AN1048: Regulatory RF Module Certifications

This application note provides a brief summary of general radio certifications, focusing on the 2.4 GHz frequency band and covering the wireless modules of Silicon Labs.

Silicon Labs RF modules are certified to meet the requirements of the Federal Communications Commission (FCC), Innovation, Science, and Economic Development (ISED), European Conformity (CE), and other regulatory bodies. When using Silicon Labs pre-certified modules, customers can refer to these certifications and related test reports to achieve regulatory compliance.

This document also provides answers to frequently-asked questions and general guidance for radio certification.

Certification requirements depend on regions and modules. This document highlights the main differences between the different modules, module types, and certification requirements between different countries. It also describes a list of requirements that the pre-certified module must meet in order to get a full modular certification as well as differences between the FCC and CE and other countries.

KEY POINTS

- Brief review of Silicon Labs radio module certifications
- Regulatory overview of various countries
- Radio certification flow
- RF Exposure considerations
- Accredited test house examples
- Silicon Labs certification-related documentation for customers
- Wireless Module Certification FAQ

1. Introduction

Certification requirements depend on regions and modules. This document highlights the main differences between the different modules, module types, and certification requirements of different countries. It also describes a list of requirements that the pre-certified module must meet in order to get a full modular certification as well as differences between the FCC and CE and other countries.

The FCC has two main categories: full modular approval and limited modular approval. A module that does not meet all conditions listed in FCC part 15.212 is certified to the Limited Modular Approval category. Both for full and limited modular approval, the end product will be labeled with the module's FCC ID. For instance, the BGM12x SiP module shields the passive components in the substrate, which acts as an intrinsic shield but does not include metallic shielding on top due to its highly optimized size and performance. However, the module fully meets radiated testing requirements of FCC and other standards without the metallic shield. The current state of FCC rules requires metallic shielding. For this reason, module customers need to perform verification testing with Class 1 Permissive Change for FCC and, additionally, apply for a Class 2 Permissive Change for ISED. As an additional example, the BGM13S SiP module (or PCB modules as BGM111) includes metallic shielding on the package with the FCC ID label, so it has a full FCC modular approval.

CE is not a certification, and there are no modular certifications in Europe or in countries following RED directives, as opposed to FCC. CE requires a declaration from the manufacturer that the product meets the requirements of the R&TTE or RED directive. For example, the BGM12x SiP module certification for CE does not differ from traditional PCB modules like the Blue Gecko BGM111.

The SoC/IC level wireless components cannot be pre-certified because they lack a fixed RF path and antenna. Customers must perform RF measurements to validate and certify design compliance with the regulatory rules.

Table 1.1. Silicon Labs Modules Main Regulatory Certifications Summary

Certification	SiP Modules[1]	PCB Modules
CE (Europe)	Pre-certification	Pre-certification
FCC (USA)	Full / Limited Modular Certification	Full Modular Certification
ISED (Canada)	Full / Limited Modular Certification	Full Modular Certification
MIC (Japan)	Full Modular Certification	Full Modular Certification
KCC (South Korea)	Full Modular Certification	Full Modular Certification

Note:

1. SiP modules are typically certified for limited modular certification due to the lack of metallic shielding and/or space for an FCC ID label, but, in some cases, it has full modular certification. Related information can be found in the data sheet of the particular SiP part.

1.1 Certification Terminology / Acronyms

- FMA (or MA) = Full Modular Approval – meets criteria set for full modular certification.
- LMA = Limited Modular Approval – does not meet criteria set for full modular certification.
- C1PC = Class 1 Permissive Change – applies to modular approval (LMA, FMA) and relates to changes not increasing emissions.
- C2PC = Class 2 Permissive Change – applies to modular approval (LMA, FMA) and relates to changes increasing emissions or changes to remove particular grant restrictions (antenna type, RF layout change, radio co-location).
- CB = Certification Body – a person authorized by the specific authority to review applications and admit certificates.
- TCB = Telecommunication Certification Body – issues grants for equipment subject to certifications.
- NB = Notified Body – an organization designated by an EU country to assess the conformity of certain products before being placed on the market.
- DoC = Declaration of Conformity – mandatory self-declaration written under full responsibility by the manufacturer stating product compliance.
- RED = Radio Equipment Directive – EU directive 2014/53/EU for compliance of radio equipment.
- TCF = Technical Construction File – technical documentation for a product providing evidence of compliance (test reports, declarations) and conformity to a relevant regulation; also includes technical design material.
- EU-TEC = EU Type Examination Certificate - optional document confirming directive conformity and compliance by testing against harmonized standards (also known as the NB Opinion); provides statement by NB that TCF is appropriate for DoC.
- GMA = Global Market Access – service offered by test houses to help manufacturers cover global certification needs; applying reuse of certification in countries for which not certified.
- OEM = Original Equipment Manufacturer – in the context of certifications, this is an end-product producer as opposed to a component vendor. Also referred to as Module Integrator.
- OPN = Orderable Part Number – the part number used when customers place component orders.
- DUT/EUT = Device Under Test / Equipment Under Test – the device/equipment being tested.
- SAR = Specific Absorption Rate.

1.2 Customer Selection of Silicon Labs Solution

The solution selected by the customer determines design complexity, certification requirements, costs, etc., as listed below.

