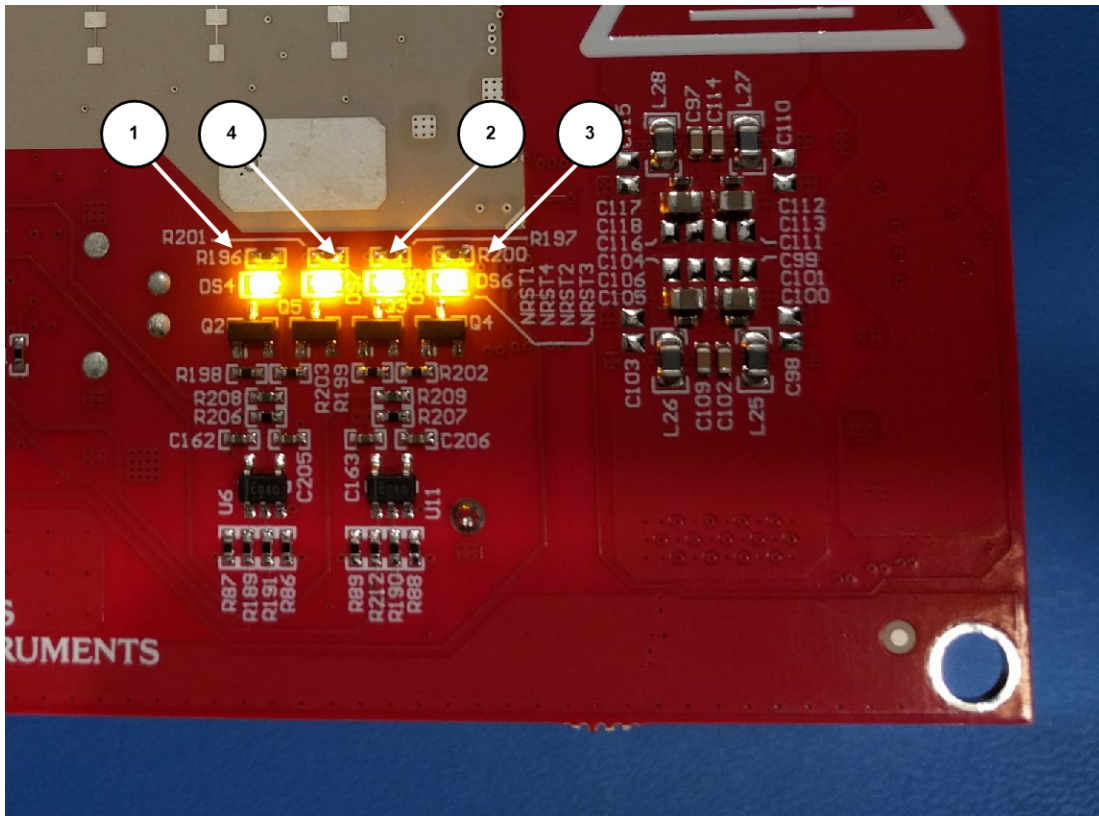
**Figure 6. MMWAVCAS-RF-EVM Power Status LED Indicators**

Power Status LED Callouts:

1. 5 V Power On LED (DS1) - Red LED active when 5 V power is available to MMWAVCAS-RF-EVM board
2. 3.3 V Power On LED (DS3) - Amber LED active when TPS73733 LDO (U5) 3.3V output is enabled

## 2.4 Reset LED Indicators

The MMWAVCAS-RF-EVM board provides four LED for visually evaluating AWRx NRESET status. The NRESET is generated from a combination of PMIC #1 and PMIC #2 power good outputs and host board NRESET signals. When powering on the MMWAVCAS-RF-EVM from the MMWAVCAS-DSP-EVM the NRESET signals will be initially de-asserted. A full reset sequence will be driven later by the TDA2 host processor to initialize the AWRx devices.



**Figure 7. MMWAVCAS-RF-EVM AWRx NRESET Status LED Indicators**

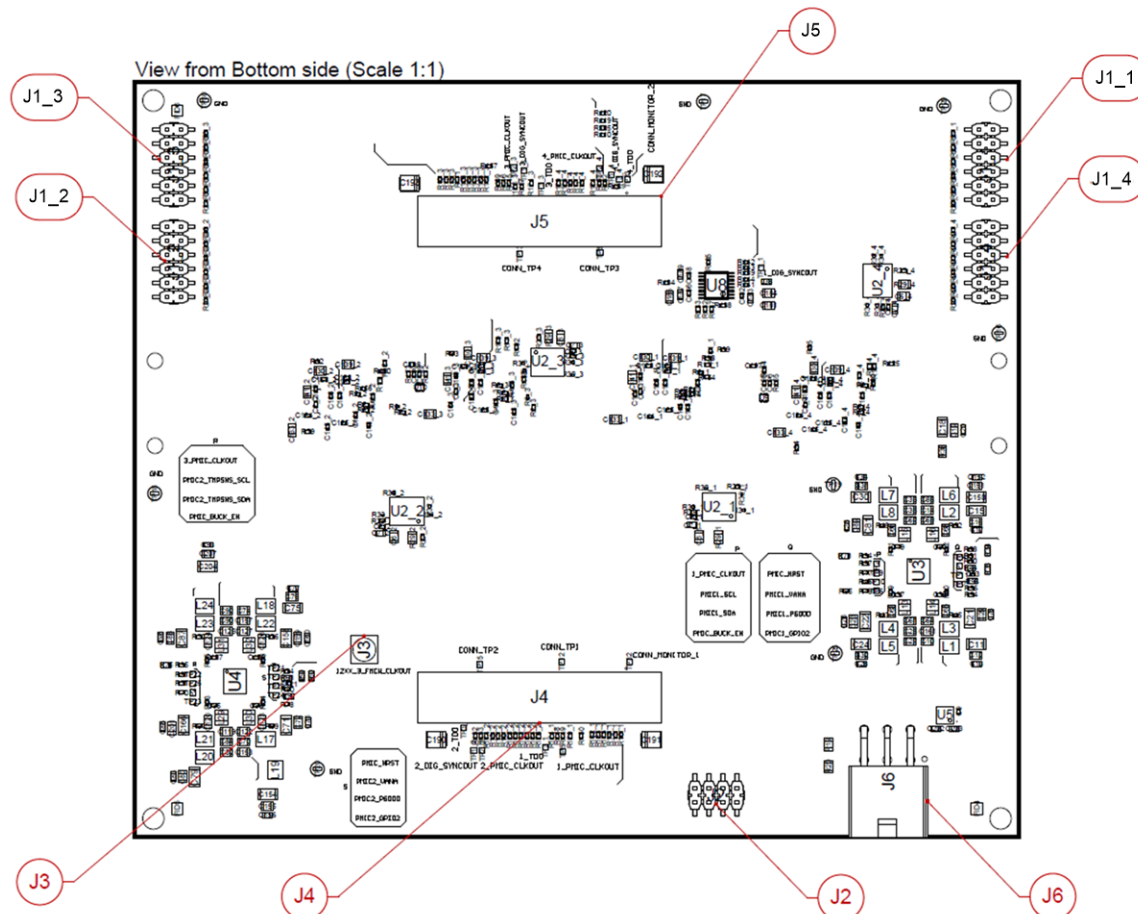
Reset Status LED Callouts:

1. AWRx #1 NRESET LED (DS4) - Amber LED active when NRESET is de-asserted (logic high)
2. AWRx #2 NRESET LED (DS5) - Amber LED active when NRESET is de-asserted (logic high)
3. AWRx #3 NRESET LED (DS6) - Amber LED active when NRESET is de-asserted (logic high)
4. AWRx #4 NRESET LED (DS7) - Amber LED active when NRESET is de-asserted (logic high)



## 2.5 Connectors

To keep out of the field of view of the etched antenna array on the top layer (front) of the board, all connectors are placed on the bottom layer (back) of the board.



**Figure 8. MMWCAS-RF-EVM (Bottom-View) Connector Placements and Callouts**

### Connector Callouts

- J6 - Auxillary Power Connector
- J4 - Host Board Connector (AWRx #1, AWRx #2)
- J5 - Host Board Connector (AWRx #3, AWRx #4)
- J3 - 20 GHz LO Debug Connector
- J2 - AWR OSC\_CLKOUT Debug Header
- J1\_1 - AWRx #1 Debug Header
- J1\_2 - AWRx #2 Debug Header
- J1\_3 - AWRx #3 Debug Header
- J1\_4 - AWRx #4 Debug Header

### 2.5.1 Host Board Connectors(J4, J5)

The primary connector set on the MMWAVCAS-RF-EVM is the host board connector #1 (J4) and host board connector #2 (J5). These connectors are each implemented with a Hirose FX23-120P-0.5SV15 Header. Connector #1 pinout contains all of the reset, boot, digital control and CSI2.0 data paths for AWRx #1 and AWRx #2. Connector #2 pinout contains the same for AWRx #3 and AWRx #4. Both connectors share a common 5.0 V power and GND return path. Primary power to the MMWAVCAS-RF-EVM is expected to be provided from a compatible host board through these connectors.

#### **WARNING**

**It is required that any attached host board provide 5.0 V power conditioning. No 5.0 V power rail protection exists on the MMWAVCAS-RF-EVM design itself. The attached host board is expected to provide reverse polarity protection and turn-on/off transient suppression. This is especially important to note when testing in an automotive alternator/battery powered system. The MMWAVCAS-DSP-EVM host board includes an automotive 12 V input supply rail for this purpose.**

