FE5NA0020
5G NAD Module

OEM Manual and User Guide v3

(For Use during Certification)

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Terms and Acronyms

- BB Baseband
- DCM Data Connectivity Module (also, "TCU")
- DRX Discontinuous Reception
- EN-DC **E**-UTRAN **N**ew Radio – **D**ual **C**onnectivity (LTE and NR simultaneously)
- ES Engineering Sample
- FDD Frequency Division Duplex
- GLONASS GLObalnaya NAvigatsionnaya Sputnikovaya Sistema
- GNSS Global Navigation Satellite System
- GPIO General Purpose Input Output
- GSM Global System for Mobile
- HSIC High Speed Inter-Chip
- HU Head Unit
- LTE Long Term Evolution
- MP Mass Production
- NAD Network Access Device
- OEM Original Equipment Manufacturer
- PCB Printed Circuit Board
- PCIe Peripheral Component Interconnect Express
- PHY Physical Layer
- PMIC Power Management IC
- SIM Subscriber Identity Module
- SoC System-On-a-Chip (refers to the Qualcomm SA515M IC)
- TCU Telematics Control Unit (also, "DCM")
- TDD Time Division Duplex
- TSP Telematics Service Provider
- UMTS Universal Mobile Telecommunication System
- WCDMA Wideband Code Division Multiple Access

5G NAD Module

1 5G NAD Module

The 5G NAD Module incorporates 5G New Radio technology with 4x4 MIMO Antenna technology. The NAD is part of a family of proprietary embedded 5G wireless modules designed by Continental Automotive Systems, Inc. The modules are intended to be integrated into Data Connectivity Modules (DCMs) or Head Units (HUs) designed and produced by Continental or by a 3rd party for use by automotive OEMs. DCMs will be installed into vehicles during the OEM's factory assembly process and will not be accessible without use of special tools. Primary use-cases are data-centric with data and voice connections to Telematics Service Providers (TSP).

1.1 Key Features

1.1.1 Air Interface Support

- 5G NR: 3GPP Release 15
- Sub-6 Ghz 5G NR bands, including n77, n78
- LTE FDD/TDD: 3GPP Rel. 15 Category 19
- LTE UL CA 2 CC (intraband)
- UMTS: HSUPA CAT6
- GSM: EGPRS Rel-12
- C-V2x, CDD supported
- VoLTE – HD Voice
- Embedded Qualcomm GNSS Sub-system
- High Precision L1/L5 GNSS supporting:
    - L1 Frequency: BDS, Galileo, GLONASS, GPS and SBAS
    - L5 Frequency: Galileo and GPS
- SBAS supported: EGNOS/MSAS/QZSS/WAAS/GAGAN

1.2 Package

- 725-pin LGA module of size 52 x 52 x 3.1 mm

1.3 Band Configurations Supported

Table 1-1 FE5NA0020 Band Support

Model	Region	5G NR Bands	LTE Bands (FDD + TDD)	C-V2X Bands	UMTS Bands	GSM	GNSS
FE5NA0020	NA	n2, n5, n7, n41, n66, n71, n77, n78	1, 2, 3, 4, 5, 7, 12, 13, 14, 17, 25, 26, 29Rx, 30Rx, 41, 66, 71	---	1, 2, 3, 4, 5, 6	2, 3, 5, 8	L1, L5

2 Regulatory Compliance Notes

2.1 Regulatory Compliance Notes

2.1.1 FCC:

This device complies with Part 15, Part 22(H), Part 24(E) Part 27 and Part 96 of the FCC Rules. The FCC ID for this device is LHJ-FE5NA0020. Operation is subject to the following two conditions:

1. This device may not cause harmful interference.
2. This device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, the user is encouraged to try to contact the dealer or an experienced technician for help.

2.1.2 Industry of Canada:

This device contains license-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's license-exempt RSS(s). Operation is subject to the following two conditions: (1) This device may not cause interference. (2) This device must accept any interference, including interference that may cause undesired operation of the device.