- Chip down / SoC
  - 100% of customers of Silicon Labs. RF design experience is required. Lowest device cost but high certification cost.
  - Example: EFR32MG21 SoC customer design.
- Uncertified module
  - High certification cost. RF design experience is not required.
  - Example: ZGM130S SiP PCB module customer design.
    - Silicon Labs provides evidence/test report showing passing test results (only for EU, US, Japan, Korea).
- Certified module with LMA
  - Extra certification cost. RF design experience is not required.
  - Example: BGM121 SiP PCB module customer design.
    - LMA due to lack of metallic shield requiring extra testing and C1PC/C2PC.
- Certified module with FMA
  - Low certification cost. RF design experience is not required.
  - Examples: BGM13S SiP module or BGM13P PCB module customer designs.

1.3 Detail on Marking for SiP and PCB Modules

1.3.1 PCB Modules

Full modular approval.

- Five standard certifications are marked on the part: FCC, ISED, CE, Japan, and Korea.
- Reel/Delivery package markings are not needed since they are on the part.
- Data sheet includes required wording from FCC, ISED, CE, Japan, and Korea.

1.3.2 SiP Modules

SiP modules can have FMA, LMA with C1PC needed, and LMA with C2PC needed, while LMA with C1PC is the most common due to the space limitation for marking on the parts. Furthermore, SiP modules with the lack of metallic shielding do require verification testing with C1PC for FCC, and, additionally, C2PC for ISED. Data sheet includes required wording from FCC, ISED, CE, Japan, and Korea. However, in some cases, FCC approves SiP modules without a certification label on the part as FMA if the OPN is clearly visible on it and the related data sheet contains certification details (for instance, WFM200).

- Limited only in the sense that the mark (certification label) is missing.
  - In some cases, it is approved as FMA when only the label is missing due to space constraints.
- Due to limited space, part markings only include Part Number (OPN) and Trace Code.
- Markings included on the delivery package:
  - Required if not on part: ISED, FCC, CE, Japan, and Korea.
  - Recommended if not on part: Taiwan.
- BGM13S22 example: Limited certifications listed due to space constraints.
- WFM200 example:
  - Marking has three lines – Model name / OPN / trace code that are clearly visible on the part's package.
  - Packaging label requires CE logo and markings.
  - FMA even without the FCC/ISED label, but data sheet contains required certification information.
- SiP module regulatory markings will not be added due to limited space and cannot fit more than 2-3 IDs.
  - FMA is even possible and approved by FCC.
- Older designs, such as BGM13S, may have FMA, which is stated in the relevant part's data sheet.

1.4 Customer Process for LMA SiP Module Certification

- When a product design including a SiP module with LMA is finalized, the customer shall contact the company providing certification services for their product's general FCC, CE, and other country regulatory certifications and perform compliance testing on the final product.
- The company providing the certification services will use Silicon Labs certification test reports and finalize the certification for the customer.
  - Documents can be downloaded at public certification databases.
  - Documents can be downloaded from silabs.com.
- www.silabs.com/support serves customers and certification houses and can answer any questions.

2. Certifications/DoC Basics and Certification Flows

2.1 Market and Application-Specific Certification Examples

- Europe: CE
- USA: FCC
- Canada: ISED (Former IC)
- South-Korea: KCC
- Japan : MIC (commonly known as Telec)
- Australia : RCM
- Typically split into three separate categories: RF, EMC and Safety
- Application-specific requirements: Medical, Automotive and Aviation

2.2 Certification versus DoC Basic Difference

2.2.1 Certification

- Testing takes place in an accredited test lab.
- The manufacturer, or an agent authorized by the manufacturer, submits an application to a CB.
- CB approves the application; admits the certificate to the manufacturer, and uploads the certification listing to the specific database.
- Typical countries Silicon Labs considers when applying for radio approvals include the USA, Canada, Japan, and Korea.
- Taiwan and Brazil are not typically certified by Silicon Labs but are occasionally included based on priority determination/customer-base demand.

2.2.2 DoC

- The EUT is tested according to any applicable standards, typically (but not necessarily) in an accredited test lab.
- The manufacturer will file the test evidence together with any technical information to an internal compliance folder.
- The manufacturer signs a DoC, which states the applicable standards according to which the product was found to be compliant.
- NB involvement required if testing occurs against non-harmonized standards.
- Countries: EU countries, Australia, New Zealand.

2.3 Process Flow in Certifications

2.3.1 FCC, ISED, MIC

1. Prepare samples and book a test slot from an accredited test lab.
2. Test lab will test according to the test instructions given by the module manufacturer.
3. Test lab provides the test reports.
4. Module manufacturer submits test reports and a certification application to a CB.
5. The CB reviews the application and admits the certificate to the manufacturer.
6. The CB uploads the certification listing to the specific database.

2.3.2 CE

1. Prepare samples and book a test slot from an accredited test lab.
2. Test lab will test according to the test instructions given by the module manufacturer.
3. Test lab provides the test reports.
4. If all testing was done according to harmonized standards:
   - Manufacture files the test evidence and all technical material to TCF.
   - Manufacturer will sign a DoC in which the manufacturer states all the standards with which the product is found to be compliant.
5. If all testing was not done according to harmonized standards:
   - Manufacturer submits an NB application to an NB.
   - The NB will review the test reports and all technical material and user manuals.
   - If the NB approves, they will provide the manufacturer with a letter in which they state that they have found the product to be compliant with all applicable standards.
   - Manufacture files the NB letter, test evidence, and all technical material to TCF.
   - Manufacturer will sign a DoC in which the manufacturer states all the standards with which the product is found to be compliant.

2.4 Classical versus Self Declaration versus Restrictive

2.4.1 Classical

- Globally, the most common, including USA, Canada, Japan, Korea.
- Less flexible than self-declaration.
- Authority or CB must assess the test reports, design material, and hardware integration instructions and issue a certificate.
- End products can inherit approval from a module under some conditions.
- OEM is required to test their product, even if they are using a module with full approval.
  - Repeating full testing is not required; sufficiently frequent spot-checking is suggested.

