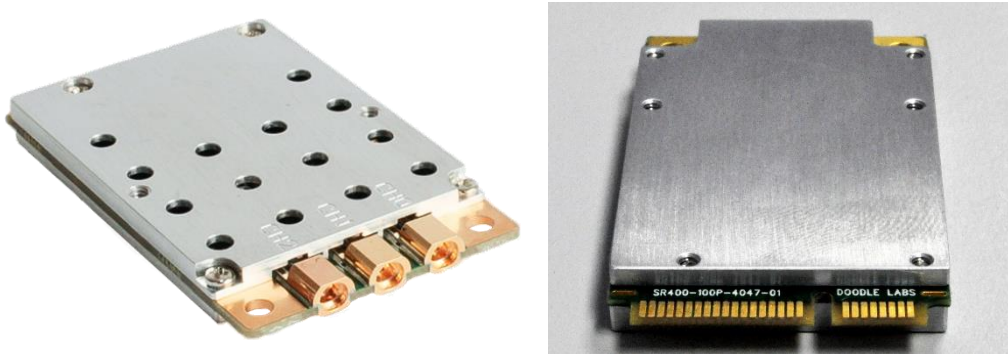


Doodle Labs NM-DB-2M Industrial Wi-Fi® Radio Transceiver

Product Family Overview

Doodle Labs' portfolio of Industrial Wi-Fi transceivers offer the industry's best-in-class performance. These transceivers have high transmit power for long-range communication and has been designed to withstand operation in extremely challenging environments. In addition, these transceivers feature high interference immunity that allows successful operation in today's congested Wi-Fi environments. The transceivers are FCC, CE, and IC certified and have been deployed in numerous demanding applications.

Figure 1. Top and bottom views of the NM-DB-2M transceiver with MMCX connectors.



Target Applications

The Doodle Labs Industrial Wi-Fi transceivers meet the demanding needs of customers across a broad range of industries. Examples include:

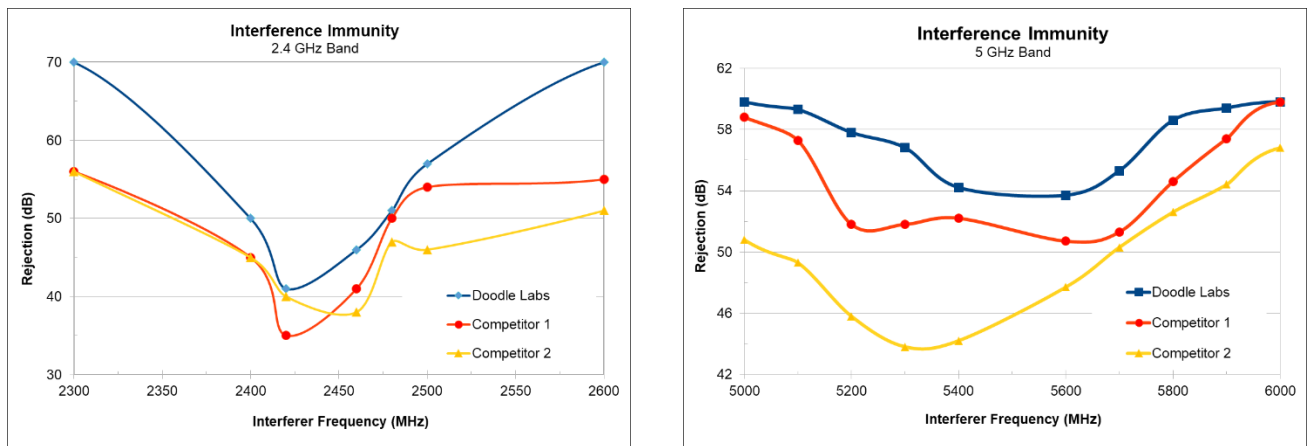
- Unmanned Vehicles – Drones
- Unmanned Robots
- Industrial IoT applications
- Rugged/Military requirements with extended temperature and vibration resiliency
- Mesh Networking deployments
- Passenger Wi-Fi access aboard airplanes and trains
- Streaming HD Video Surveillance Cameras
- Wireless Infrastructure in harsh operating conditions of the Oil/Gas fields and Mines

Features

Best-in-class features include:

- Modular FCC, CE and IC certifications to expedite system integration
- Integrated LNA for best-in-class Rx sensitivity to pick up low energy signals from mobile phones
- Up to 30 dBm of RF power to get the largest possible area coverage
- Extended temperature range from -40C to +85C.
- Electrical Stress protection on Antenna ports for outdoor operation
- Long product life cycle to meet the needs of Industrial IoT applications
- High interference immunity for Wi-Fi congested environment
- Hardware “RF Kill” feature to meet the FAA requirement for airborne applications
- High band isolation to support concurrent dual band operation for multi-band routers

Figure 2. Interference immunity performance compared to leading competitors.