Host Board Connector 1

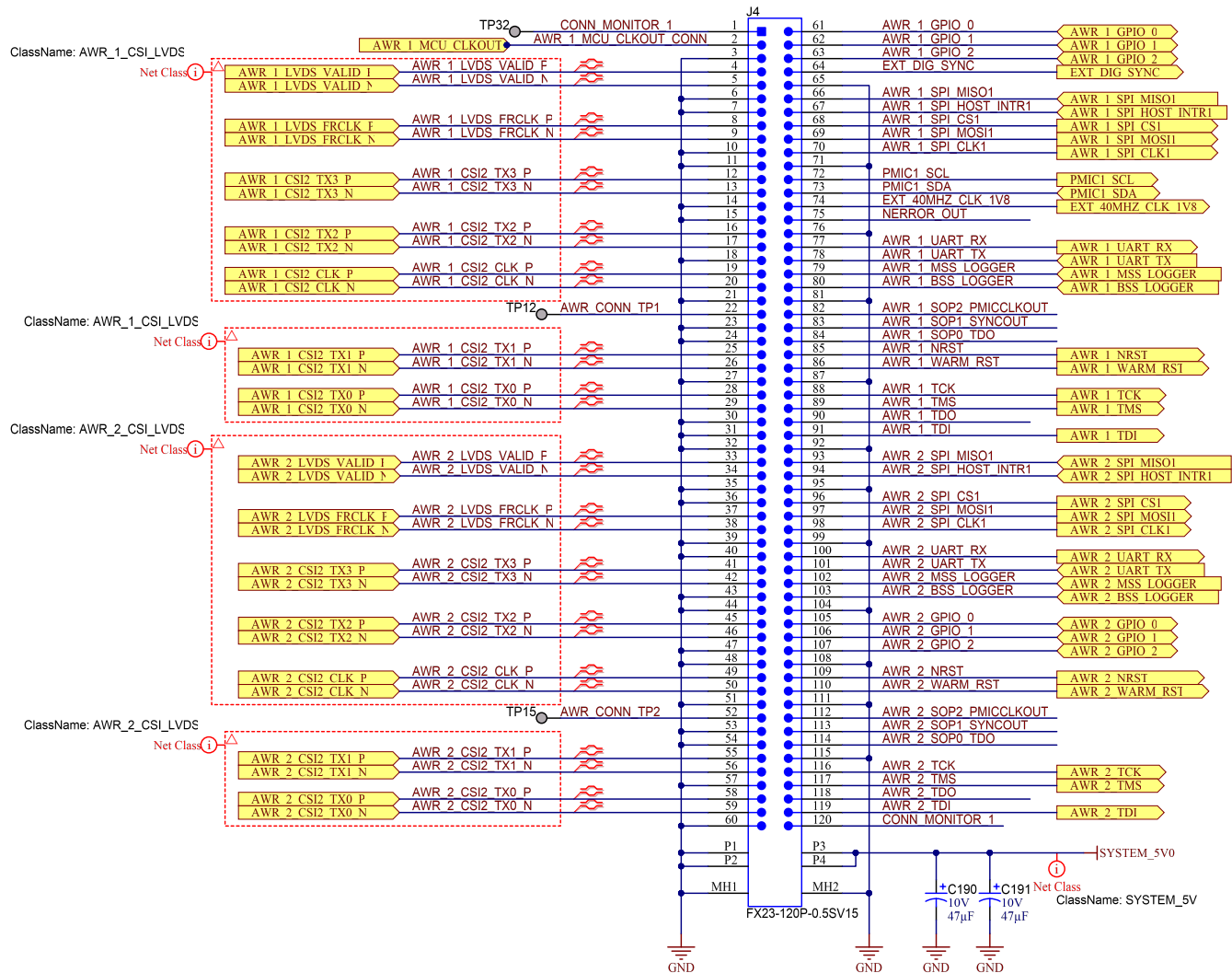


Figure 9. Host Board Connector #1 (J4), Schematic Excerpt

Host Board Connector 2

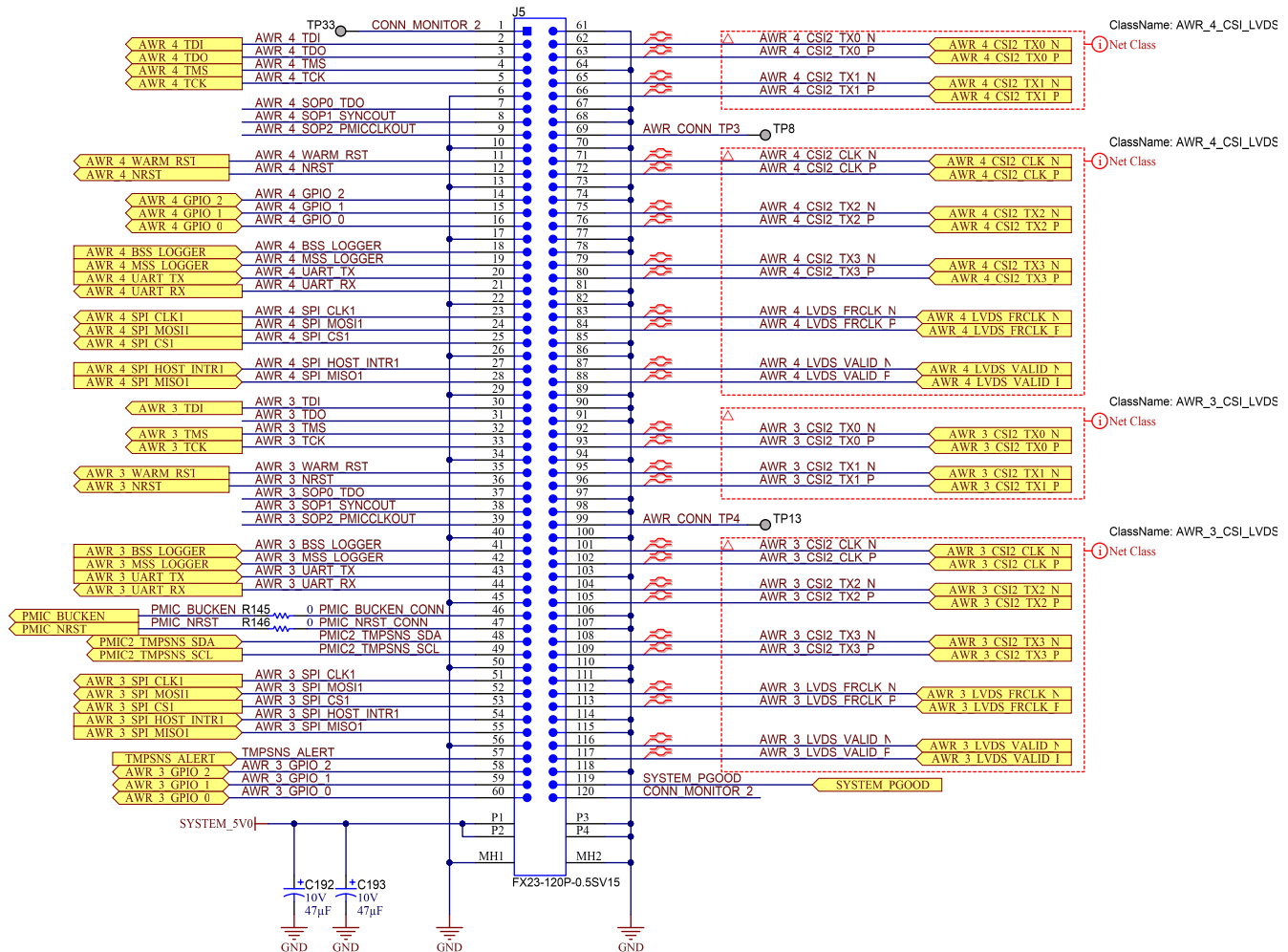


Figure 10. Host Board Connector #2 (J5), Schematic Excerpt

Table 2. Host Board Connector #1 (J4) Connector Definition

Pin Number	Pin Name	Pin Type <sup>(1)</sup>	Pin Description
1	CONN_MONITOR_1	Passive	Connection monitor - To be used with pin 120
2	AWR_1_MCU_CLKOUT_CONN	Passive	AWR #1 MCU_CLKOUT
3	GND	Power	System ground return
4	AWR_1_LVDS_VALID_P	Output	AWR #1 LVDS
5	AWR_1_LVDS_VALID_N	Output	AWR #1 LVDS
6	GND	Power	System ground return
7	GND	Power	System ground return
8	AWR_1_LVDS_FRCLK_P	Output	AWR #1 LVDS
9	AWR_1_LVDS_FRCLK_N	Output	AWR #1 LVDS
10	GND	Power	System ground return
11	GND	Power	System ground return
12	AWR_1_CSI2_TX3_P	Output	AWR #1 CSI2 TX3
13	AWR_1_CSI2_TX3_P	Output	AWR #1 CSI2 TX3

**Table 2. Host Board Connector #1 (J4) Connector Definition (continued)**

Pin Number	Pin Name	Pin Type <sup>(1)</sup>	Pin Description
14	GND	Power	System ground return
15	GND	Power	System ground return
16	AWR_1_CSI2_TX2_P	Output	AWR #1 CSI2 TX2
17	AWR_1_CSI2_TX2_N	Output	AWR #1 CSI2 TX2
18	GND	Power	System ground return
19	AWR_1_CSI2_CLK_P	Output	AWR #1 CSI2 Clock
20	AWR_1_CSI2_CLK_N	Output	AWR #1 CSI2 Clock
21	GND	Power	System ground return
22	XWR_CONN_TP1	Passive	Unused
23	GND	Power	System ground return
24	GND	Power	System ground return
25	AWR_1_CSI2_TX1_P	Output	AWR #1 CSI2 TX1
26	AWR_1_CSI2_TX1_N	Output	AWR #1 CSI2 TX1
27	GND	Power	System ground return
28	AWR_1_CSI2_TX0_P	Output	AWR #1 CSI2 TX0
29	AWR_1_CSI2_TX0_N	Output	AWR #1 CSI2 TX0
30	GND	Power	System ground return
31	GND	Power	System ground return
32	GND	Power	System ground return
33	AWR_2_LVDS_VALID_P	Output	AWR #2 LVDS
34	AWR_2_LVDS_VALID_N	Output	AWR #2 LVDS
35	GND	Power	System ground return
36	GND	Power	System ground return
37	AWR_2_LVDS_FRCLK_P	Output	AWR #2 LVDS
38	AWR_2_LVDS_FRCLK_N	Output	AWR #2 LVDS
39	GND	Power	System ground return
40	GND	Power	System ground return
41	AWR_2_CSI2_TX3_P	Output	AWR #2 CSI2 TX3
42	AWR_2_CSI2_TX3_N	Output	AWR #2 CSI2 TX3
43	GND	Power	System ground return
44	GND	Power	System ground return
45	AWR_2_CSI2_TX2_P	Output	AWR #2 CSI2 TX2
46	AWR_2_CSI2_TX2_N	Output	AWR #2 CSI2 TX2
47	GND	Power	System ground return
48	GND	Power	System ground return
49	AWR_2_CSI2_CLK_P	Output	AWR #2 CSI2 Clock
50	AWR_2_CSI2_CLK_N	Output	AWR #2 CSI2 Clock
51	GND	Power	System ground return
52	XWR_CONN_TP2	Passive	Unused
53	GND	Power	System ground return
54	GND	Power	System ground return
55	AWR_2_CSI2_TX1_P	Output	AWR #2 CSI2 TX1
56	AWR_2_CSI2_TX1_N	Output	AWR #2 CSI2 TX1
57	GND	Power	System ground return
58	AWR_2_CSI2_TX0_P	Output	AWR #2 CSI2 TX0
59	AWR_2_CSI2_TX0_P	Output	AWR #2 CSI2 TX0
60	GND	Power	System ground return

**Table 2. Host Board Connector #1 (J4) Connector Definition (continued)**

Pin Number	Pin Name	Pin Type <sup>(1)</sup>	Pin Description
61	AWR1_GPIO0	Bidirectional	AWR #1 GPIO0
62	AWR1_GPIO1	Bidirectional	AWR #1 GPIO1
63	AWR1_GPIO2	Bidirectional	AWR #1 GPIO2
64	EXT_DIG_SYNC	Input	Alternative input to AWRx digital sync fanout buffer (U8)
65	GND	Power	System ground return
66	AWR_1_SPI_MISO1	Output	AWR#1 SPI Slave MISO
67	AWR_1_SPI_HOST_INTR1	Output	AWR#1 SPI Slave Interrupt
68	AWR_1_SPI_CS1	Input	AWR#1 SPI Slave CS0N
69	AWR_1_SPI_MOSI1	Input	AWR#1 SPI Slave MOSI
70	AWR_1_SPI_CLK1	Input	AWR#1 SPI Slave SCLK
71	GND	Power	System ground return
72	PMIC1_SCL	Input	LP8752 4P (U3) PMIC I2C
73	PMIC1_SDA	Bidirectional	LP8752 4P (U3) PMIC I2C
74	EXT_40MHZ_CLK_1V8	Input	Optional 40 MHz clock input for AWR #1 (U1_1) CLKP.
75	NERROR_OUT	Input	Open-Drain Logic OR ERROR_OUT from AWR#1, 2, 3 and 4
76	GND	Power	System ground return
77	AWR_1_UART_RX	Input	AWR#1 UART RX
78	AWR_1_UART_TX	Output	AWR#1 UART TX
79	AWR_1_MSS_LOGGER	Output	AWR #1 MSS debug log UART output
80	AWR_1_BSS_LOGGER	Output	AWR #1 MSS debug log UART output
81	GND	Power	System ground return
82	AWR_1_SOP2_PMICCLKOUT	Input	AWR#1 PMICCLKOUT/SOP2
83	AWR_1_SOP1_SYNCOUT	Input	AWR#1 SYNCOUT/SOP1 signal
84	AWR_1_SOP0_TDO	Input	AWR#1 TDO/SOP0 signal
85	AWR_1_Nrst	Input	AWR#1 NRESET signal
86	AWR_1_WARM_RST	Input	AWR#1 WARM_RESET signal
87	GND	Power	System ground return
88	AWR_1_TCK	Input	AWR #1 JTAG
89	AWR_1_TMS	Input	AWR #1 JTAG
90	AWR_1_TDO	Output	AWR #1 JTAG
91	AWR_1_TDI	Input	AWR #1 JTAG
92	GND	Power	System ground return
93	AWR_2_SPI_MISO1	Output	AWR#2 SPI Slave MISO
94	AWR_2_SPI_HOST_INTR1	Input	AWR#2 SPI Slave Interrupt
95	GND	Power	System ground return
96	AWR_2_SPI_CS1	Input	AWR#2 SPI Slave CS
97	AWR_2_SPI_MOSI1	Input	AWR#2 SPI Slave MOSI
98	AWR_2_SPI_CLK1	Input	AWR#2 SPI Slave SCLK
99	GND	Power	System ground return
100	AWR_2_UART_RX	Output	AWR#2 UART RX - TDA2x TX to AWR RX
101	AWR_2_UART_TX	Input	AWR#2 UART TX - AWR TX to TDA2x RX

**Table 2. Host Board Connector #1 (J4) Connector Definition (continued)**

Pin Number	Pin Name	Pin Type <sup>(1)</sup>	Pin Description
102	AWR_2_MSS_LOGGER	Output	AWR #1 MSS debug log UART output
103	AWR_2_BSS_LOGGER	Output	AWR #1 BSS debug log UART output
104	GND	Power	System ground return
105	AWR_2_GPIO_0	Bidirectional	AWR #1 GPIO0
106	AWR_2_GPIO_1	Bidirectional	AWR #1 GPIO1
107	AWR_2_GPIO_2	Bidirectional	AWR #1 GPIO2
108	GND	Power	System ground return
109	AWR_2_NRST	Output	AWR#2 NRESET signal
110	AWR_2_WARM_RST	Output	AWR#2 WARM_RESET signal
111	GND	Power	System ground return
112	AWR_2_SOP2_PMICCLKOUT	Output	AWR#2 PMICCLKOUT/SOP2
113	AWR_2_SOP1_SYNCOUT	Output	AWR#2 SYNCOUT/SOP1 signal
114	AWR_2_SOP0_TDO	Output	AWR#2 TDO/SOP0 signal
115	GND	Power	System ground return
116	AWR_2_TCK	Input	AWR #2 JTAG
117	AWR_2_TMS	Input	AWR #2 JTAG
118	AWR_2_TDO	Output	AWR #2 JTAG
119	AWR_2_TDI	Input	AWR #2 JTAG
120	CONN_MONITOR_1	Passive	Connection monitor - To be used with pin 1
P1	GND	Power	Ground return
P2	GND	Power	Ground return
P3	EVM_5V0	Power	System 5.0V power
P4	EVM_5V0	Power	System 5.0V power
MH1	GND	Power	Plated mounting hole used for additional ground return
MH2	GND	Power	Plated mounting hole used for additional ground return

- (1) Pin direction relative to the MMWAVCAS-RF-EVM. Output are signals generated by transmitters on the MMWCAS-RF-EVM. Inputs are signal intended for receivers on the MMWCAS-RF-EVM.