L'émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) L'appareil ne doit pas produire de brouillage; (2) L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

This device and its antenna(s) must not be co-located or operating in conjunction with any other antenna or transmitter, except in accordance with FCC/ISED multi-transmitter product procedures.

Cet appareil et son antenne ne doivent pas être situés ou fonctionner en conjonction avec une autre antenne ou un autre émetteur, sauf conformément aux procédures de produits multi-émetteurs FCC/ISED.

Radiation Exposure Statement:

This equipment complies with IC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20cm between the radiator & your body. Additional testing and certification for SAR will be required if the distance limitation cannot be met.

Déclaration d'exposition aux radiations:

Cet équipement est conforme aux limites d'exposition aux rayonnements IC établies pour un environnement non contrôlé. Cet équipement doit être installé et utilisé avec un minimum de 20 cm de distance entre la

source de rayonnement et votre corps. Des tests et une certification supplémentaires pour le SAR seront requis si la limitation de distance ne peut pas être respectée.

2.2 Device Installation and User Manual

The FE5NA0020 module is a proprietary product designed and manufactured by Continental Automotive Systems, Inc. for integration into Telematics control units manufactured by Continental Automotive Systems, Inc. for automotive OEMs.

i. The module is limited to installation ONLY in an integrated device manufactured by Continental Automotive Systems, Inc.
ii. During manufacturing process of the integrated device, the module is soldered onto the PCB of the integrated device.
iii. The integrated device must provide RF connectors to external antennas or RF traces to connect the FE5NA0020 modules to antennas inside the integrated device. The typical reference design for the RF trace layout, including PCB stack-up and trace length is described in Section 9 of this document.
iv. Automotive OEM is responsible for ensuring that the end-user has no manual instructions to remove or install module.
v. The module is limited to installation in mobile applications, according to Part 2.1091(b).
vi. No other operation configurations are allowed.
vii. Changes or modifications to this system by other than a facility authorized by Continental could void authorization to use this equipment.
viii. The module does not have a pre-defined antenna. The module must be installed to provide a separation distance of at least 20 cm from all persons and antenna. Under No conditions may an antenna gain be used that would exceed the ERP and EIRP power limit as specified in Part 22, Part 24, Part 27 and Part 96.
ix. The module must be installed to provide a separation distance of at least 20 cm from all persons and antenna and must not be co-located or operate in conjunction with any other antenna or transmitter, except in accordance with FCC multi-transmitter evaluation procedures as documented in this filing. Additional testing and certification for SAR will be required if the distance limitation cannot be met.
x. The integrator is responsible for fulfilling FCC and IC requirements for the integrated device. The module must be installed to provide a separation distance of at least 20 cm from all persons and antenna. SAR is related to the final product's implementation and should be assessed based on its proximity to human body.

If Continental chooses to re-use modular approval, then the TCU shall be clearly labeled with an external label containing the integrated modem's FCC ID. For example, the label can include text "Contains device with FCC ID: LHJ-FE5NA0020 and IC: 2807E-FE5NA0020".

2.3 Instructions to OEMs:

Continental must instruct the automotive OEM and provide them to include the following information into the car user's manual (i.e. for the DCM):

1. End-users must be provided with transmitter/antenna installation requirements and operating conditions for satisfying RF exposure compliance:
2. A separate section should clearly state “FCC RF Exposure requirements:”
3. Required operating conditions for end users.
4. The antenna used with this device must be installed to provide a separation distance of at least 20cm from all persons, and must not transmit simultaneously with any other transmitter, except in accordance with FCC/ISED multi-transmitter product procedures. Additional testing and certification for SAR will be required if the distance limitation cannot be met.
5. The Maximum ERP/EIRP and maximum antenna gain required for compliance with Parts 15, 22H, 24E, 27, and 96.
6. Clear instructions describing the other party’s responsibility to obtain station licensing.