2.4.2 Self-Declaration

- EU, Australia, New Zealand.
- Extremely flexible. OEM simply creates a DoC for their product. They do not have to contact any CB. However, the customer may want or have to be in contact with an NB.
- OEM has the full legal responsibility for the product they put on the market. Therefore, Silicon Labs strongly recommends that customers test the end-product to prove compliance and not just assume that the module's own compliance evidences can be reused as-is for the end-product.
- Silicon Labs also provides its own DoC and test reports for the modules to show compliance.

2.4.3 Restrictive Markets

- China, Russia, etc.

  Note: In these markets there are difficulties in access which make them restrictive.

2.5 Silicon Labs Documentation for Customers

2.5.1 Data Sheet

- Minimal regulatory information except that which is required by regulatory bodies.
- Highlights the modular approval type.

2.5.2 Test Reports and Certificates

- Zip packages for region or authority containing various PDF reports and certificates for customer reference.
- Find these in Technical Resource Search: https://www.silabs.com/support/resources.ct-module-certifications.

2.5.3 Installation Guide

- Detailed layout guidelines, including dimensions.
- Possibly includes FCC “test list” help.
- Possibly includes other general regulatory advice.

2.5.4 Layout Template

- File that is importable into a CAD design on a non-printable layer that shows outlines and dimensions that would help OEMs.

2.5.5 Design Files for Modules

- Module design files are Silicon Labs IP, so they cannot generally be shared with customers. If it is required for certification purposes, Silicon Labs can share design files with the certification test house under NDA.

2.6 Customer Certification: Engineering Flow

The flowchart below is designed to enable a customer's design to pass emissions requirements for whatever region they are interested in. There are no legal assumptions required or built-in. It is an engineering flow customers can follow to achieve a passable design. All customers will need to design their system and test it.

Customers are expected to visit a test house, even when using a fully certified module. This is especially valid for regions following the DoC approach, but also, for example, for FCC, where testing of the end-product has always been officially strongly recommended but not explicitly highlighted until very recently through the KDB publication 996369 D04, and has not always been enforced.

Silicon Labs role:

- Customers are not required to have deep knowledge of RF circuits or other technical details, although that may speed up the process, while Silicon Labs experts are available to provide guidance and provide hints on a suitable design meeting regulatory requirements. Using a certified module clearly offers benefits validating the above.
- Silicon Labs requires customers to understand their legal responsibilities. They may not be engineers, but they are business people.
- Silicon Labs might point customers to TCBs when they need to notify or work with a regulatory body regarding permissive changes.

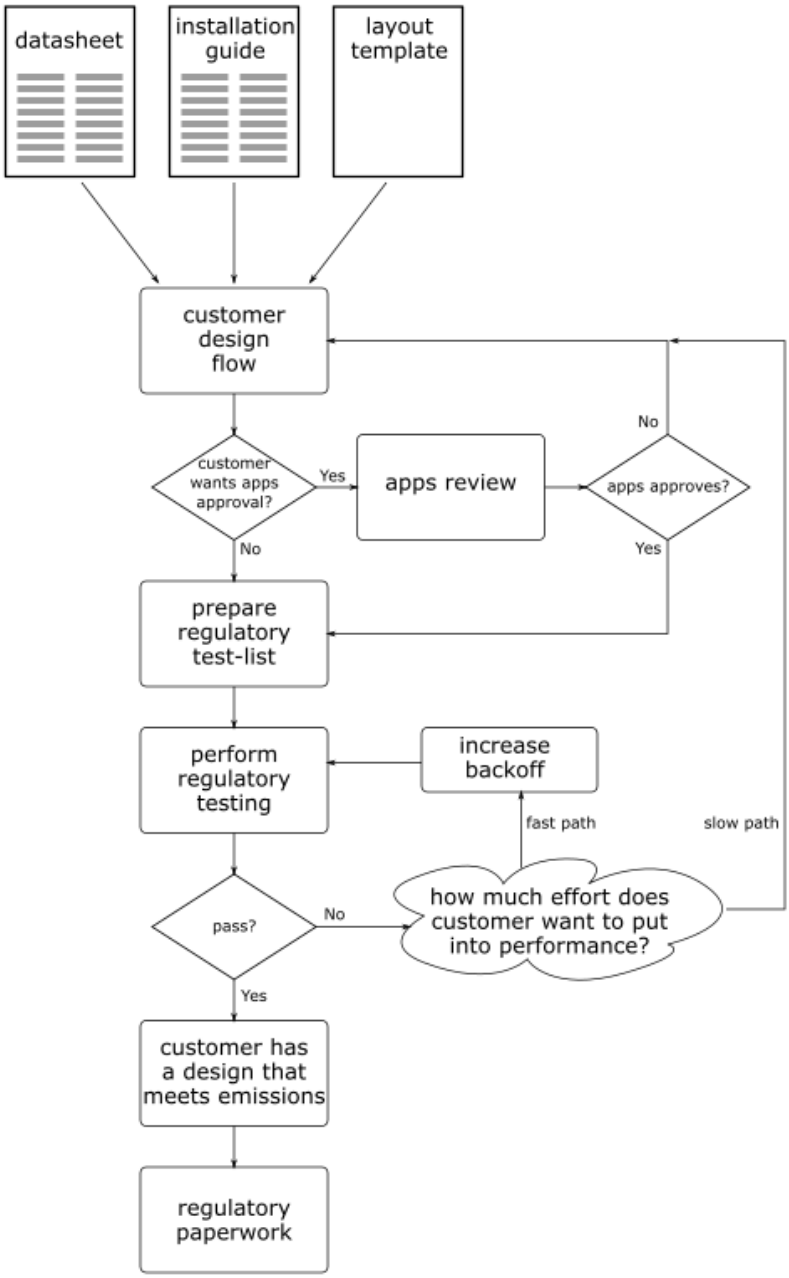


Figure 2.1. Certification Engineering Flow

2.7 Customer Certification: Paperwork Flow

The flow chart below is only provided as a guideline, not a legal contract. All customers should work with a TCB to answer questions specific to their situation.