NM-DB-2M Specifications

Table 1. Technical Specifications.

Model No.	NM-DB-2M (Rugged/Military Applications)
Ordering Code	NM-DB-3M with MMCX connectors NM-DB-3U with U.FL connectors
Radio Configuration	2x2 MIMO, Dual Band
Special Features	<ul style="list-style-type: none"> – Extended lifespan with planned availability for long time – Extreme Reliability, IPC Class 2 standard with Class 3 options – Compliant to MIL-STD-202G, Qualified for high shock/vibration environments
Design-In Documentation	https://www.doodlelabs.com/technologies/technical-library/
MAC Chipset	Qualcomm Atheros: QCA9590-BR4B with Extended Temperature range
Software Support	Open Source Linux Drivers ath10k for 11n models <u>OpenWRT</u> (Wireless Router/Linux OS)
Center Frequency Range	5.180 GHz ~ 5.825 GHz 2.412 GHz ~ 2.462 GHz This varies by the regulatory domain
Channel Bandwidth*	20, 40 MHz channels
Radio Modulation/Data Rates (Dynamic Link Adaptation)	<u>802.11a</u> : 6, 9, 12, 18, 24, 36, 48 and 54 Mbps (5.x GHz) <u>802.11n</u> : MCS0-23 (5.x and 2.4 GHz) <u>802.11b/g</u> : 1, 2, 5.5, 6, 9, 11, 12, 18, 24, 36, 48 and 54 Mbps (2.4 GHz)
802.11n version 2.0 Capabilities	<ul style="list-style-type: none"> • 802.11 dynamic frequency selection (DFS) as an AP and Client • Packet aggregation: A-MPDU (Tx/Rx), A-MSDU (Tx/Rx), Maximal ratio combining (MRC), Cyclic shift diversity (CSD), Frame aggregation, block ACK, 802.11e compatible bursting, Spatial multiplexing, cyclic-delay diversity (CDD), low-density parity check (LDPC), Space Time Block Code (STBC) • Phy data rates up to 450 Mbps (40 MHz channel)

Operating Modes	AP, Client, and Adhoc modes for Access Point, PtP, PtmP, and Mesh networks
MAC Protocol	TDD with Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
Wireless Error Correction	FEC, ARQ
Wireless Data Security	128 bit AES, WEP, TKIP and WAPI hardware encryption. Support for IEEE 802.11d, e, h, i, k, r, v, w and time stamp standards
FIPS Certification	<ul style="list-style-type: none"> • Small packet size (96 bytes) in AES encryption at full packet rate. • FIPS 140-2, Level 2 (Temper Evidence Shield), Loop back mode to facilitate FIPS AES certification.

Table 2. Tx and Rx performance at 5 GHz.

Tx/Rx Specification	Radio Modulation	Coding Rate	Tx Power ($\pm 2\text{dBm}$) ²	Rx Sensitivity (Typ)
5 GHz (20 MHz Channel) – 11n models				
802.11a, STBC	BPSK	1/2	27	-96
802.11a	64 QAM	3/4	22	-80
802.11n	BPSK	1/2	27	-96
802.11n	16 QAM	3/4	25	-84
802.11n	64 QAM	5/6	22	-75
5 GHz (40 MHz Channel) – 11n models				
802.11n	BPSK	1/2	27	-93
802.11n	16 QAM	3/4	25	-81
802.11n	64 QAM	5/6	22	-75

Table 3. Tx and Rx performance at 2.4 GHz.

Tx/Rx Specification	Radio Modulation	Coding Rate	Tx Power ($\pm 2\text{dBm}$) ²	Rx Sensitivity (Typ)
2.4 GHz (20 MHz Channel) – 11n models				
802.11b Single Stream, STBC	1 Mbps	CCK	29	-102
802.11g	64 QAM	3/4	24	-80
802.11n	BPSK	1/2	29	-95
802.11n	16 QAM	3/4	27	-83
802.11n	64 QAM	5/6	24	-76
2.4 GHz (40 MHz Channel) – 11n models				
802.11n	BPSK	1/2	29	-91
802.11n	16 QAM	3/4	27	-80
802.11n	64 QAM	5/6	24	-73

Note 1: It is advantageous to use the smallest channel bandwidth that can support the throughput requirements. Smaller bandwidths provide more channels to choose and help avoid interference issues.