**Table 3. Host Board Connector #2 (J5) Connector Definition**

Pin Number	Pin Name	Pin Type	Pin Description
1	CONN_MONITOR_2	Passive	Connection monitor - To be used with pin 120
2	AWR_4_TDI	Input	AWR #4 JTAG
3	AWR_4_TDO	Output	AWR #4 JTAG
4	AWR_4_TMS	Input	AWR #4 JTAG
5	AWR_4_TCK	Input	AWR #4 JTAG
6	GND	Power	Ground return
7	AWR_4_SOP0_TDO	Input	AWR#4 TDO/SOP0
8	AWR_4_SOP1_SYNCOUT	Input	AWR#4 SYNCOUT/SOP1
9	AWR_4_SOP2_PMICCLKOUT	Input	AWR#4 PMICCLKOUT/SOP2
10	GND	Power	Ground return
11	AWR_4_WARM_RST	Input	AWR#4 WARM_RESET signal



**Table 3. Host Board Connector #2 (J5) Connector Definition (continued)**

Pin Number	Pin Name	Pin Type	Pin Description
12	AWR_4_NRST	Input	AWR#4 NRESET signal
13	GND	Power	Ground return
14	AWR_4_GPIO_2	Bidirectional	AWR #4 GPIO2
15	AWR_4_GPIO_1	Bidirectional	AWR #4 GPIO1
16	AWR_4_GPIO_0	Bidirectional	AWR #4 GPIO0
17	GND	Power	Ground return
18	AWR_4_BSS_LOGGER	Passive	AWR #4 BSS debug log UART output
19	AWR_4_MSS_LOGGER	Passive	AWR #4 MSS debug log UART output
20	AWR_4_UART_TX	Output	AWR #4 UART TX
21	AWR_4_UART_RX	Input	AWR #4 UART RX
22	GND	Power	Ground return
23	AWR_4_SPI_CLK1	Output	AWR #4 SPI CLK
24	AWR_4_SPI_MOSI1	Output	AWR #4 SPI MOSI
25	AWR_4_SPI_CS1	Output	AWR #4 SPI CS
26	GND	Power	Ground return
27	AWR_4_SPI_HOST_INTR1	Input	AWR #4 SPI Host Interrupt
28	AWR_4_SPI_MISO1	Input	AWR #4 SPI MISO
29	GND	Power	Ground return
30	AWR_3_TDI	Input	AWR #3 JTAG
31	AWR_3_TDO	Output	AWR #3 JTAG
32	AWR_3_TMS	Input	AWR #3 JTAG
33	AWR_3_TCK	Input	AWR #3 JTAG
34	GND	Power	Ground return
35	AWR_3_WARM_RST	Input	AWR#4 WARM_RESET signal
36	AWR_3_NRST	Input	AWR#4 NRESET signal
37	AWR_3_SOP0_TDO	Input	AWR #3 TDO/SOP0
38	AWR_3_SOP1_SYNCOUT	Input	AWR #3 SYNCOUT/SOP1
39	AWR_3_SOP2_PMICCLKOUT	Input	AWR #3 MICCLKOUT /SOP2
40	GND	Power	Ground return
41	AWR_3_BSS_LOGGER	Passive	AWR #3 BSS debug log UART output
42	AWR_3_MSS_LOGGER	Passive	AWR #3 MSS debug log UART output
43	AWR_3_UART_TX	Input	AWR #3 UART TX
44	AWR_3_UART_RX	Output	AWR #3 UART RX
45	GND	Power	Ground return
46	PMIC_BUCKEN_CONN	PassInputive	LP87524P (U3) and (U4) power enable input
47	PMIC_NRST_CONN	Passive	LP87524P (U3) and (U4) reset input
48	PMIC2_TMPSNS_SDA	Bidirectional	LP87524P (U4) and TMP112 (U9, U10) I2C
49	PMIC2_TMPSNS_SCL	Input	LP87524P (U4) and TMP112 (U9, U10) I2C
50	GND	Power	Ground return
51	AWR_3_SPI_CLK1	Input	AWR #3 SPI CLK
52	AWR_3_SPI_MOSI1	Input	AWR #3 SPI MOSI

**Table 3. Host Board Connector #2 (J5) Connector Definition (continued)**

Pin Number	Pin Name	Pin Type	Pin Description
53	AWR_3_SPI_CS1	Input	AWR #3 SPI CS
54	AWR_3_SPI_HOST_INTR1	Output	AWR #3 SPI Host Interrupt
55	AWR_3_SPI_MISO1	Output	AWR #3 SPI MISO
56	GND	Power	Ground return
57	TMPSNS_ALERT	Output	TMP112 (U9, U10) I2C temperature alert (3.3V open-drain)
58	AWR_3_GPIO_2	Bidirectional	AWR #3 GPIO2
59	AWR_3_GPIO_1	Bidirectional	AWR #3 GPIO1
60	AWR_3_GPIO_0	Bidirectional	AWR #3 GPIO0
61	GND	Power	Ground return
62	AWR_4_CSI2_TX0_N	Output	AWR #4 CSI2 TX0
63	AWR_4_CSI2_TX0_P	Output	AWR #4 CSI2 TX0
64	GND	Power	Ground return
65	AWR_4_CSI2_TX1_N	Output	AWR #4 CSI2 TX1
66	AWR_4_CSI2_TX1_P	Output	AWR #4 CSI2 TX1
67	GND	Power	Ground return
68	GND	Power	Ground return
69	XWR_CONN_TP3	Passive	Unused
70	GND	Power	Ground return
71	AWR_4_CSI2_CLK_N	Output	AWR #4 CSI2 Clock
72	AWR_4_CSI2_CLK_P	Output	AWR #4 CSI2 Clock
73	GND	Power	Ground return
74	GND	Power	Ground return
75	AWR_4_CSI2_TX2_N	Output	AWR #4 CSI2 TX2
76	AWR_4_CSI2_TX2_P	Output	AWR #4 CSI2 TX2
77	GND	Power	Ground return
78	GND	Power	Ground return
79	AWR_4_CSI2_TX3_P	Output	AWR #4 CSI2 TX3
80	AWR_4_CSI2_TX3_P	Output	AWR #4 CSI2 TX3
81	GND	Power	Ground return
82	GND	Power	Ground return
83	AWR_4_LVDS_FRCLK_N	Output	AWR #4 LVDS
84	AWR_4_LVDS_FRCLK_P	Output	AWR #4 LVDS
85	GND	Power	Ground return
86	GND	Power	Ground return
87	AWR_4_LVDS_VALID_N	Output	AWR #4 LVDS
88	AWR_4_LVDS_VALID_P	Output	AWR #4 LVDS
89	GND	Power	Ground return
90	GND	Power	Ground return
91	GND	Power	Ground return
92	AWR_3_CSI2_TX0_N	Output	AWR #3 CSI2 TX
93	AWR_3_CSI2_TX0_P	Output	AWR #3 CSI2 TX0
94	GND	Power	Ground return
95	AWR_3_CSI2_TX1_N	Output	AWR #3 CSI2 TX1
96	AWR_3_CSI2_TX1_P	Output	AWR #3 CSI2 TX1
97	GND	Power	Ground return

**Table 3. Host Board Connector #2 (J5) Connector Definition (continued)**

Pin Number	Pin Name	Pin Type	Pin Description
98	GND	Power	Ground return
99	XWR_CONN_TP4	Passive	Unused
100	GND	Power	Ground return
101	AWR_3_CSI2_CLK_N	Output	AWR #3 CSI2 TX2
102	AWR_3_CSI2_CLK_P	Output	AWR #3 CSI2 TX2
103	GND	Power	Ground return
104	AWR_3_CSI2_TX2_N	Input	AWR #3 CSI2 TX2
105	AWR_3_CSI2_TX2_P	Input	AWR #3 CSI2 TX2
106	GND	Power	Ground return
107	GND	Power	Ground return
108	AWR_3_CSI2_TX3_N	Input	AWR #3 CSI2 TX3
109	AWR_3_CSI2_TX3_P	Input	AWR #3 CSI2 TX3
110	GND	Power	Ground return
111	GND	Power	Ground return
112	AWR_3_LVDS_FRCLK_N	Passive	AWR #3 LVDS
113	AWR_3_LVDS_FRCLK_P	Passive	AWR #3 LVDS
114	GND	Power	Ground return
115	GND	Power	Ground return
116	AWR_3_LVDS_VALID_N	Passive	AWR #3 LVDS
117	AWR_3_LVDS_VALID_P	Passive	AWR #3 LVDS
118	GND	Power	Ground return
119	SYSTEM_PGOOD	Output	System power good. Wired logic OR from LP87524P (U3, U4) PMIC.
120	CONN_MONITOR_2	Passive	Connection monitor - To be used with pin 1
P1	SYSTEM_5V0	Power	System 5.0V power
P2	SYSTEM_5V0	Power	System 5.0V power
P3	GND	Power	Ground return
P4	GND	Power	Ground return
MH1	GND	Power	Ground return
MH2	GND	Power	Ground return

### 2.5.2 Bench Power Connector(J6)

A separate, 6-pin, Molex Minifit Jr connector provides for the connection of bench 5.0 V power to the MMWAVCAS-RF-EVM. 5.0 V power, GND return and a 5.0 V sense and GND sense path are also provided for a 4-terminal, "Kelvin" connection.

**NOTE:** The Host Board Connectors, J4, and J5 are the primary 5.0 V power inputs to the MMWCAS-RF-EVM. If this bench power connector, J6, is to be used, an attached host board should ensure that either the J4, J5, 5.0 V nets are being supplied from the same supply sourcing J6, **or** that the 5.0 V nets on J4 and J5 are open and not providing 5.0 V power to the MMWCAS-RF-EVM.

The MMWCAS-DSP-EVM host board has no method of disconnecting these 5.0 V power nets and therefore it is incompatible with this J6 bench power connector.

### **WARNING**

**It is required that any attached host board provide 5.0V power conditioning. No 5.0 V rail protection exists on the MMWAVCAS-RF-EVM design itself. The attached host board is expected to provide reverse polarity protection and turn-on/off transient suppression. This is especially import to note when testing in an automotive alternator/battery powered system.**

**Table 4. Bench Power Connector (J6)**

Pin Number	Pin Name	Pin Type	Pin Description
1	GND_SENSE	Power	GND return sense path
2	GND	Power	GND return
3	GND	Power	GND return
4	SYSTEM_5V0_SENSE	Power	5.0V sense path
5	SYSTEM_5V0	Power	5.0V System Power
6	SYSTEM_5V0	Power	5.0V System Power

### 2.5.3 20 GHz LO Debug Connector (J3)

J3 is a footprint for a Rosenberger model 19S101-40ML5, 50-Ω, SMP connector capable of 26 GHz operation with very low loss and reflection. This connector exposes the AWR\_3\_FMCW\_CLKOUT 20 GHz local oscillator (LO) net from AWR #3. Depending on how the AWR #3 is configured, this connector allows the user to sample an example AWR master-mode or slave-mode LO output signal. This connector is not installed by default.

### 2.5.4 AWR OSC\_CLKOUT Debug Header (J2)

A footprint for terminal strip of 25 mil square posts, 100 mil pitch, are provided to enable sampling of the AWR #1, #2, #3 and #4 OSC\_CLKOUT paths. These terminal strips are not installed by default.