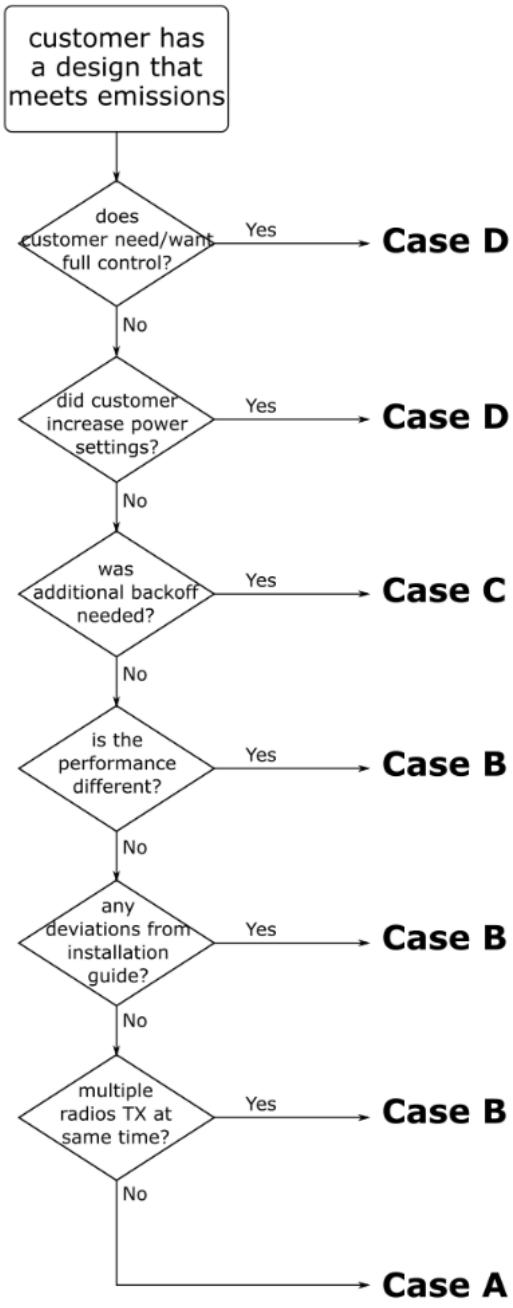


Figure 2.2. Certification Paperwork Flow

Table 2.1. Summary of Certifications Paperwork Flow

Case	FCC	ISED	RED (DoC Based)	Korea	Japan[1]
A	FCC ID owner: Silicon Labs No notification needed. (~1000 USD for spot checking compliance)	Same as FCC	Customer DoC Customer tests EMC, safety, some emissions. Customer can adjust levels as desired. Customers assess their own risk. (~5000 USD for testing)	Similar to FCC but no spot check required	Similar to FCC but no spot check required
B	FCC ID owner: Silicon Labs[2] We authorize C2PC against original grant. (~500 USD for C2PC, ~2000 USD for testing if applies)	Same as FCC		Request for change assumed	Request for change assumed
C	FCC ID owner: Silicon Labs[2] We authorize C2PC against original grant. (~500 USD for C2PC, ~2000 USD for testing if applies)	Same as FCC		Request for change assumed	Request for change assumed
D	New certification needed. FCC ID markings must be covered or removed. [3] (Cost depends on changes and tests)	Same as FCC		Apply for end product certification	Apply for end product certification

Note:

1. Japan requires only conducted testing of the module. Antennas are added based on antenna specification only.
2. As for xGM SiP Modules, they all are FMA except BGM12x, which is LMA due to lack of shielding. This is an additional example where some extra effort with permissive changes is needed. WFM200 could be approved with a FMA despite the lack of label; so, in this case, there is no need for any permissive change.
3. A new certification is more work for a customer, but their test house will be allowed to reuse applicable materials from Silicon Labs, such as block diagrams, schematics, and test reports.

2.8 Customer Certification: Expected Process Timeline

An example of Silicon Labs' typical module certification timeline is shown below.

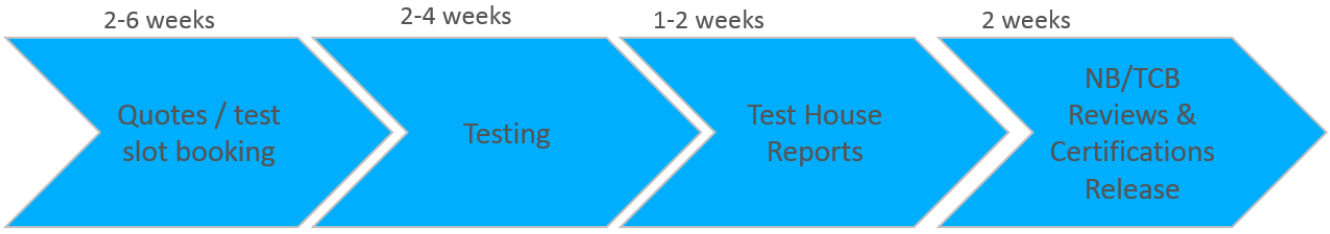


Figure 2.3. Silicon Labs Module Certification Timeline

2.8.1 Customer CE Testing

Assume same timeline as above.