Antenna requirements for use with FE5NA0020 module:

The module must be installed to provide a separation distance of at least 20cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter. Additional testing and certification for SAR will be required if the distance limitation cannot be met.

The FE5NA0020 module does not contain internal antennas and external antenna must be provided by the integrator or OEM. Based on FCC OET Bulletin 65 Supplement C and 47 CRF §2.1091 and on RSS-102 Issue 5, for all standalone NR/LTE/WCDMA/GSM operations the maximum antenna gain including cable loss shall not exceed the following values:

- GSM850: 6.6 dBi
- GSM900: 10.5 dBi
- GSM1800: 8.5 dBi
- GSM1900: 11.5 dBi
- UMTS Band 1: 9.0 dBi
- UMTS Band 2: 8.5 dBi
- UMTS Band 3: 8.5 dBi
- UMTS Band 4: 6.0 dBi
- UMTS Band 5: 7.1 dBi
- UMTS Band 6: 10.4 dBi
- LTE Band 1: 9.0 dBi
- LTE Band 2: 9.0 dBi
- LTE Band 3: 8.5 dBi
- LTE Band 4: 6.0 dBi
- LTE Band 5: 7.1 dBi
- LTE Band 7: 9.0 dBi
- LTE Band 12: 6.6 dBi
- LTE Band 13: 6.9 dBi
- LTE Band 14: 6.9 dBi
- LTE Band 17: 6.6 dBi
- LTE Band 25: 9.0 dBi
- LTE Band 26: 7.1 dBi
- LTE Band 41: 6.0 dBi
- LTE Band 66: 6.0 dBi

- LTE Band 71: 6.4 dBi
- NR Band n2: 9.0 dBi
- NR Band n5: 7.1 dBi
- NR Band n7: 9.0 dBi
- NR Band n41: 6.0 dBi
- NR Band n66: 6.0 dBi
- NR Band n71: 6.4 dBi
- NR Band n77: 3.0 dBi
- NR Band n78: 0.0 dBi

Material Statement:

The End of Life Vehicle Directive (EVL) must be applied to the FE5NA0020 module. This means that the component is included into the overall vehicle (since it is permanently installed) and if the explanation of the materials used and, if applicable, disposal descriptions from the vehicle manufacturer.

3 Recommended NAD Interfaces

Integrators are strongly recommended to provide access to the following NAD communication ports to be used for debugging, certification, or other developmental activity.

- HS-USB 2.0
- 2-wire UART
- JTAG
- **RF Ports:** If any on-board antennas are used by the product, provisions should be made to support conducted RF measurements on all antenna interfaces
- **SIM Interface:** Electrical performance of the SIM interface is always evaluated during certification testing of the final product. Product teams should insure that the SIM interface can be accessed for testing without degrading its integrity.

4 Example of NAD Module Label

Figure 4-1: Module Label Example

Type Name	Characters	Content
Conti SAP No.	13	TRC000xxxxxxx
CERT Model	10	FE5xxxxxxx
Date Code	6	XXXXXX
HW Version	2	P4.1
Serial No.	15	XXXXXXXXXXXXXXX
Decimal IMEI	15	XXXXXXXXXXXXXXX

Table 4-2 Conti QR Code Content

5 NAD Module RF Characteristics

All RF parameters are referenced at the antenna terminals *of the NAD*. The RF performance of the host device (i.e. TCU) can differ depending on the additional line losses – as well as the impedance match – presented to each of the NAD's antenna terminals.