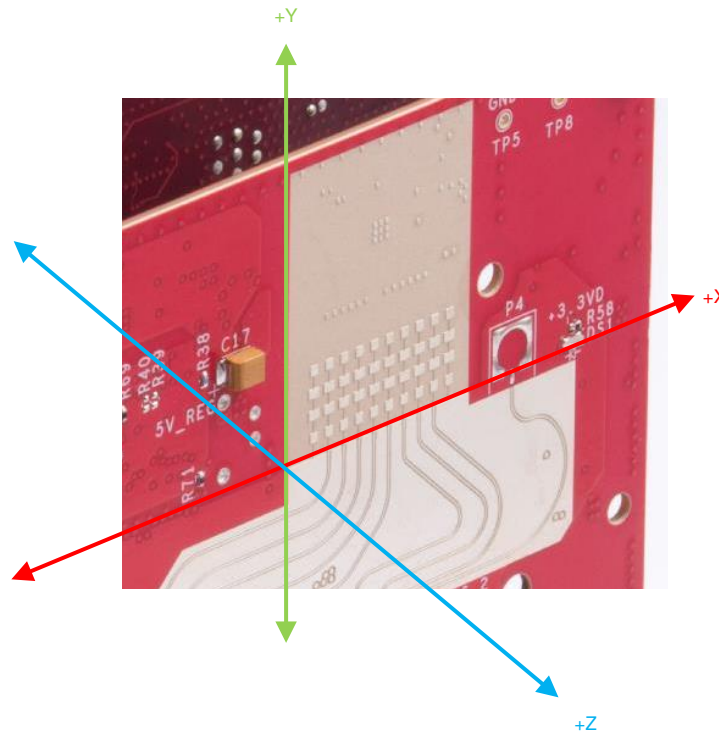
### 2.5.5 AWR Debug Headers (J1\_1, J1\_2, J1\_3, J1\_4)

A footprint for terminal strip of 25 mil square posts, 100 mil pitch, are provided to enable sampling of the AWR #1, #2, #3 and #4 GPADC debug headers. These terminal strips are not installed by default.

## 2.6 Antennas

Each of the 12 TX channels and 16 RX channels (across the four AWRx cascaded radar devices) is routed to an etched antenna element. This antenna array allows for the creation of MIMO and TX-Beamforming array generation, allowing for high angular resolution and longer range detection of targets in a 3D space.

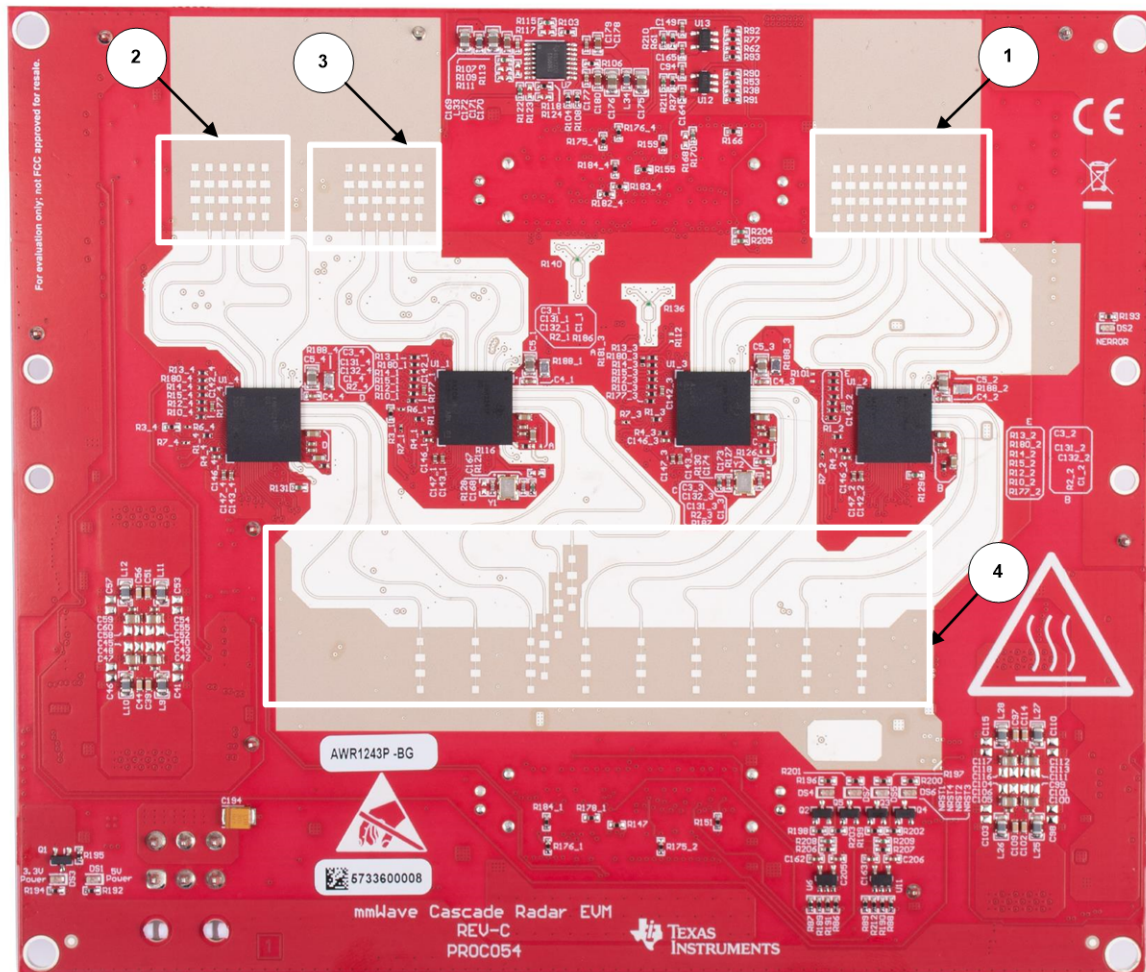
The antenna array axes are defined such that the azimuth axis is along the XZ-plane with azimuth bore-sight along the +Z-axis. Likewise, the elevation axis is along the YZ-plane with elevation bore-sight along the +Z-axis. Antenna patterns presented are relative to these axes as well. The E-plane defined polarization ( $\Phi = 90$  in spherical coordinates) being along the YZ-plane and the H-plane being ( $\Phi = 0$  in spherical coordinates) along the XZ-plane.



**Figure 11. Antenna Axes Definition**

## 2.6.1 TX and RX Antenna Arrays

The following sections describe the TX and RX antenna array structures included on the board. The element spacing information can be used to form the necessary processing models of the MIMO virtual array and Beam-Forming phased array.



**Figure 12. PCB Antenna Arrays**

Reset Status LED Callouts:

1. RX Array A - 8,  $\lambda/2$ , linear elements - azimuth displacement only
2. RX Array B - 4,  $\lambda/2$ , linear elements - azimuth displacement only
3. RX Array C - 4,  $\lambda/2$ , linear elements - azimuth displacement only
4. TX array - 9,  $\lambda \times 2$ , linear elements in azimuth. 4 minimum redundancy array (MRA) elements in elevation.



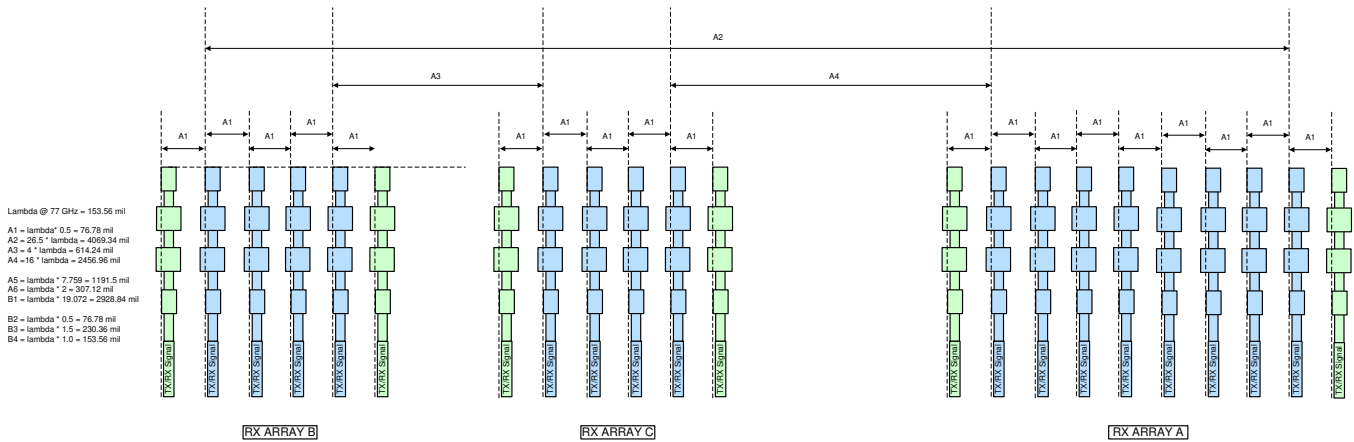


Figure 13. RX Antenna Array Dimensions

Table 5. RX Antenna Array Dimensions

Dimension Label	Dimension (mils)	Dimension (78.5 GHz lambda)
A1	76.78	0.5
A2	4069.34	26.5
A3	614.24	4.0
A4	2456.96	16.0

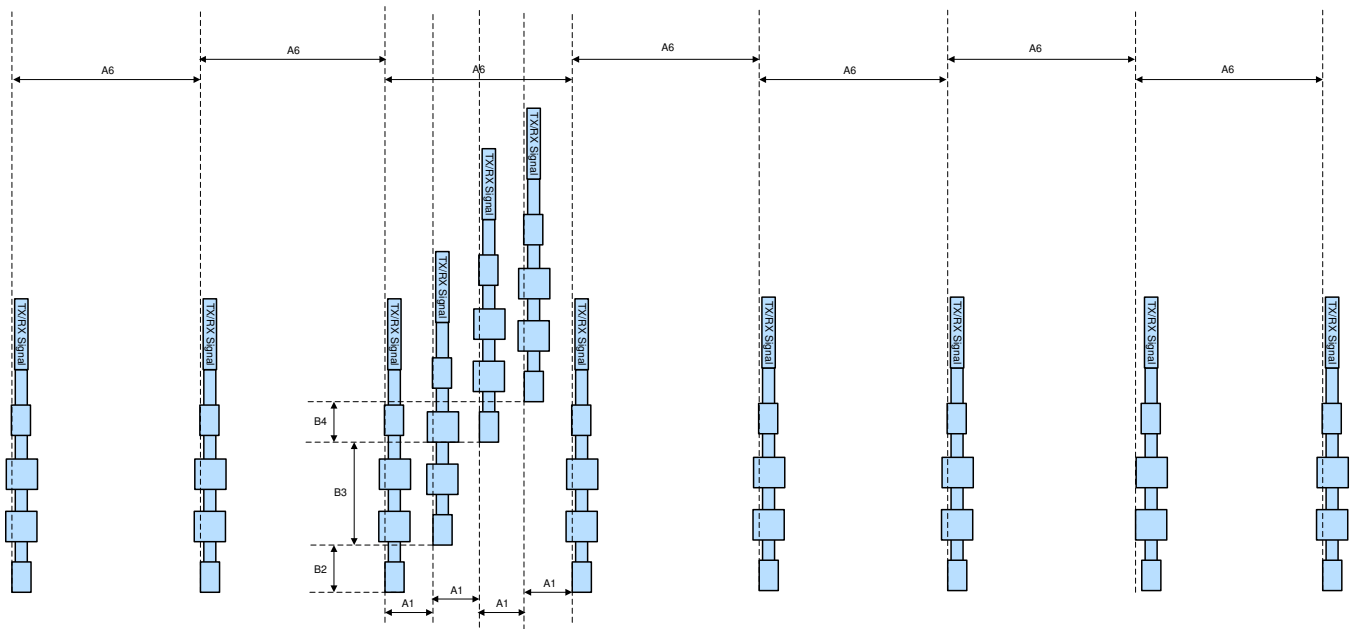


Figure 14. TX Antenna Array Dimensions

Table 6. TX Antenna Array Dimensions

Dimension Label	Dimension (mils)	Dimension (77 GHz lambda)
A1	76.78	0.5
A5	1191.5	7.759
A6	307.12	2.0



Table 6. TX Antenna Array Dimensions (continued)

Dimension Label	Dimension (mils)	Dimension (77 GHz lambda)
B1	2928.84	19.072
B2	76.78	0.5
B3	230.36	1.5
B4	153.56	1.0