Note 2: Total Tx power for all streams. Max allowed Tx power depends on the regulatory domain. De-rating of -1 dBm for U.FL connector.

Table 4. Additional RF performance information.

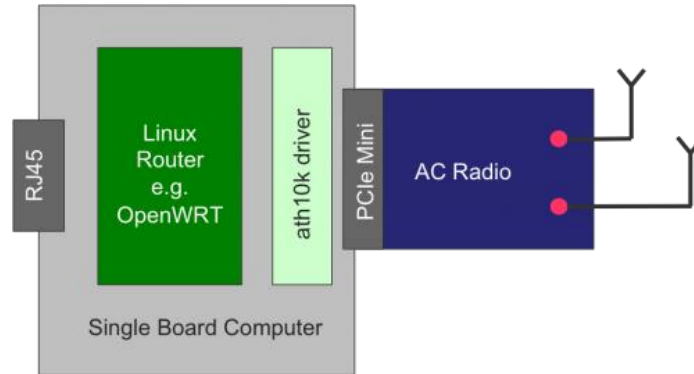
Antenna Signal Strength	-35 to -85 dBm (Recommended), Absolute Maximum=+12 dBm
Interference Immunity	SAW filters on RF ports for immunity against high power cellular transmissions in the neighboring 2.4 GHz bands.
Antenna port isolation for concurrent operation	Up to +10 dBm signal strength for 5 GHz signal without degrading 2.4 GHz operation Up to +5 dBm signal strength for 2.4 GHz signal without degrading 5.x GHz operation
Integrated Antenna Port Protection	10 kV
Receiver LNA Gain	>10 dB
Receiver Adjacent Channel Rejection (ACR)	>18 dB @ 11a, 6 Mbps (Typ)
Receiver Alternate Channel Rejection (ALCR)	>35 dB @ 11a, 6 Mbps (Typ)
Receive chain Noise Figure	+6 dB
Transmitter Adjacent Channel Leakage Power Ratio (ACLR)	45 dB ($F_c \pm ChBW$)
Transmitter Spurious Emission Suppression	-40 dBc
RF Power control	In 0.5 dBm steps. Accuracy of power calibration loop ± 2 dBm. Each transceiver individually calibrated and tested.
RF Hardware Disable (RF Kill)	Pin 20 of miniPCI-E interface. (Required for FAA compliance)
Spectral Analysis	8 bit resolution spectral FFTs available for software analysis

Table 5. Physical, Environment, and Other Specifications.

Host Interface	miniPCI-Express 1.2 Standard
Host CPU Board	Any CPU board with miniPCIe interface with minimum 6 mm connector height
Operating Voltage	3.3 Volts from miniPCI-Express connector
Power Consumption	5.3W @ Max power, in continuous data transfer mode on all chains 2.5W @ 20 dBm power (ETSI max), in continuous data transfer mode on all chains 0.9W in continuous data receive mode 250 mW in Sleep mode
Temperature range	-40°C to +85°C (shield case)
Humidity (Operating)	0% – 95% (Non-condensing)
Dimensions	30 x 50 x 4.75 mm, 12 grams. High Res Photos – Mechanical drawings and 3D-CAD files available upon request
MTBF	29 years
Regulatory Requirements	Designed and verified to meet various regulatory requirements. Formal testing and approval is required based on the Integrator’s particular host platform and antenna type. The Integrator is also responsible for obtaining all required regulatory approvals in target markets for the finished product.
FCC ID	2AG87NM-DB-2M. DFS compliance in both Master and Client modes.
CE/ETSI	Conforms with all the requirements of the European Directive 1999/5/EC – EN 301 893 V1.8.1, EN 300 328 V.1.8.1, EN 301 489-1 V1.9.2, EN 301 489-17 V2.2.1, EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011+ A2:2013
Industry Canada (IC)	21411-NMDB2M
RoHS/WEEE Compliance	Yes. 100% Recyclable/Biodegradable packaging

System Integration

Figure 3. System Integration Block Diagram.