5.1.1 NAD Module RF Transmitter Output Power

The Transmitter Power at the NAD antenna terminal (not the RF connector of the evaluation board or the Telematics/host module) at Room Temperature:

- GSM low bands (850/900): +32.5 dBm +1.0/-2.0 dB
- GSM hi bands (1800/1900): +29.5 dBm +1.0/-2.0 dB
- EDGE low bands (850/900): +26.5 dBm +1.0/-2.0 dB
- EDGE hi bands (1800/1900): +25.5 dBm +1.0/-2.0 dB
- WCDMA bands: + 23.0 dBm to +1.0/-2.0 dB
- LTE bands: +23 dBm +1.0/-2.0 dB
- LTE B41 HPUE: +26 dBm +1.0/-2.0 dB
- 5G NR FDD bands and n78: +23 dBm +1.0/-2.0 dB
- 5G TDD HPUE bands n41 and n77: +26 dBm +1.0/-2.0

Allowance for reduction in maximum transmitter power is specified in the 3GPP standard for GPRS multi-slot operation. Per 3GPP TS 05.05, the following Maximum Output Power Reduction will be taken during Multi-slot GPRS operation (MSPP = 0):

- 0 dB back -off for 1TX slot
- 3 dB back-off for 2TX slots
- 4.5 dB back-off for 3TX slots
- 6 dB back-off for 4TX slots

Per 3GPP TS 05.05, the following Maximum Output Power Reduction will be taken during Multi-slot EDGE operation (MSPP = 0):

- 0 dB back -off for 1TX slot
- 2.0 dB back-off for 2TX slots
- 3.0 dB back-off for 3TX slots
- 4.0 dB back-off for 4TX slots

5.1.2 NAD Module RF Receiver Sensitivity

The Receiver Sensitivity at the NAD antenna terminal (not the RF connector of the evaluation board or the Telematics/host module) at Room Temperature:

- GSM low bands (800/900): 3GPP TS 51.010-1 Section 14.2
- WCDMA bands: 3GPP TS 34.121-1 Section 6.2
- LTE bands: 3GPP TS GPP 36.521 Section 7.3
- 5G NR bands: 3GPP TS GPP 38.521 Section 7.3
- GNSS bands: -163 dBm (in Out-Of-Service mode)