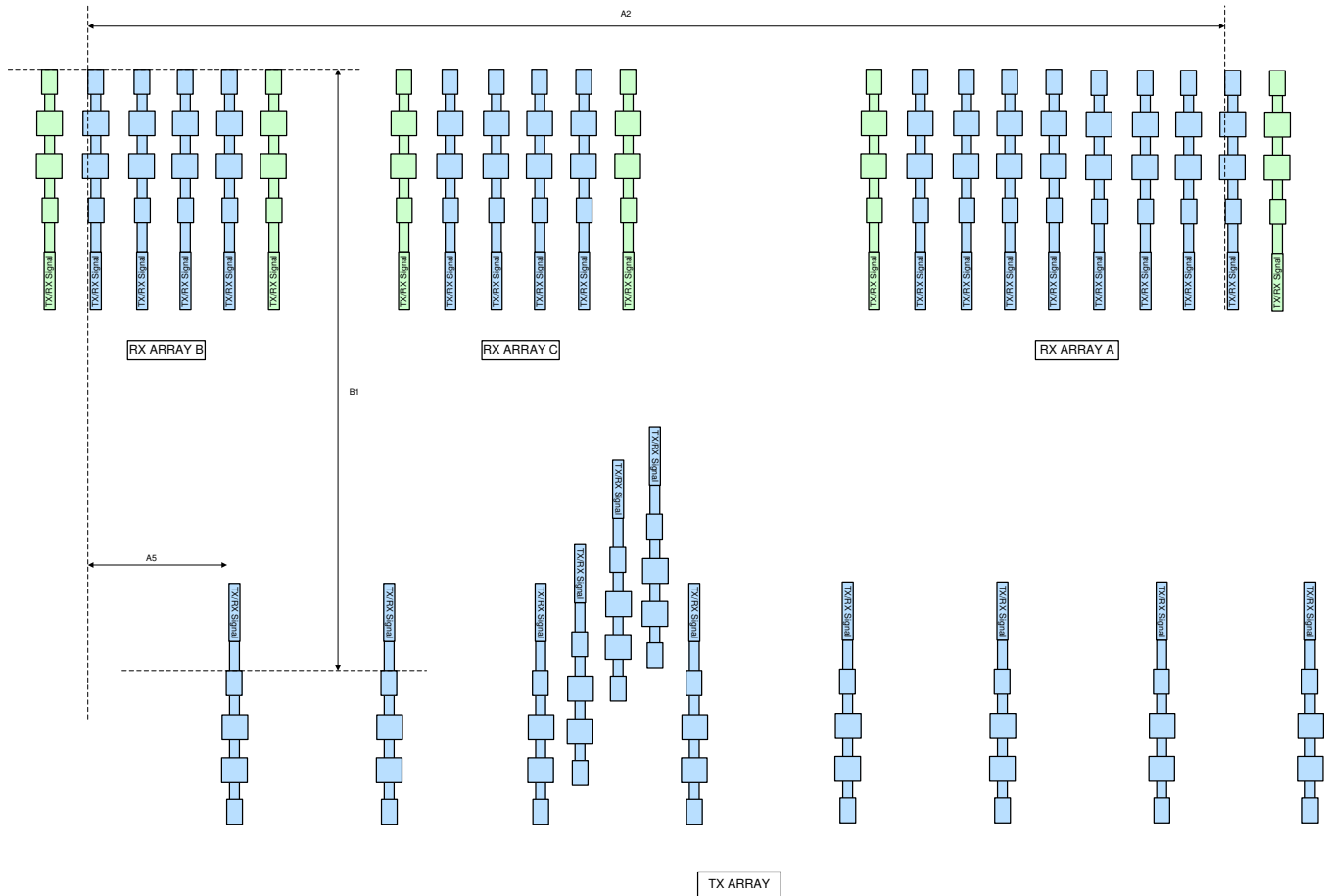
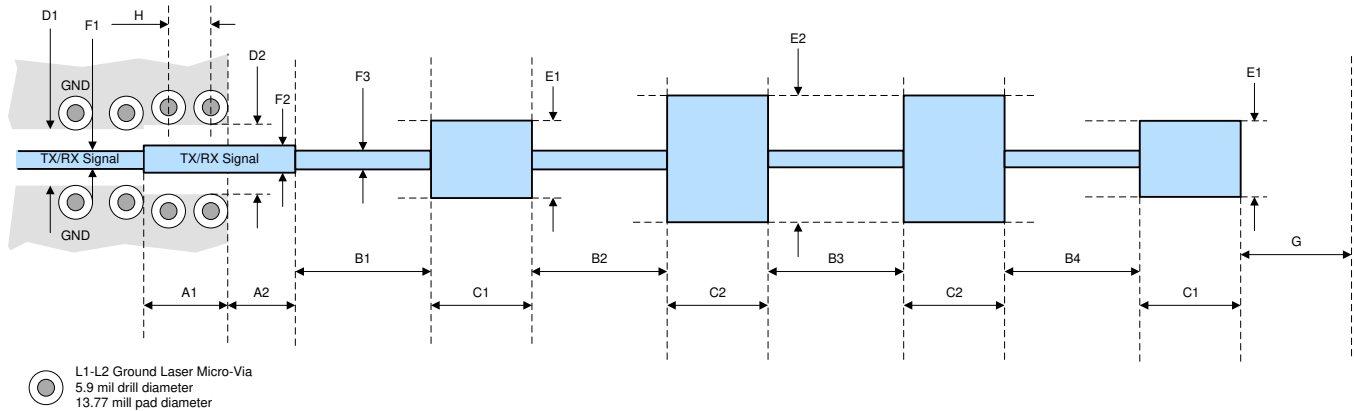


Figure 15. TX and RX Antenna Array Relative Dimensions

### 2.6.2 PCB Antenna Element

Each TX/RX antenna element is implemented as a series-fed, Microstrip patch array. The following figures and tables describe this antenna element. The element is implemented with a GCPW feed to Microstrip transition, and then Microstrip stub matching into the first patch of the series-fed array.



**Figure 16. Cascade RF Series-Fed, Microstrip Patch Array Antenna Element Dimensions**

**Table 7. Cascade RF Series-Fed, Microstrip Patch Array Antenna Element Dimensions**

Dimension Label	Dimension (mils)
A1	27.568
A2	11.802
B1	47.24
B2	49.21
B3	45.27
B4	49.21
C1	42.52
C2	40.95
D1	16.722
D2	20.002
E1	39.38
E2	55.12
F1	8.4
F2	10.62
F3	3.94
G <sup>(1)</sup>	> 78.7402
H	<= 20.67

(1) Dimension G is the is the minimum keepout from any structure adjacent to the antenna (vias, traces, copper pours, and so forth).

### 2.6.2.1 RX Antenna Element Performance

Simulated RX antenna performance from RX Array A is shown below. Three different RX antenna were excerpted to show the overall performance across the array. These excerpted antenna are labeled RX1, RX4 and RX8 shown. This selection is meant to highlight behavior of the RX antenna near the edge of the RX antenna rays and near the center of the arrays. Due to coupling between antenna, the performance near the edge of the array changes from the performance near the center of the array.

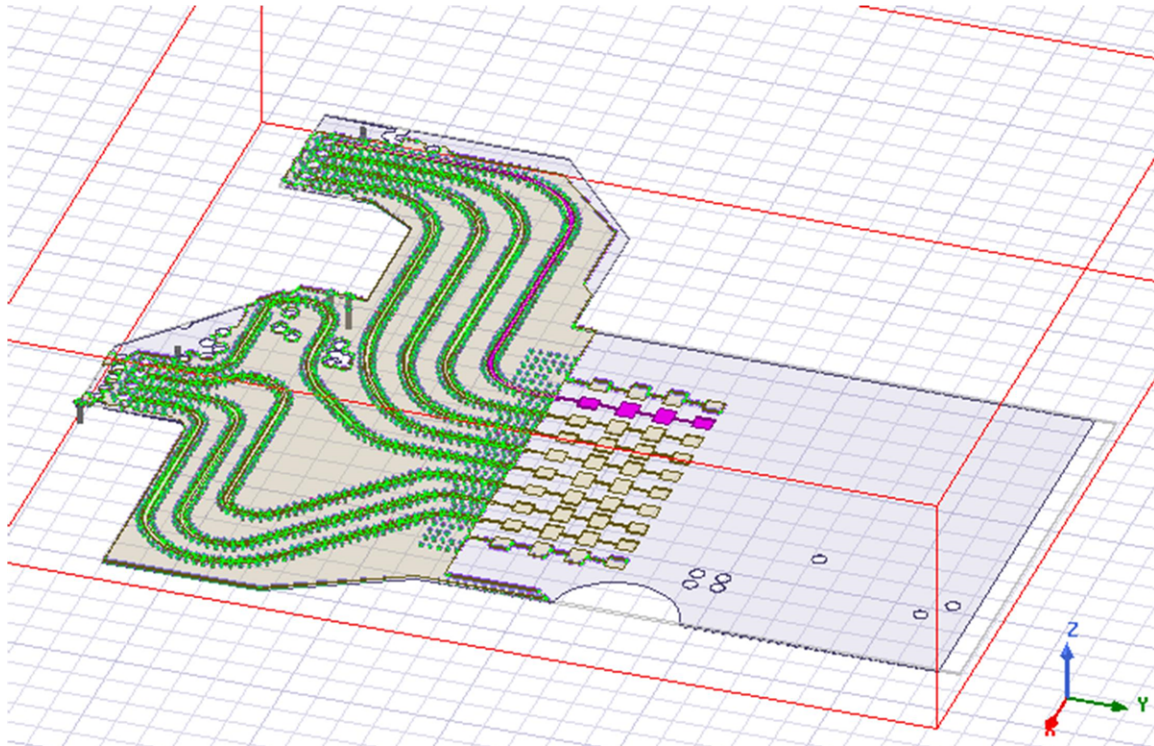
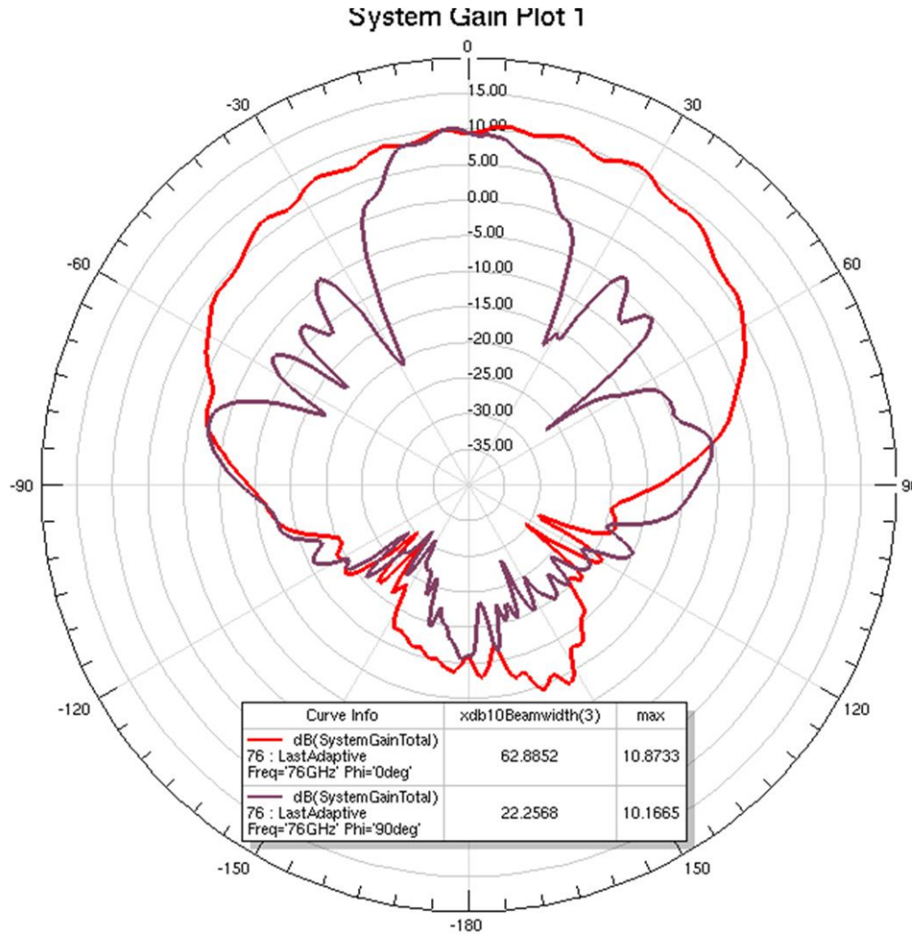


Figure 17. RX Array A Excerpt for Simulation (RX1 at the "top" of the image, RX8 at the "bottom" of the image. RX1 highlighted in purple.)