2.8.2 Customer Modular Approval

Assume a few days of required spot-testing, after agreement with the test house. C2PC requires about 1 week to prepare material and have it reviewed by TCB.

3. Regulatory Overview

3.1 RF Regulatory Overview: Summary by Region

Table 3.1. RF Regulatory Overview by Region

Radio Certification		DoC	
USA (FCC)	https://www.fcc.gov/	Europe (CE)	http://ec.europa.eu/growth/sectors/electrical-engineering/red-directive_fi
Canada (ISED)	https://www.canada.ca/en/innovation-science-economic-development.html	Australia (ACMA)	https://www.acma.gov.au/
Taiwan (NCC)	https://www.ncc.gov.tw/english/	New Zealand (RSM)	https://www.rsm.govt.nz/
Brazil (Anatel)	http://www.anatel.gov.br/institucional/		
Japan (MIC)	http://www.soumu.go.jp/english/		
Korea (KCC)	http://eng.kcc.go.kr/user/ehpMain.do		

3.2 Test House Examples

The table below lists accredited test houses that Silicon Labs has recently used for module certification efforts. Test houses primarily make available their labs and engineers for the testing of modules against relevant regulatory standards in order to verify and report their compliance. They also might offer their own NB or TCB services or propose to use NBs and TCBs that they partner with. In many cases, Silicon Labs has been using the services of a third-party TCB of our choice, namely American Certification Body (ACB, https://acbcert.com).

Table 3.2. Test House Examples

Test House	URL for Worldwide Locations
SGS (Standard Global Services)	https://www.sgs.com/en/office-directory
Bureau Veritas	http://www.us.bureauveritas.com/home/worldwide-locations/locations
Dekra	https://www.dekra.com/en/dekra-worldwide/
Element	https://www.element.com/locations
TUV-SUD	https://www.tuvsud.com/en-us/locations#/
NCC Certificações do Brasil	www.ncc.com.br | www.ncc.org.br

3.3 Authorities Contacts

Table 3.3. Authorities Contacts

Authority	Direct Contact
FCC (USA)	https://apps.fcc.gov/oetcf/kdb/forms/InquiryForm.cfm
ISED (Canada)	ic.certificationbureau-bureauhomologation.ic@canada.ca
CE (Europe)	Market surveillance authorities for all EU countries can be found here: https://ec.europa.eu/growth/sectors/electrical-engineering/red-directive_en
ACMA (Australia)	comply.label@acma.gov.au
MIC (Japan)	N/A (contact Silicon Labs local office)
KCC (Korea)	N/A (we work through test house)

Authority	Direct Contact
Anatel (Brazil)	N/A (we work through test house)
NCC (Taiwan)	https://cabletvweb.ncc.gov.tw/swsUSFront35/SWSF/SWSF01014.aspx

3.4 CE

- CE requires a declaration from the manufacturer that the product meets the requirements of the R&TTE or RED directive.
  - CE is a “self-declaration” and not a certification.
- Since there is no certification, there is no modular approval / certification either.
  - A module manufacturer is responsible for their module's compliance, and the end product manufacturer is responsible for their end product's compliance.
  - Test reports of Silicon Labs modules are available and show compliance, but any end product needs its own evidence.
- The manufacturer of the end product (OEM) is responsible for the product being compliant.
  - Silicon Labs strongly recommends that the OEM perform radiated testing on the end product.
  - Conducted test results can be inherited from Silicon Labs module test reports.
- Typically, test evidence (reports) must be presented.
- Optionally, an NB opinion can be requested as a formal “certificate”.
- RED Guide can be found here: https://ec.europa.eu/docsroom/documents/23321/attachments/1/translations/en/renditions/native
- A product is tested according to harmonized standards.
  - Harmonized standards: A harmonized standard is a European standard developed by a recognized European Standards Organization, such as CEN, CENELEC, or ETSI. It is created following a request from the European Commission to one of these organizations. Manufacturers, other economic operators, or conformity assessment bodies can use harmonized standards to demonstrate that products, services, or processes comply with relevant EU legislation.
- Relevant standards for radio products:
  - RF: ETSI EN300328 (radio emissions): https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/red_en
  - EMC: ETSI EN301489 (other emissions and immunity): https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/electromagnetic-compatibility_en
  - Safety: ETSI EN60950 (safety): https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/general-product-safety_en
- All harmonized standards with status information: https://portal.etsi.org/webapp/WorkProgram/Frame_WorkItemList.asp?qSORT=DIRECTIVES&qHARMONIZED=True&butPredefined=Search&qDIRECTIVE=2014%2F53%2FEU&optDisplay=ALL&butHarmonized=Search
- If harmonized standards are not followed, it is mandatory to use Notified Body.
- Manufacturer can also use Notified Body, just to gain more confidence in the compliance. Manufacturer maintains TCF.
  - Test reports
  - Description of the device (schematic, layout, BOM, photos, etc.)
  - DoC
  - NB opinion letter (if applied)

3.4.1 Limitations

- CE is not a certification, so there is no modular certification. Each end product will require its own test evidence of compliance. Typically, conducted test results can be inherited from the module test reports. The radiated tests and immunity tests must be performed with the end product assembly.
- If transmit power is higher than +13 dBm (20 mW), RF exposure must be evaluated.
  - Typically requires SAR testing.
  - Dependent on end product and use case, such as proximity to human body.
  - If the product's TX power exceeds 13 dBm, RF exposure evaluation should be evaluated by a suitable test laboratory.
- Multiple radios used in a single end product.
  - If co-located radios are transmitting simultaneously, RF exposure must be re-evaluated.
  - If co-located radios are not transmitting simultaneously, RF exposure is evaluated for each radio independently.
- For non-adaptive transmitters, the maximum EIRP is +10 dBm. For non-hopping transmitters, the maximum PSD (Power Spectral Density) is 10 mW/MHz. In practice, these requirements limit the maximum nominal transmit power of 802.15.4-based protocols to +12 dBm and BLE (Bluetooth Low-Energy) to +10 dBm with antenna gain of 0 dBi. If the antenna gain is higher, the transmit power must be reduced accordingly.