As shown in the block diagram, the modular nature of the MIMO radio transceivers allow for accelerated development of the wireless modem. Any embedded Single Board Computer with standard miniPCI-Express interface is required. The Linux distribution OpenWRT has evolved over time and provides advanced features in a wireless router. It is a stable distribution and many OEMs are using OpenWRT as a starting point and customize further for their application. The distribution includes the ath10k driver to interface with the MIMO transceivers. Both OpenWRT and open source drivers (ath9k and ath10k) have extensive online documentation available. User group forums also provide responsive technical support.

Portfolio Index

Doodle Labs' Industrial Wi-Fi transceiver portfolio provides configurations optimized for a vast variety of project needs. All models are form-factor compatible. For information on other models, please visit - <http://www.doodlelabs.com/products/wi-fi-band-radio-transceivers/>

Doodle Labs provides extensive design-in documents at:

<https://www.doodlelabs.com/technologies/technical-library/>

FCC Statement

FCC standards: FCC CFR Title 47 Part 15 Subpart C Section 15.247 and FCC CFR Title 47 Part 15 Subpart E Section 15.407: 2016 paper presents antenna with gain ANT0: 2.4G Wifi: ANT0: 2.1dBi, ANT1: 2.1dBi 5.G Wifi: Band1: 3.2 dBi, Band3: 4.2dBi

FCC Regulatory Compliance:

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

- (1) this device may not cause harmful interference, and
- (2) this device must accept any interference received, including interference that may cause undesired operation.

Note: 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, which can be

determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Warning: changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

If power exceeds the limit and the distance(Over 20cm distance in actual use between the device and user) is compliance with the requirement

RF Exposure Compliance:

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with a minimum distance of 20cm between the radiator and any part of your body.

Notice to OEM integrator

If the FCC ID is not visible when the module is installed inside another device, then the outside of the device into which the module is installed must also display a label referring to the enclosed module. The end product shall have the words "Contains Transmitter Module FCC ID: 2AG87NM-DB-2M".

The device must be professionally installed.

The intended use is generally not for the general public. It is generally for industry/commercial use.

The connector is within the transmitter enclosure and can only be accessed by disassembly of the transmitter that is not normally required. The user has no access to the connector.

Installation must be controlled. Installation requires special training.

Any company of the host device which installs this modular with unlimited modular approval should perform the test of radiated & conducted emission and spurious emission, etc. according to FCC part 15C: 15.247 and 15.207, 15B Class B and Part 15 Subpart E Section 15.407 requirement, only if the tests result comply with FCC part 15C: 15.247 and 15.207, 15B Class B and Part 15 Subpart E Section 15.407 requirement, then the host can be sole legally.

When the module is installed inside another device, the user manual of the host contain below

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

IC statement

This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-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 received, including interference that may cause undesired operation of the device.

The term "IC: " before the certification/registration number only signifies that the Industry Canada technical specifications were met.

This product meets the applicable Industry Canada technical specifications.

Cet appareil contient des émetteurs / récepteurs exemptés de licence conformes aux RSS (RSS) d'Innovation, Sciences et Développement économique Canada. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

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.

Please notice that if the ISED certification number is not visible when the module is installed inside another device, then the outside of the device into which the module is installed must display a label referring to the enclosed module. This external label can use wording such as the following: "Contains IC:21411-NMDB2M" any similar wording that expresses the same meaning may be used.

L'appareil hôte doit porter une étiquette donnant le numéro de certification du module d'Industrie Canada, précédé des mots « Contient un module d'émission », du mot « IC:21411-NMDB2M » ou d'une formulation similaire exprimant le même sens, comme suit

The device meets the exemption from the routine evaluation limits in section 2.5 of RSS 102 and compliance with RSS-102 RF exposure, users can obtain Canadian information on RF exposure and compliance.

Le dispositif rencontre l'exemption des limites courantes d'évaluation dans la section 2.5 de RSS 102 et la conformité à l'exposition de RSS-102 rf, utilisateurs peut obtenir l'information canadienne sur l'exposition et la conformité de rf.

This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter. This equipment should be installed and operated with a minimum distance of 20 centimeters between the radiator and your body.

Cet émetteur ne doit pas être Co-placé ou ne fonctionnant en même temps qu'aucune autre antenne ou émetteur. Cet équipement devrait être installé et actionné avec une distance minimum de 20 centimètres entre le radiateur et votre corps.