**Figure 18. RX Array A, RX1, 76 GHz Operation (Maximum E-plane (Phi = 90) and H-plane (Phi = 0) slices shown. 3dB beamwidths shown.)**

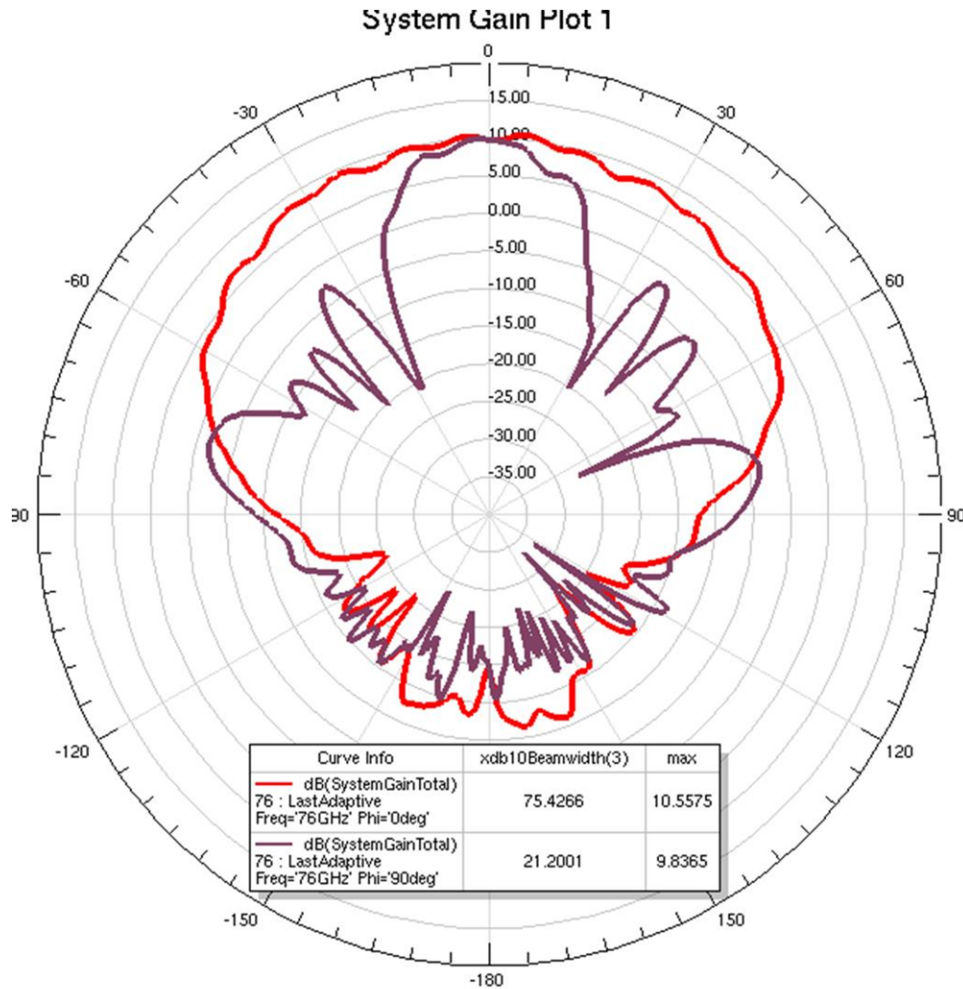


Figure 19. RX Array A, RX4, 76 GHz Operation (Maximum E-plane (Phi = 90) and H-plane (Phi = 0) slices shown. 3dB beamwidths shown.)

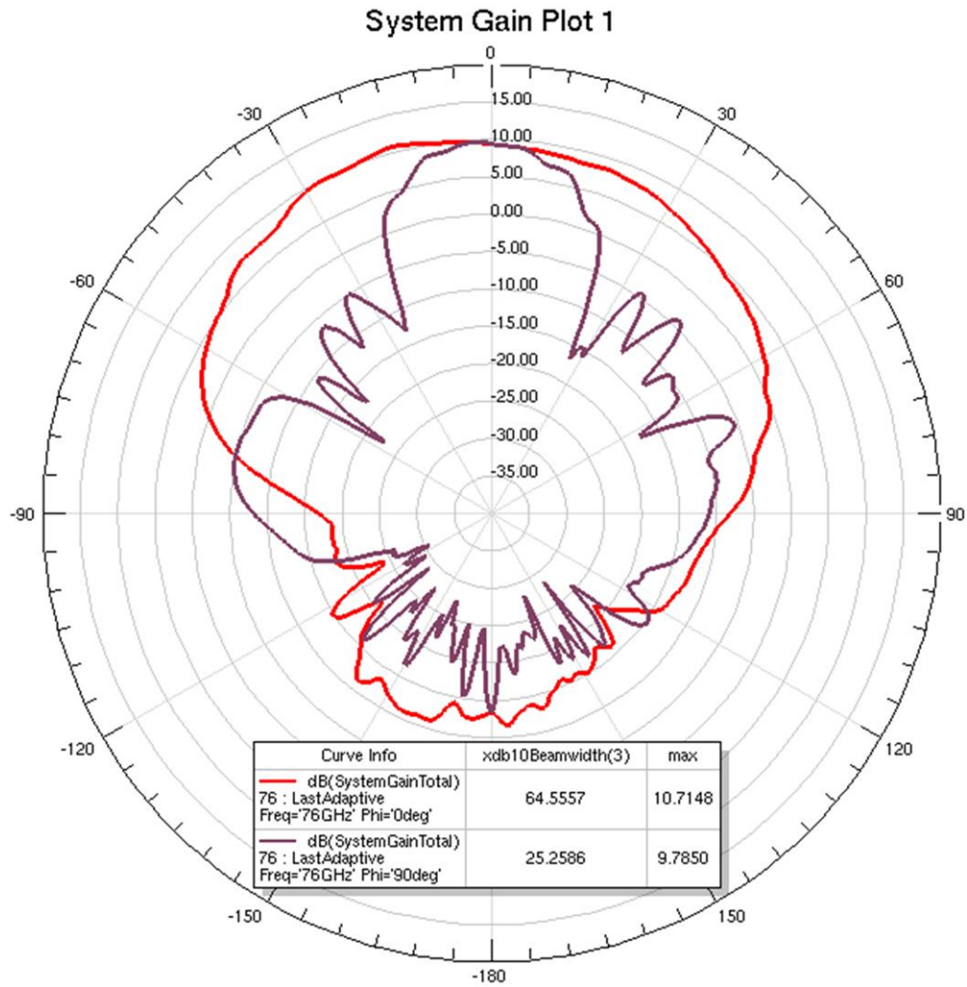


Figure 20. RX Array A, RX8, 76 GHz Operation (Maximum E-plane (Phi = 90) and H-plane (Phi = 0) slices shown. 3dB beamwidths shown.)



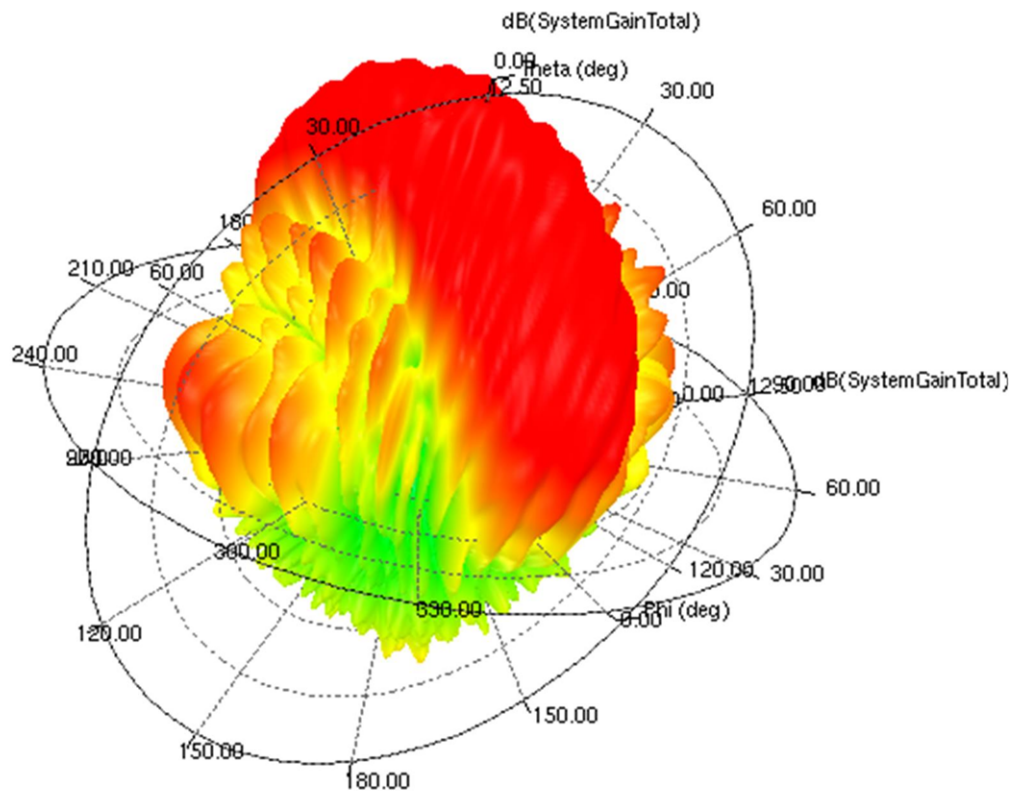


Figure 21. RX Array A, RX4, 76 GHz Operation (3D Antenna Gain Pattern)



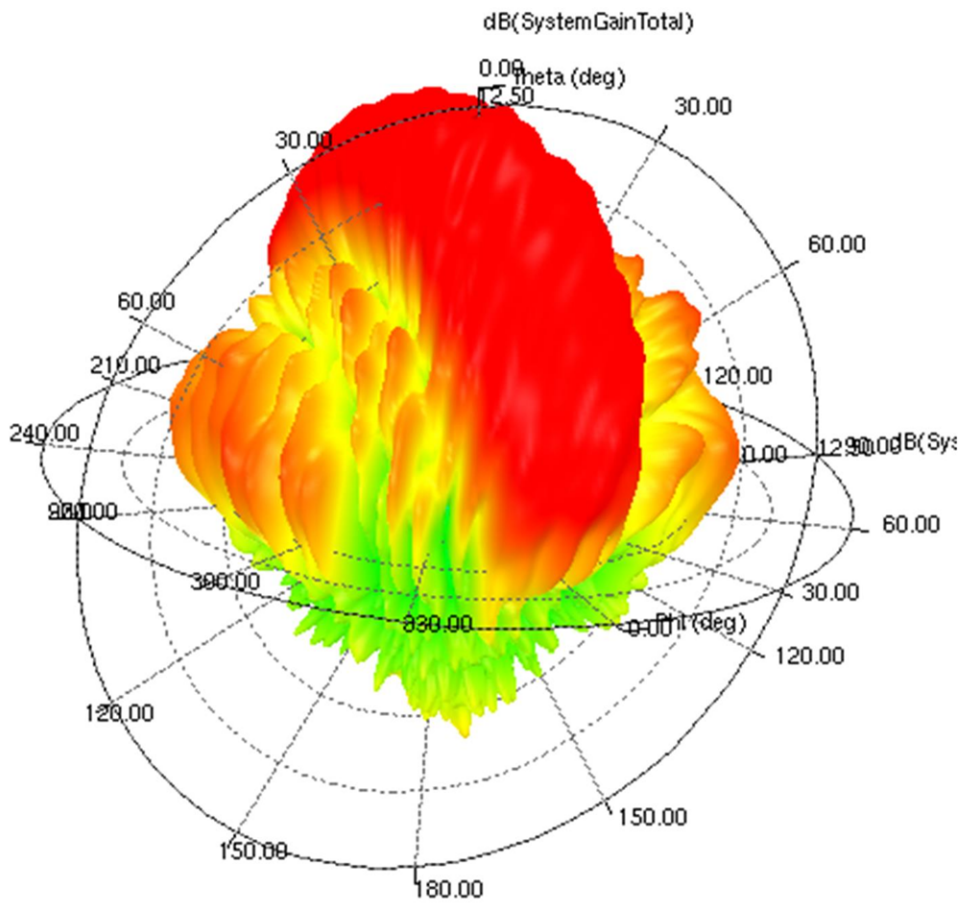


Figure 22. RX Array A, RX4, 78.5 GHz Operation (3D Antenna Gain Pattern)

### 2.6.2.2 TX Antenna Element Performance

Simulated TX antenna performance from center of the TX Array is shown below. Six different TX antenna were excerpted to show the overall performance across the array. These excerpted antenna are labeled TX1 and TX2. Like the RX antenna simulations, the TX selected here are meant to highlight the differences in performance between the more widely separated antenna and the more closely placed antenna.