3.4.2 Modules Tested for CE: What Does the Customer Need to Do?

- DoC (RE-D Declaration of Conformity) and test reports are available.
- For the end product, all conducted test cases of EN300328 can be inherited from the module test report.
- Any radiated test cases or ESD under EN300328 and EN301489 must be tested with the end product.
- RF exposure evaluation depends on the application and the transmit power of the module.

3.4.3 Countries Following the CE Standard

EU countries, ETFA countries: Iceland, Norway, Switzerland (and Liechtenstein), French DOMs, Guadeloupe, Martinique, French Guiana, Reunion, Afghanistan, Andorra, Georgia, Gibraltar, Maldives, Monaco, San Marino, Sao Tome and Principe, Seychelles, Vatican City, Faroe Islands, Greenland, Svalbard, Azores, Madeira, Canary Islands, Guernsey, Jersey, Isle of Man, Montserrat, and Pit-cairn Islands.

3.4.4 Australia (ACMA) and New Zealand (RSM)

- Similar to CE with few difference.
  - Local representative or local office register to ACMA.
  - Local representative or local office is responsible for maintenance of TCF and DoC.
  - ACMA accepts FCC and CE test reports.
- Submit questions to ACMA officers: comply.label@acma.gov.au .
- Under the Trans-Tasman Mutual Recognition Agreement (TTMRA) between Australia and New Zealand, all devices compliant with Australia's electromagnetic compatibility (EMC) compliance and labeling regime can be supplied in New Zealand, and all devices compliant with New Zealand's EMC compliance and labeling regime can be supplied in Australia.

3.5 FCC

- Types of authorization: Certification (radio), DoC (computer peripheral) or Verification (other electronic devices).
- Relevant standards for a product implementing a radio: Intentional radiators 47 CFR FCC Part 15C and Unintentional radiators 47 CFR FCC Part 15B.

3.5.1 Single or Full Modular Approval

- Definition: a completely self-contained RF transmitter that is missing only an input signal and power source to make it functional.
- A module to be used in any host. Typically, compliance is ensured independent of the host board.
- A module that meets all eight module criteria listed below.
  1. Transmitter/RF portion must have its own metallic shield.
  2. Buffered data input.
  3. Own power supply regulation.
  4. Embedded antenna or unique antenna coupler (RF pin is a unique antenna coupler).
  5. Module tested in a standalone configuration.
  6. FCC ID label.
  7. Must comply with all applicable rules applicable to the transmitter.
  8. Must comply with any applicable RF exposure requirements.
- FMA is tested in standalone configuration.
- Module integrator must follow module's grant limitations, e.g., distance and co-location for RF exposure.
- Module integrator can use the module without additional testing or permissive changes provided that the restrictions listed in the FCC grant (e.g., co-location or RF exposure) are not a problem with the new host. However, FCC strongly recommends that spot testing for additional emissions be performed with the new host. KDB 996369 gives comprehensive instructions for the module integrators. The KDB can be found here: https://apps.fcc.gov/oetcf/kdb/forms/AdvancedExternalSearch.cfm.
- Installation guide is required.
  - The installation guide is, in practice, a HW layout guide. This is provided by Silicon Labs for each FMA modules.
  - Compliance must not rely on instruction regarding SW configurations. For instance, some modules may have TXP limitations across the full frequency band or on a few (higher) channels for FCC band-edge compliance.

3.5.1.1 How Do Customers use FMA?

- No separate certification with the end product; just label the product and get instant access to the markets.
- The host must be labelled that it includes a certified module.
- An end product using a radio with full modular approval will not need radio certification testing if the restrictions mentioned in the module grant are met.
- The host must follow the module grant limitations.
  - Distance and co-location for RF exposure.
  - If the host does not follow the module grant restrictions (RF exposure, antenna types / antenna gain), a permissive change is needed to remove the restrictions in that particular assembly.
- The host must still comply with its own requirements, such as part 15B verification (unintentional radiators).
- RF exposure limits:
  - The minimum separation distance to a human body for the SAR measurement exemption is stated in the user manual.
  - With modules, it is possible to measure the worst-case SAR to allow smaller separation from a human body.
  - Depending on the nature of the end-product, head SAR must always be tested.

3.5.2 Limited Modular Approval

- A module that does not meet all eight criteria set above for a module.
- A module to be used in a known host or a known environment.
- For a licensed limited single module, the manufacturer must state how control of the end product into which the module will be installed is to be maintained, such that full compliance of the end product is always assured.
- LMA is not tested as standalone but is instead tested inside a specific host.
- The certification is valid only for the specific host and the module integrator or the module manufacturer must take actions, such as performing testing or calculations, in order to approve the new host. In practice, the required actions depend on how the certification is limited.
- If the host or end environment is known, Limited Modular Approval may be possible.
  - Limited to application
  - Limited to host
  - Limited to installer (typically the Grantee or partner)

3.5.2.1 How Co Customers Use LMA?

- An LMA module cannot be sold to anyone as if it had full Modular Approval.
- The Grantee is always responsible for compliance in any host, full or limited module.
  - Cannot rely on OEM to re-test in their host.
- The LMA module will be certified for use by the Grantee or an authorized OEM.
  - The Grantee must maintain control of the installation; so, typically, installation is only permitted by the Grantee.
  - Installation by an OEM may be permitted; for example, if there is a contractual agreement.
    - OEM must understand the limitations of installation.
    - It is more than simply following the Grant notes.