6 Mechanical Information

6.1 Module Exploded View

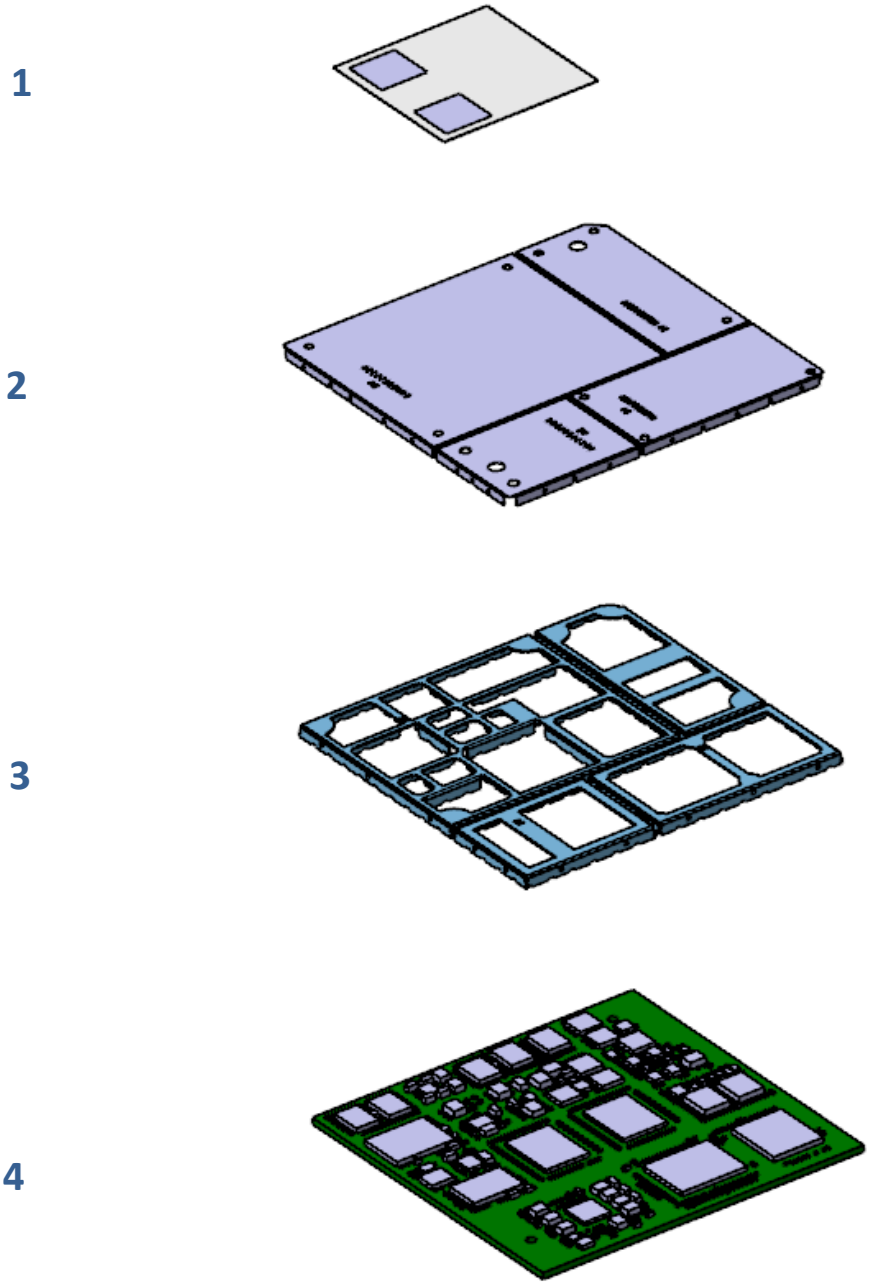

Figure 6-1: Module Exploded View

- 1: Label
- 2: Shield Cover(s)
- 3: Shield Frame
- 4: PCB Assembly

6.2 Module Top View

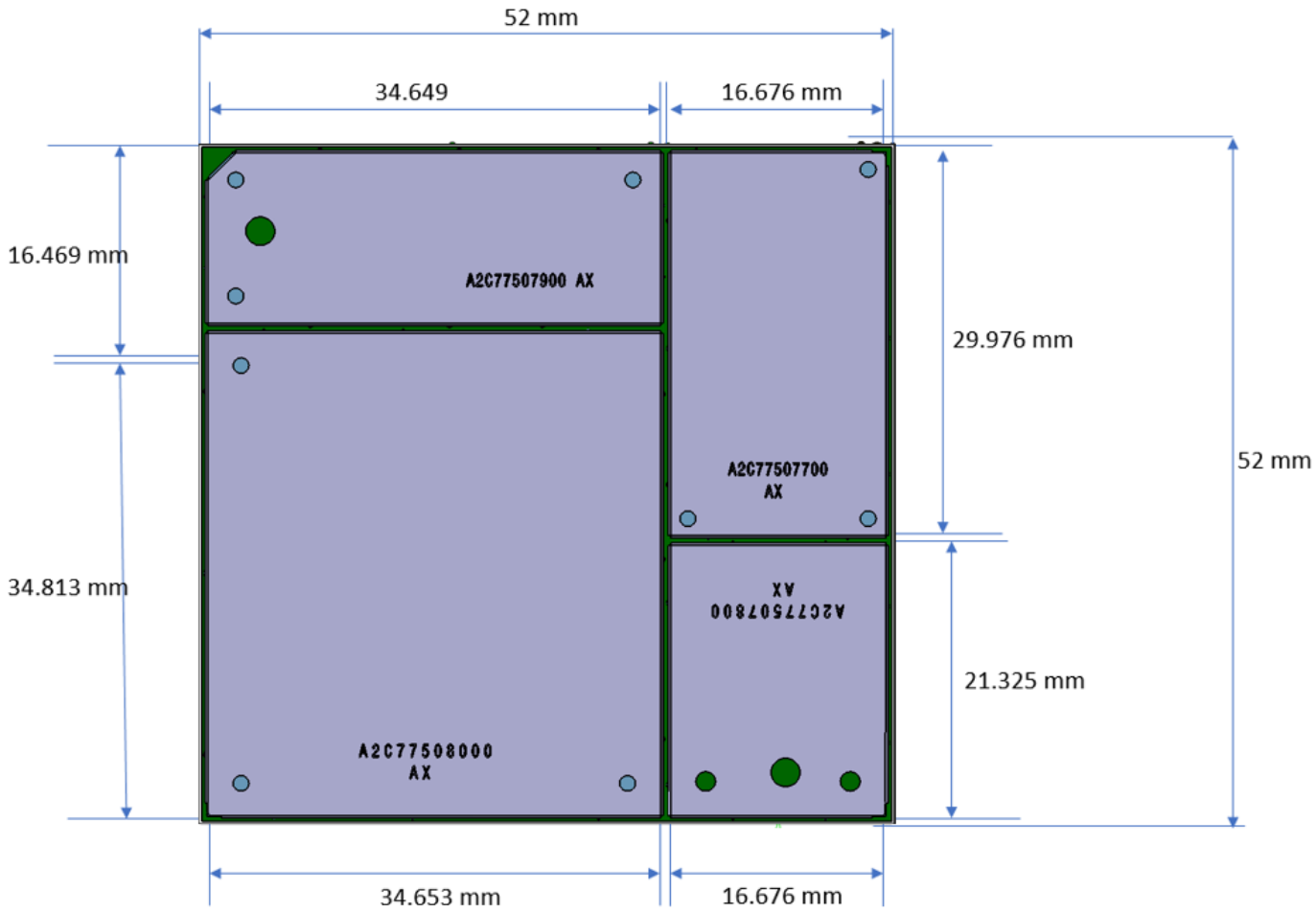

Figure 6-2: Module Top View

All dimensions are in mm.

6.3 Module Side View

Figure 6-3 Module Side View

7 Storage and Handling

7.1 Moisture Sensitivity Level (MSL)

All NAD modules are moisture sensitive and should be kept in their sealed moisture resistant bags until ready for assembly onto the DCM via the soldering process. Any parts that are not used immediately should be properly resealed in the same moisture resistant bag using appropriate equipment or placed into a dry box until they are needed again. The moisture sensitivity level (MSL) shown below is the amount of time the NAD modules may be exposed before this action must be taken. If the allowed MSL time elapses, the NAD modules must be baked per standard protocol to remove moisture.

Moisture Sensitivity Level: MSL Level 3 (1 Week)

This remainder of this section will be completed in a future release of this document.

8 Part Reliability

This section will be completed in a future release of this document.

9 Layout and Routing Recommendations

9.1 ANTENNAS

The NAD has eight antenna pins.

- **LTE/5G NR**: LTE_ANT_1 – LTE_ANT_4
- **GNSS**: GNSS_ANT_1, GNSS_ANT_2

9.1.1 NAD Antenna Breakout

The 5G NAD should be oriented on the main board to minimize the length of the primary Cellular TX/RX antenna (ANT1). This 50ohm line should be as short as possible to the external RF connector or internal antenna feed point.

The RF traces on the main board connecting from the NAD antenna pins can be either stripline or microstrip, but the microstrip routing must be on the layer opposite from the NAD, since the bottom layer of the NAD will be mostly ground and it would become a near RF short to any trace that runs on the main board's top layer, while still underneath the NAD. For a given line length, the stripline approach will tend to be more lossy, so it is generally not recommended. Thus, microstrip antenna lines are favored in most cases.