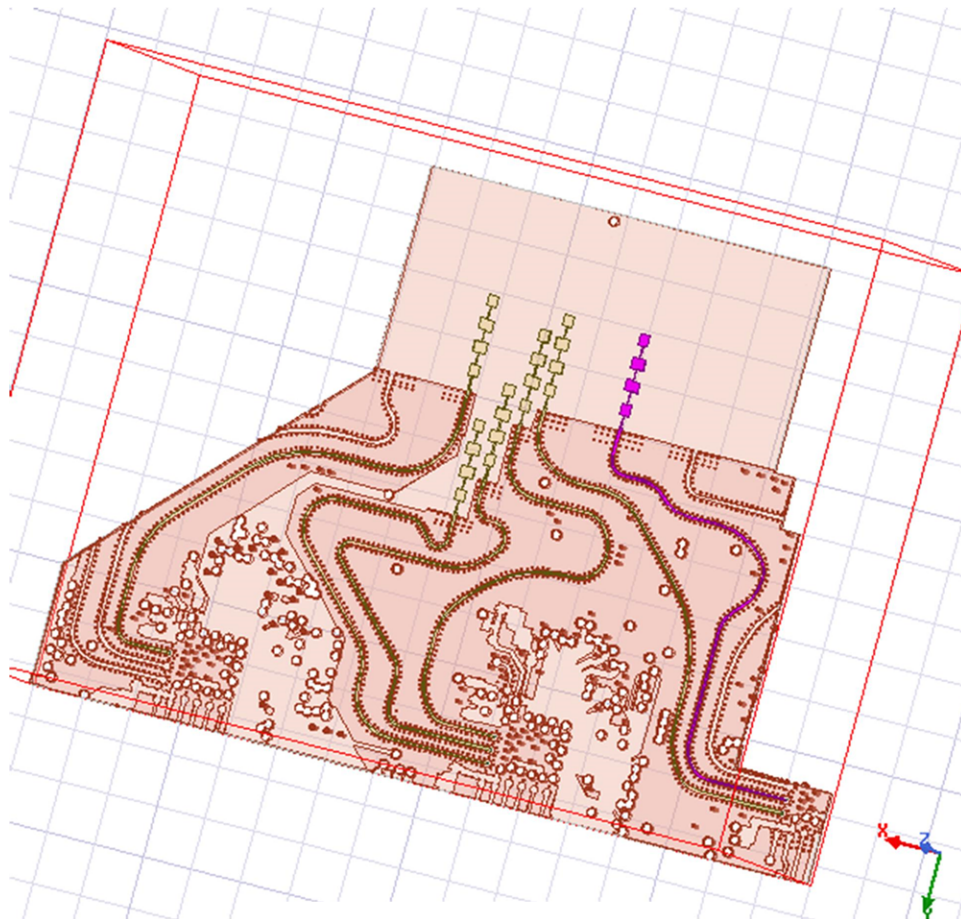


Figure 23. TX array Excerpt for Simulation (TX1 at the "right" of the image and TX2 adjacent to TX1 to the left. TX1 highlighted in purple.)

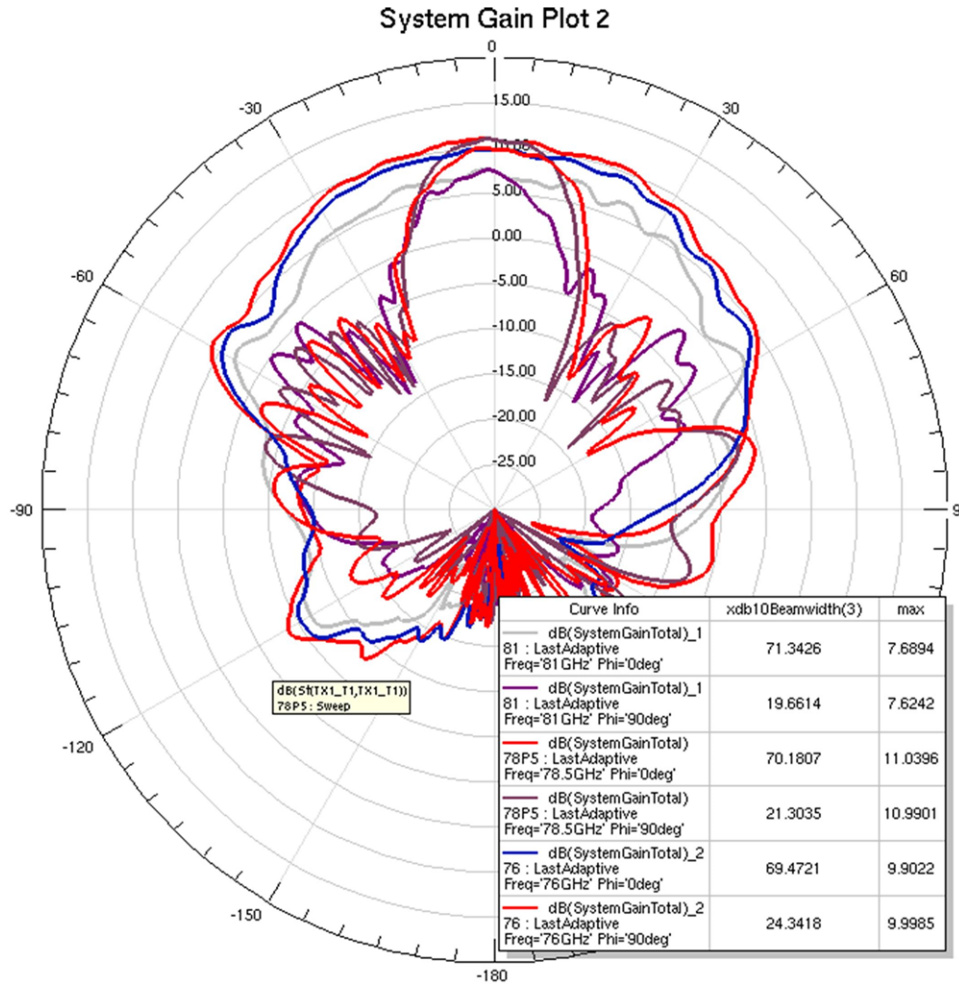
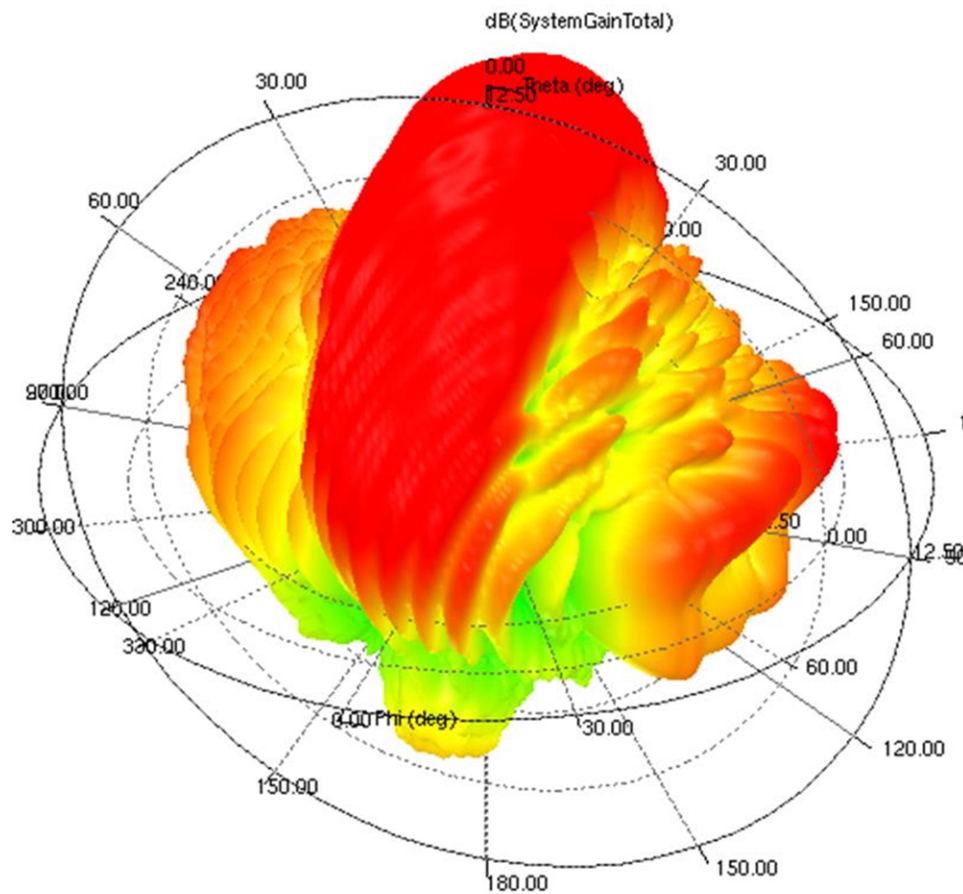


Figure 24. Combined TX Array TX1, TX2, 76 GHz, 78.5 GHz and 81 GHz Operation (Maximum E-plane (Phi = 90) and H-plane (Phi = 0) slices shown. 3dB beamwidths shown.)



**Figure 25. TX Array, TX2, 78.5 GHz Operation (3D Antenna Pattern)**

### 2.6.3 Virtual Antenna Array

The TX and RX antenna placement described above can be used to create a large, 192- element (12 TX x 16 RX) virtual antenna array. [Figure 26](#) and [Figure 27](#) describe the RX, TX and resulting combined virtual antenna array offsets in terms of lambda offsets. This information is useful when constructing a TX beam-form or MIMO AWR chirp, profile and framing scenario.

All antenna position offsets are in terms of lambda. Where lambda is the free-space wavelength at 78.5 GHz, or 153.56 mils. This lambda was chosen as a compromise between the AWRx RF lower 76 GHz, and higher 81 GHz range.

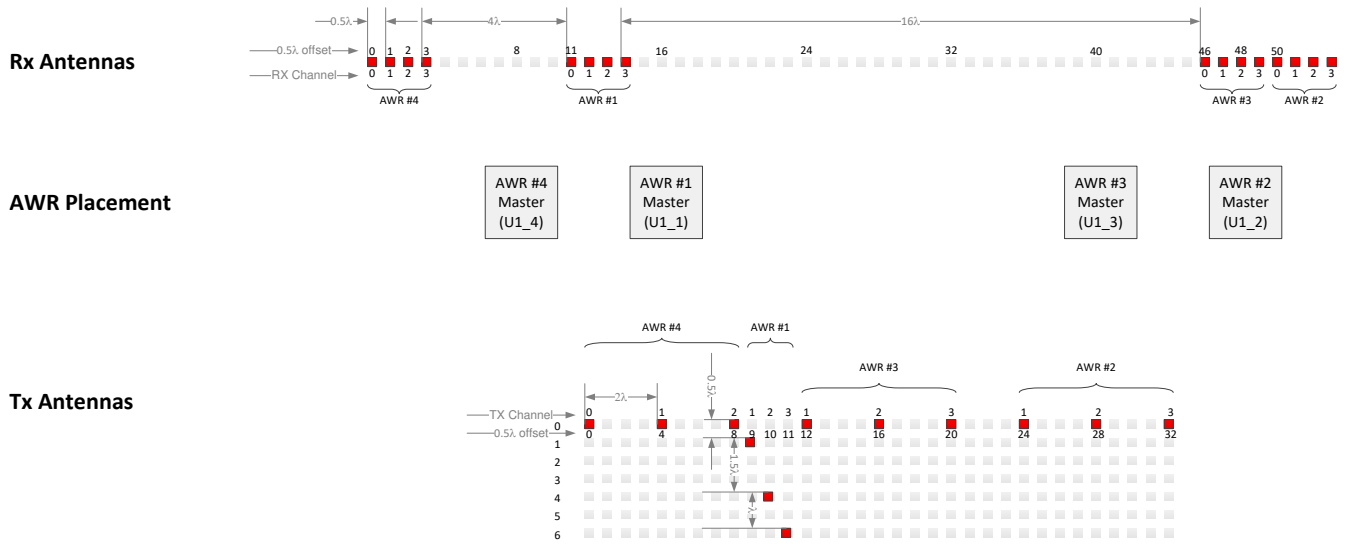


Figure 26. RX/TX Antenna Offsets

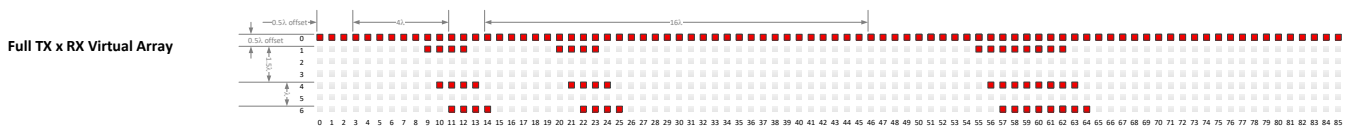


Figure 27. Resulting Virtual Antenna Array

## 3 Design Files and Software Tools

### 3.1 Hardware Collateral

All PCB design documents for the MMWCAS-RF-EVM are available on ti.com enabling AWRx users to fabricate, modify and extend the MMWCAS-RF-EVM to suite their own specific use-case requirements. This design was created with Altium Designer 18.

MMWCAS-RF-EVM Rev C Design:

- [MMWCAS-RF-EVMCAD Files Revision C](#)
- [MMWCAS-RF-EVMCAD Files Revision D](#)

### 3.2 Software, Development Tools, and Example Codes for MMWCAS-RF-EVM

The Cascade Radar kit belongs to a larger TI ecosystem of hardware and software tools.

To enable immediate evaluation of the Cascade Radar kit TI provides the mmWave Studio RF evaluation GUI and Lua scripting environment. This mmWave Studio tool interfaces to the MMWCAS-RF-EVM through the MMWCAS-DSP-EVM host board and masters the TDA2Sx host processor, enabling configuration, control and data capture of the AWRx devices on the MMWCAS-RF-EVM. mmWave Studio includes example single-device, multi-device MIMO and multi-device TX-beamforming configurations. Example capture Lua scripts are also included.