3.5.3 Permissive Changes

- Describe the modifications that may be made to an RF device without new authorization.
- Permissive Change policy is described in more detail in official FCC documents of KDB Publications 178919 D01 and D02. KDB publication 996369 also includes some further guidance on permissive changes.
  - https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?switch=P&id=33013
  - https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=44637&switch=P
- Each new host PCB requires reassessment
- **Class 1 Permissive Change (C1PC)**
  - Changes that do not increase emissions or change RF characteristics.
  - Modifications that do not degrade the reported characteristics.
  - Does not need application to FCC, i.e., no filing to FCC is required.
  - Typical C1PC changes: equivalent antenna change or small BOM change.
- **Class 2 Permissive Change (C2PC)**
  - Changes that increase emissions or any changes to remove particular restrictions mentioned in the grant.
  - Modifications that degrade the performance characteristics as reported but still meet the minimum requirements of the applicable rules.
  - Official test report required; must be filed to FCC through a TCB, together with a cover letter explaining the changes, for the new grant release and registration.
  - Typical C2PC changes include antenna change with higher gain, antenna type change, co-location of radios, and small RF layout changes that result in an electrically equivalent device. The appropriateness of a C2PC can be confirmed by a TCB or directly by the FCC. However, these typical C2PC changes can be handled by a different extended approach as well: the so-called "Change in ID". Silicon Labs recommends getting authorized for "Change in ID" first for these cases (before the actual C2PC work), since after the simple procedure related to the "Change in ID", the module integrator will be free to independently proceed with their own C2PC and make any further changes in the future on their own.
- **Class 3 Permissive Change (C3PC)**
  - Includes modifications to the software of a software defined radio transmitter that change the frequency range, modulation type or maximum output power (either radiated or conducted) outside the parameters previously approved or that change the circumstances under which the transmitter operates in accordance with FCC rules.
- **Permissive changes may only be made by the holder of the grant of certification.**
  - Silicon Labs can provide customers with a signed authorization letter and allow the customers to make these permissive changes on behalf of Silicon Labs, especially when the host makes use of a different external antenna or in a co-location scenario. Silicon Labs, as the grantee, would still be responsible for the grant and for the compliance to the requirements. However, Silicon Labs prefers to authorize a "Change in ID" for the module integrator to first obtain their grant ID by inheriting the module's FCC ID and then become free to independently proceed with their own C2PC and make any further changes in the future under their own grant.

    In fact, the "Change in ID" approach is meant for the purpose of re-using the original grant and related application material, under a different FCC ID of which the new grantee will be fully responsible, also in terms of what to do next, like adding an antenna of different type/characteristics and/or of higher gain. This requires an extra small step for the integrator of the original module (i.e., Silicon Labs module customer) before the actual C2PC as follows. Basically, the TCB will issue a new grant to the authorized grantee based on Silicon Labs' existing grant and following the Silicon Labs authorization. This is a quick procedure by the TCB (just the time it takes to write the grant and file it to the FCC database), and the cost should not be more than a couple of hundred USD, which may be covered by the testing and C2PC costs if the TCB is part of the same family as the testing lab.

3.5.4 New FCC ID and Authorization

A new FCC ID and a new equipment authorization application to the FCC are required for the following changes:

- Frequency multiplication stages
- Basic modulator circuit
- Maximum power or field strength ratings
- Modifications to the RF path / layout that result in a non-electrically equivalent device will require completely new certification – particular changes can be confirmed by FCC by submitting a ticket here: https://apps.fcc.gov/oetcf/kdb/forms/InquiryForm.cfm to check what change can be considered as electrically equivalent and thus approved under C2PC.
- Basic frequency measurement and stabilizing circuitry (including clock and data rates).
- Changes described in Section 2.1043(a) that result in a non-electrically equivalent device.
- Different internal active hardware components (e.g., amplifiers and crystals) that result in different radio parameters (e.g., output power, frequency).
- Adding or subtracting an onboard amplifier component.
- Depopulated versions of a transmitter require authorization under separate FCC IDs for each version.
- Minor circuitry for non-transmitter portions (such as receiver or peripheral circuits) can be depopulated and may be approved under one FCC ID.

3.5.5 FCC Limitations

- Typical scenarios requiring extra testing with FCC in case of the following:
  - Co-location of radios.
  - Antenna change.
  - Product being used close to a human body.
- Limitations are described in the product's FCC grant.
- If restrictions cannot be met, the end customer typically needs to file C2PC.

3.5.6 Antenna Changes

- Additional equivalent antennas are allowed without new authorization.
  - Exception: Portable devices - SAR levels should be evaluated for PC, either Class 1 or Class 2 must be filed.
    - Any changes in antenna and/or key radiating or metallic structures for portable devices require SAR evaluation.
      - C1PC or C2PC is required.
  - Additional equivalent antennas must be of the same type and must be of equal or less gain.
  - Must have similar in-band and out-of-band characteristics.
- Listed antennas in the module's FCC grant can be used without any permissive change.
- Equivalent but non-listed antennas with the same type and non-higher gain can be used with C1PC.
  - If the documentation of a same-type antenna desired to be used can prove that it has similar in-band and out-of-band characteristics with non-higher gain and emissions compared to the certified antenna, then it only requires C1PC.
- New or different antenna type or antenna with higher gain (even if same type) requires C2PC.