B1 for indoor use only

B1 pour usage intérieur uniquement

Compliance list INTEGRATION INSTRUCTIONS for 996369 D03 OEM the and 996369 D03 OEM by Sections 2.2 through 2.10.

Requirement	Yes	N/A	Comment
2.2 List of applicable FCC rules List the FCC rules that are applicable to the modular transmitter. These are the rules that specifically establish the bands of operation, the power, spurious emissions, and operating fundamental frequencies. DO NOT list compliance to unintentional-radiator rules (Part 15 Subpart B) since that is not a condition of a module grant that is extended to a host manufacturer. See also Section 2.10 below concerning the need to notify host manufacturers that further testing is required.	YES		Refer to instruction FCC standards: FCC CFR Title 47 Part 15 Subpart C Section 15.247 and FCC CFR Title 47 Part 15 Subpart E Section 15.407: 2016
2.3 Summarize the specific operational use conditions Describe use conditions that are applicable to the modular transmitter, including for example any limits on antennas, etc. For example, if point-to-point antennas are used that require reduction in power or compensation for cable loss, then this information must be in the instructions. If the use condition limitations extend to professional users, then instructions must state that this information also extends to the host manufacturer's instruction manual. In addition, certain information may also be needed, such as peak gain per frequency band and minimum gain, specifically for master devices in 5 GHz DFS bands.	YES		Refer to instruction Antenna Type: paper presents antenna Antenna Gain: 2.4G : ANT0: 2.1dBi, AN1: 2.1dBi 5G: Band1: 3.2dBi, Band3: 4.2dBi
2.4 Limited module procedures If a modular transmitter is approved as a "limited module," then the module manufacturer is responsible for approving the host environment that the limited module is used with. The manufacturer of a limited module must describe, both in the filing and in the installation instructions, the alternative means that the limited module manufacturer uses to verify that the host meets the necessary requirements to satisfy the module limiting conditions. A limited module manufacturer has the flexibility to define its alternative method to address the conditions that limit the initial approval, such as: shielding, minimum	Yes		Refer to instruction Antenna Type: paper presents antenna Antenna Gain: 2.4G : ANT0: 2.1dBi, AN1: 2.1dBi 5G: Band1: 3.2dBi, Band3: 4.2dBi

signaling amplitude, buffered modulation/data inputs, or power supply regulation. The alternative method could include that the limited module manufacturer reviews detailed test data or host designs prior to giving the host manufacturer approval. This limited module procedure is also applicable for RF exposure evaluation when it is necessary to demonstrate compliance in a specific host. The module manufacturer must state how control of the product into which the modular transmitter will be installed will be maintained such that full compliance of the product is always ensured. For additional hosts other than the specific host originally granted with a limited module, a Class II permissive change is required on the module grant to register the additional host as a specific host also approved with the module.			
2.5 Trace antenna designs For a modular transmitter with trace antenna designs, see the guidance in Question 11 of KDB Publication 996369 D02 FAQ – Modules for Micro-Strip Antennas and traces. The integration information shall include for the TCB review the integration instructions for the following aspects: layout of trace design, parts list (BOM), antenna, connectors, and isolation requirements.	NO		The module has its own fixed antenna path
a) Information that includes permitted variances (e.g., trace boundary limits, thickness, length, width, shape(s), dielectric constant, and impedance as applicable for each type of antenna); b) Each design shall be considered a different type (e.g., antenna length in multiple(s) of frequency, the wavelength, and antenna shape (traces in phase) can affect antenna gain and must be considered); c) The parameters shall be provided in a manner permitting host manufacturers to design the printed circuit (PC) board layout; d) Appropriate parts by manufacturer and specifications; e) Test procedures for design verification; and			