A Matlab code base for MIMO and TX-Beamforming post-processing and calibration has also been developed and included in mmWave Studio. This post-processing code is designed to work on the raw captured ADC samples and includes examples of basic 1D, 2D and 3D-FFT processing for creating range-doppler and point-cloud datasets from the MIMO and TX-Beamforming data.

To enable development of an end application with single-device and cascaded AWRx, TI provides the device firmware packages (DFP).

The DFP includes the MSS and BSS firmware, or firmware patches, as well as the mmWave Link Framework and framework implementation examples. The mmWave Link Framework provides a C-source implementation of the AWRx Interface Control Document (ICD) defined API.

Links:

- [MMWCAS-DSP-EVM](#)
- [mmWave Studio \(MMWAVE-STUDIO\)](#)
- [AWR1243 DFP \(MMWAVE-DFP\)](#)
- [RTOS Processor SDK for Radar](#)
- [PROCESSOR-SDK-VISION](#)



### 3.3 Critical AWRx Setup Notes

This section covers critical details concerning setup of the AWRx devices on the Cascade RF board.

#### 3.3.1 LDO Bypass Requirement

The MMWCAS-RF-EVM use a 1.0-V supply on the RF1 and RF2 power rails of each AWRx device. To support simultaneous, 3 TX operations, the VOUT\_PA output is shorted to the RF2 1.0 V power rail. For best performance and to prevent damage to the device, the on-die 1.3 V to 1.0 V LDO must be bypassed. This is done in a few different ways.

When using mmWave studio to configure the AWRx devices, select the 'RF LDO Bypass Enable' and 'PA LDO I/P Disable' options in the Static Configuration tab prior to RF initialization.

Likewise, when issuing DFP API commands to the device, the RF LDO bypass can be configured using the AWR\_RF\_LDO\_BYPASS\_SB API from the host processor. To enable the RF LDO Bypass and PA LDO I/P Disable through the API, issue an ar1.RfLdoBypassConfig(0x3) command.

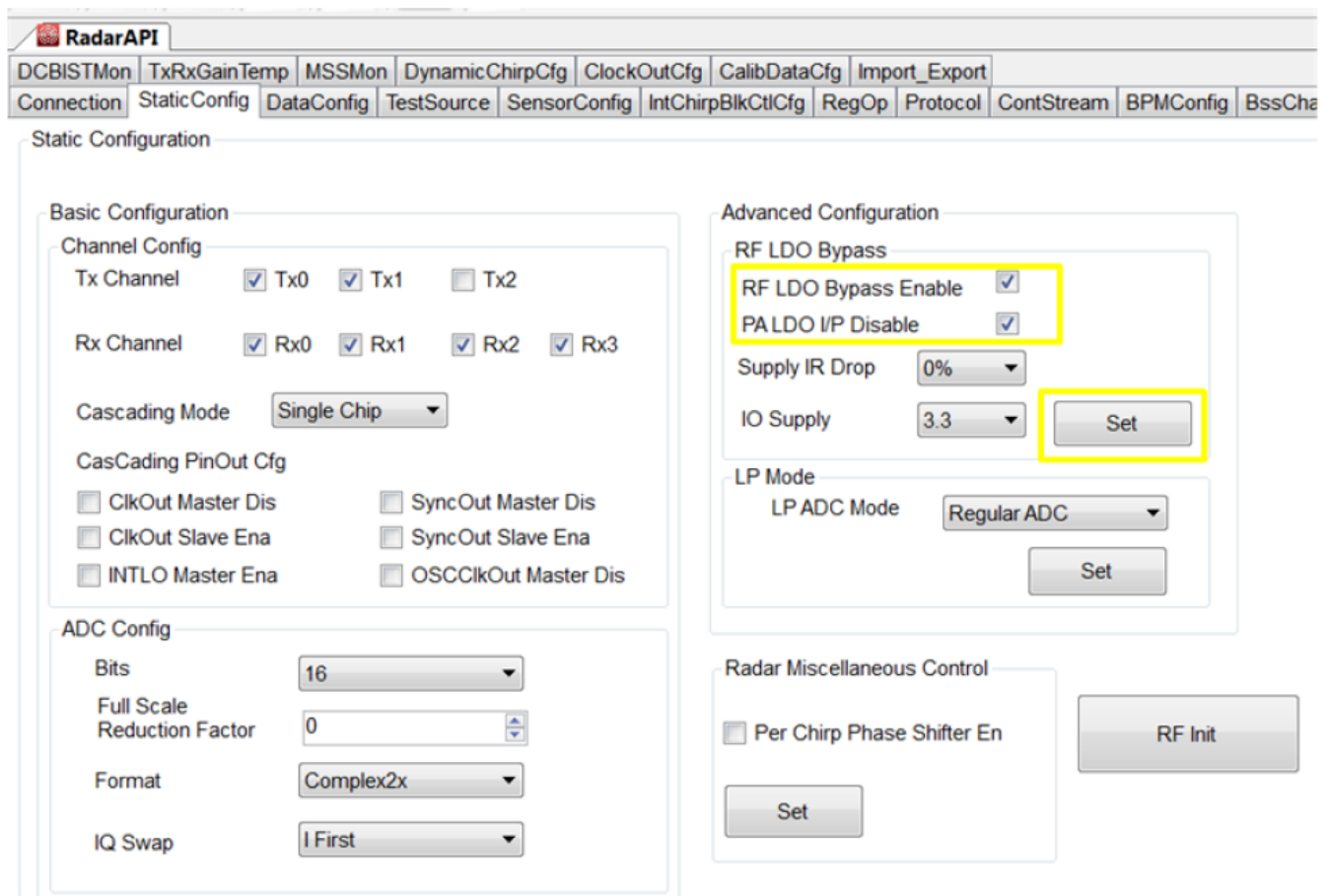
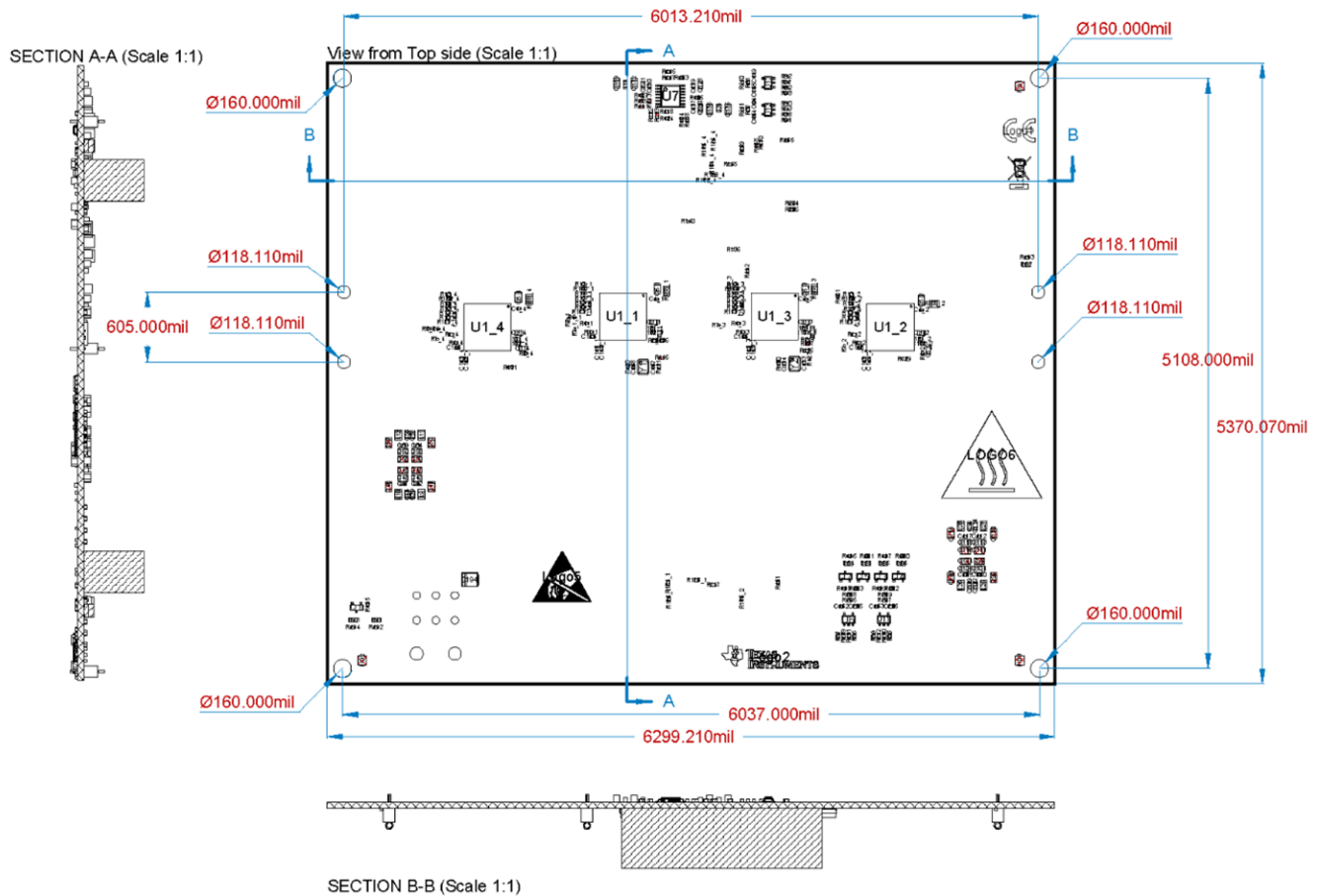


Figure 28. LDO Bypass Enable Options in mmWave Studio

#### 4 PCB Dimensions and Mounting Information

The field of view of the radar sensor is orthogonal to the PCB top layer where the etched antenna are placed. See the above antenna sections for more details on the antenna element gain patterns.

Mounting to the MMWCAS-DSP-EVM is accomplished through the 4, plated, through-holes in each corner of the PCB. An optional pattern of 4, plated through-hole are provided in the same lateral area as the AWRx devices and are meant to support a user-designed heat-sink plate across the AWRx packages.



**Figure 29. MMWCAS-RF-EVM Overall Mechanical Dimensions and Mounting Drill Dimensions**

The MMWCAS-RF-EVM PCB is composed of an 8-layer, heterogenous, sequential lamination, stack-up. Rogers RO3003 is used for the Layer 1 RF GCPW routing, etched antenna structures and the 20 GHz LO splitters. RO4450F prepreg and RO4835 LoPro are used to create Stripline routing on Layer 3 for 20 GHz LO distribution. The lower 4 core and prepreg layers are in Isola 370HR. These layers are dedicated to power distribution and high-speed digital routing.



**Figure 30. MMWCAS-RF-EVM PCB and Drill Stack-Up Table**

Three via types are utilized throughout the design:

- L1-L8, 12.2mil drill, 22.4 mil pad - primary via used throughout the design for power and high-speed digital routing
- L1-L2, 5.9 mil drill, 13.77 mil pad (blind, micro-via) - L1 to L2 ground plane shorting for RF and LO routing distribution
- L1-L3, 12 mil drill, 24 mil pad, (backdrilled up to L3) - 20 GHz LO distribution L1 GCPW to L3 Stripline transition

## 5 PCB Storage and Handling Recommendations

All of the 77-81GHz RF and 20 GHz LO transmission-line and antenna structures on this design have been left exposed on the top soldermask layer. An immersion silver finish is applied to these solder-mask free regions to protect the underlying copper. The immersion silver finish provides the RF structures with a more simple and controlled high-frequency finish compared to solder mask.

However, the immersion silver finish is also prone to oxidation in an open atmosphere environment. This oxidation causes the surface around the antenna region to blacken or tarnish as a layer of silver-oxide forms. To avoid this effect, store the PCB in an ESD cover and keep it at controlled room temperature with low humidity conditions. It should be noted though that transmission lines and antenna which are tarnished will not experience RF performance degradation.

All ESD precautions must be taken while using and handling the EVM.

## 6 References

- Texas Instruments: [AWR2243 Cascade](#)
- Texas Instruments: [MMWCAS-RF-EVMCAD Files Revision C](#)
- Texas Instruments: [MMWCAS-RF-EVMCAD Files Revision D](#)

## 7 Regulatory Information

No additional regulatory information is available for the MMWCAS-RF-EVM.

## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Original (September 2019) to A Revision</b>	<b>Page</b>
• Title of the document was updated. ....	4
• Added new <a href="#">Section 1.2</a> . ....	4
• Updates were made in <a href="#">Section 2</a> . ....	6
• Update was made in <a href="#">Section 2.1</a> . ....	8
• Updates were made in <a href="#">Section 2.5.1</a> . ....	13
• Added new <a href="#">Section 2.6.3</a> . ....	36

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