9.1.1.1 NAD Antenna Pad Ground Cutout

It is likely that the host device's PCB will use only thru-hole vias, and so the antenna pads on the host PCB may need to be offset slightly from their vias for manufacturability reasons. The NAD bottom layers have been designed to accomodate this need, and ground cutout in these layers has been extended to avoid shorting to those vias on the host PCB's top layer, where it mates with the NAD. Figure 9-3 details the ground cutout provided on the bottom six layers of the NAD. The PCB of the host device should utilize this cutout area for placement of any thru vias which serve the antenna pads:

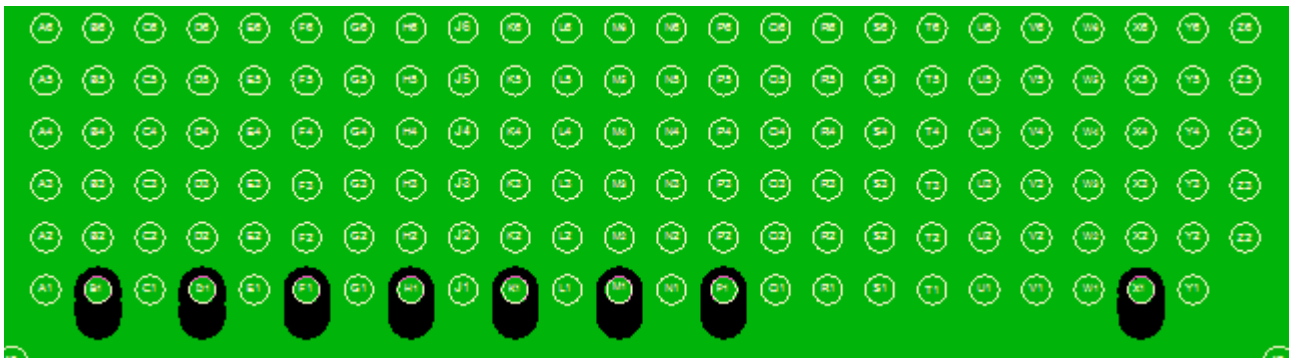

Figure 9-1: Antenna Pad Ground Cutouts (NAD bottom layer)

Figure 9-4 provides a more detailed view of the cutout around each antenna pad on the NAD PCB.

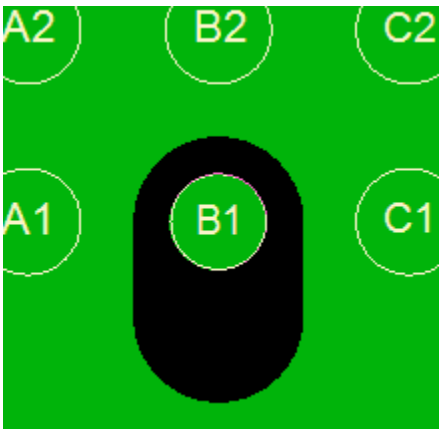

Figure 9-2 Antenna Pad Ground Cutout x8 (detail view)

9.1.1.2 Host PCB Antenna Pad Design Recommendation

The main board on which the 5G NAD will be mounted should have ground cut out under the RF antenna pins of the NAD as shown in Figure 9-3 and Figure 9-4:

Figure 9-3: Antenna Pad Ground Cutout Recommended (Main Board, top layer/NAD side)

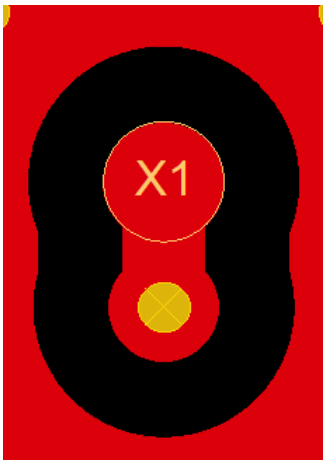

Figure 9-4 Antenna Pad Ground Cutout x8 (detail view)

The dimensions of the RF trace on the Main Board will be dependent on the layer stack-up of the board, their thicknesses and how many layers are used. As an example, the main PCB shown in Figure 9-5 is a 6 layer stack up with ***Ground cut out on layer 5*** so the microstrip lines on the bottom (layer 6) ***reference Ground on layer 4***. For this example, the dielectric thickness from L6 to L4 is 21.2 mils.