f) Production test procedures for ensuring compliance. The module grantee shall provide a notice that any deviation(s) from the defined parameters of the antenna trace, as described by the instructions, require that the host product manufacturer must notify the module grantee that they wish to change the antenna trace design. In this case, a Class II permissive change application is required to be filed by the grantee, or the host manufacturer can take responsibility through the change in FCC ID (new application) procedure followed by a Class II permissive change application.			
2.6 RF exposure considerations It is essential for module grantees to clearly and explicitly state the RF exposure conditions that permit a host product manufacturer to use the module. Two types of instructions are required for RF exposure information: (1) to the host product manufacturer, to define the application conditions (mobile, portable – xx cm from a person's body); and (2) additional text needed for the host product manufacturer to provide to end users in their end-product manuals. If RF exposure statements and use conditions are not provided, then the host product manufacturer is required to take responsibility of the module through a change in FCC ID (new application).	YES		Refer to instruction The modular can be installed or integrated in mobile or fix devices only. This modular cannot be installed in any portable device. This modular complies with FCC RF radiation exposure limits set forth for an uncontrolled environment. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter. This modular must be installed and operated with a minimum distance of 20 cm between the radiator and user body.
2.7 Antennas A list of antennas included in the application for certification must be provided in the instructions. For modular transmitters approved as limited modules, all applicable professional installer instructions must be included as part of the information to the host product manufacturer. The antenna list shall also identify the antenna types (monopole, PIFA, dipole, etc. (note that for example an "omni-directional antenna" is not considered to be a specific "antenna type")). For situations where the host product manufacturer is responsible for an external connector, for example with an RF pin and antenna trace design, the integration	YES		RRefer to instruction Antenna Type: paper presents antenna Antenna Gain: 2.4G : ANT0: 2.1dBi, AN1: 2.1dBi 5G: Band1: 3.2dBi, Band3: 4.2dBi

instructions shall inform the installer that unique antenna connector must be used on the Part 15 authorized transmitters used in the host product. The module manufacturers shall provide a list of acceptable unique connectors.	YES		Refer to instruction
2.8 Label and compliance information Grantees are responsible for the continued compliance of their modules to the FCC rules. This includes advising host product manufacturers that they need to provide a physical or e-label stating "Contains FCC ID" with their finished product. See Guidelines for Labeling and User Information for RF Devices – KDB Publication 784748.	YES		If the FCC identification number is not visible when the module is installed inside another device, then the outside of the device into which the module is installed must also display a label referring to the enclosed module. This exterior label can use wording such as the following: "Contains Transmitter Module FCC ID: 2AG87NM-DB-2M Or Contains FCC ID: 2AG87NM-DB-2M "
2.9 Information on test modes and additional testing requirements Additional guidance for testing host products is given in KDB Publication 996369 D04 Module Integration Guide. Test modes should take into consideration different operational conditions for a stand-alone modular transmitter in a host, as well as for multiple simultaneously transmitting modules or other transmitters in a host product. The grantee should provide information on how to configure test modes for host product evaluation for different operational conditions for a stand-alone modular transmitter in a host, versus with multiple, simultaneously transmitting modules or other transmitters in a host. Grantees can increase the utility of their modular transmitters by providing special means, modes, or instructions that simulates or characterizes a connection by enabling a transmitter. This can greatly simplify a host manufacturer's determination that a module as installed in a host complies with FCC requirements.	YES		Refer to instruction Any company of the host device which installs this modular with unlimited modular approval should perform the test of radiated & conducted emission and spurious emission, etc. according to FCC part 15C: 15.247 and 15.407 and 15.209 & 15.207, 15B Class B requirement, only if the tests result comply with FCC part 15C: 15.247 and 15.407 and 15.209 & 15.207, 15B Class B requirement, then the host can be sole legally
2.10 Additional testing, Part 15 Subpart B disclaimer The grantee should include a statement that the modular transmitter is only FCC authorized for the specific rule parts (i.e., FCC	No		refer to instruction Any company of the host device which installs this modular with unlimited modular approval should perform the test

<p>transmitter rules) listed on the grant, and that the host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification. If the grantee markets their product as being Part 15 Subpart B compliant (when it also contains unintentional-radiator digital circuitry), then the grantee shall provide a notice stating that the final host product still requires Part 15 Subpart B compliance testing with the modular transmitter installed.s</p>		<p>of radiated & conducted emission and spurious emission, etc. according to FCC part 15C: 15.247 and 15.407and 15.209 & 15.207, 15B Class B requirement, only if the tests result comply with FCC part 15C: 15.247 and 15.407 and 15.209 & 15.207, 15B Class B requirement, then the host can be sole legally</p> <p>When the module is installed inside another device, the user manual of the host must contain below warning statements;</p> <p>Note: 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.</p> <p>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, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:</p> <ul style="list-style-type: none"> —Reorient or relocate the receiving antenna. —Increase the separation between the
---	--	--

		<p>equipment and receiver.</p> <ul style="list-style-type: none"> —Connect the equipment into an outlet on a circuit different from that to which the receiver is connected. —Consult the dealer or an experienced radio/TV technician for help.
--	--	--