			Thickness in microns	Tolerance in microns	Thickness in mils
	Solder Mask		30 micron	+11 micron	1.17 mil
Plated 0.5oz Cu	ML1		49 micron	+/-10 micron	1.91 mil
7628 x 1+1080 x 1 Prepreg	DL1		253 micron	+/-38 micron	9.88 mil
1oz Cu	ML2		36 micron	+/-10 micron	1.41 mil
2116 x 2 Core	DL2		254 micron	+/-38 micron	9.92 mil
1oz Cu	ML3		36 micron	+/-10 micron	1.41 mil
2165 x 2 Prepreg	DL3		277 micron	+/-38 micron	10.82 mil
1oz Cu	ML4		36 micron	+/-10 micron	1.41 mil
2116 x 2 Core	DL4		254 micron	+/-38 micron	9.92 mil
1oz Cu	ML5		36 micron	+/-10 micron	1.41 mil
7628 x 1+1080 x 1 Prepreg	DL5		253 micron	+/-38 micron	9.88 mil
Plated 0.5oz Cu	ML6		49 micron	+/-10 micron	1.91 mil
	Solder Mask		30 micron	+11 micron	1.17 mil
		Total board thickness:	1593 micron	+272 mu -250 mu	62.23 mil

Figure 9-5: Recommended PCB Stack-up

Using any common microstrip impedance calculation tool, the result for a 50-ohm microstrip line (in typical dielectric constant of 4.3) with the height in the above example yields a width [w] of 37.7mils (967micron).

The line width will of course vary, particularly depending on the stack up and use of layers on the main board. In the end, the characteristics of the RF traces connecting to the NAD on the main board should remain within the guidelines of Table 9-1.

Table 9-1: RF Antenna Layout Parameters

Type of Guidance	Requirement
Trace impedance	50±10% Ohms, single-ended

Total route length	< 100 mm
Ground between signals	> 1 x [RF line width] with stitched VIA to ground layer
Spacing to other signals	> 3 times RF line width, to any non-RF traces
VSWR for Cellular Antenna ports	< 3:1

- Trace impedances apply to either microstrip or stripline.
- Length for all antenna traces should be kept to a minimum, with priority on cellular antenna 1.

9.1.2 Integrated Device RF Insertion Loss

The integrated device TX and RX performance must comply with 3GPP and MNO RF requirements at the RF connectors. In addition, in some use cases, such as on-board antenna, TRP and TIS performance requirements must be met. It is a Product Team's responsibility to insure the integrated device complies with these requirements.

The Insertion Loss between NAD's RF and the host module antenna terminal (RF connector of the evaluation board or the Telematics/host module) must be kept at minimum and not to exceed these values:

- RF Loss < 0.6dB from 700 - 1000MHz
- RF Loss < 1.2dB from 1.7 - 2.7GHz
- RF Loss < 2.0dB from 2.7 – 6.0GHz

9.2 SDC / eMMC Routing

Table 9-2: SDC / eMMC Layout Parameters

Type of Guidance	Requirement
Trace impedance	50-Ohms ± 10% single-ended
Total route length	< 50-mm recommended, but 75-mm is acceptable
Trace matching (SDC application)	< 1.6-mm
Trace matching (eMMC application)	< 5 - mm
Trace spacing	> 0.508-mm / > 20-mils
Number of vias per trace	< 5
Spacing to other signals	>= 2 times line width

- Trace impedances should follow table, either as microstrip or stripline.
- Trace lengths should follow table.
- Number of vias per trace should follow table.
- No stubs allowed on traces.
- No test points allowed on traces.
- Trace lengths should follow table.
- Spacing to ground or other signals on outside of bundled signals should follow table.