3.5.7 PCB and HW Changes that Require a New Grant of Certification (FCC ID)

- Changes described in Section 2.1043(a) that result in a non-electrically-equivalent device.
- Different internal active hardware components (e.g., amplifiers and crystals) that result in different radio parameters (e.g., output power, frequency).
- Adding or subtracting an onboard amplifier component.
- Depopulated versions of a transmitter require authorization under separate FCC IDs for each version.
- Minor circuitry for non-transmitter portions (such as receiver or peripheral circuits) can be depopulated and may be approved under one FCC ID.

3.5.8 PCB and HW Permissive Changes

- Part substitution—electrically identical parts may be substituted.
- Small RF layout changes that result in an electrically equivalent device.
- Transmitter chip replacements are considered a Class 2 permissive change under the following conditions:
  - The new chip is pin-for-pin compatible, and no change in radio parameters has occurred.
  - The new chip has the same function as the old chip from an external perspective; internal frequencies may differ.
  - The same conditions apply when a small area (approximately the same as the chip) of the PCB is replaced with an equivalent chip.

3.5.9 Enclosure Changes

For non-full-modular approved devices, only minor changes to an enclosure are allowed with a permissive change. If the basic functionality and intended usage are not the same, a new FCC ID is required.

3.5.10 Software-Only Changes

- Additional frequencies may be added.
  - Additional frequencies are allowed with C2PC if the following are true:
    - No hardware changes have been made.
    - There is no increase in output power on new frequencies.
    - The Equipment Class remains the same.
    - RF exposure changes must be addressed.
    - Only the Original Equipment Manufacturer may implement the new frequencies.
    - There are no other changes that require new FCC ID.
  - End-user software implementation for new frequencies is not allowed unless the device was approved as a software-defined radio (Class 3 permissive change).
- Additional data rates (both higher and lower rates) under existing modulations that are consistent with a Form 731 line item/emission designator may be either a Class 1 or Class 2 permissive change, depending on emissions.
- A Class 2 permissive change is required if degradation occurs; otherwise a C1PC is acceptable.

3.5.11 Modules Tested for FCC: What Needs to be Done by the Customer?

- Products have unique FCC IDs.
- Grants and test reports are available.
- End users can use our FCC ID and test reports if radio co-location rules can be followed.
  - Instructions in product data sheets.
- If the rules in the FCC grant cannot be met, then C2PC testing is needed by the end customer.
- What about the SW configuration applied by the module integrator?
  - The compliance must not rely on statements about SW configurations in the user manual. The grantee is responsible for ensuring that the module is compliant.

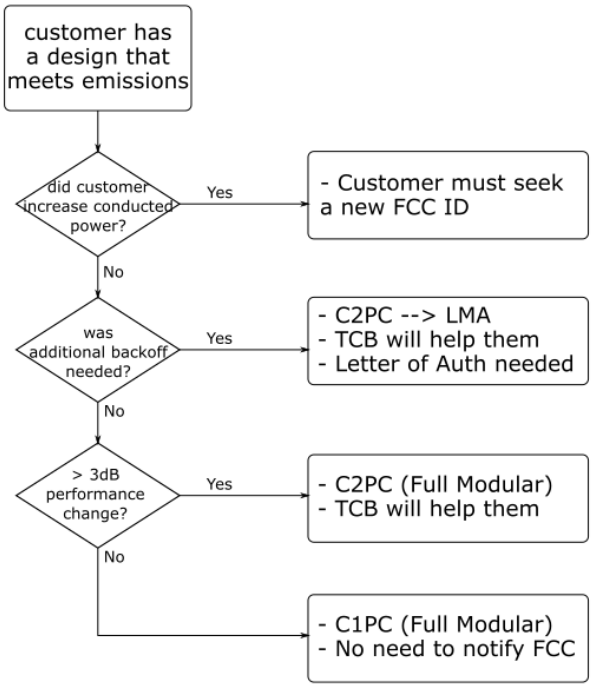


Figure 3.1. Flowchart: FCC-Approved Module into End-Product

3.5.12 Split Modular Approval

A combination of separate controller and front-end section to be used in any host and to be sold to anyone.

3.5.13 Limited Split Modular Approval

A combination of separate controller and front-end section to be used in a known host or known environment.

3.5.14 Recent FCC Changes Affecting Customer Test Requirements for Modules

- Changes in February 2019 which increase OEM responsibility in the certification process.
- OEM needs to test and cannot simply rely on vendor testing alone.
- Quote from 996369 D04: “Host product manufacturers are responsible to follow the integration guidance and to perform a limited set of transmitter module verification testing, to ensure the end product is in compliance with the FCC rules.”.
- Vendor not liable for misuse by customer.
- Officially, the grantee is still fully responsible, but these changes are open for discussion, and the authority has means to hold customers liable for any inconsistencies during market surveillance.
- References
  - 996369 D04 Module Integration Guide:nhttps://apps.fcc.gov/kdb/GetAttachment.html?id=zVUUifMY6Doa%2BO3Sg0Nygw%3D%3D&desc=996369%20D04%20Module%20Integration%20Guide%20V01&tracking_number=44637
  - 996369 D02 Module Q and A: https://apps.fcc.gov/kdb/GetAttachment.html?id=vwCq9pC68KkaN6E7YFmWHA%3D%3D&desc=996369%20D02%20Module%20Q&A%20v01&tracking_number=44637

3.5.15 Practical Examples

- A module without shield:
  - Because the criteria No. 1 (for FMA) is not met, the certification is LMA. The module integrator must go to an accredited test lab to conduct verification testing for radiated emissions. With FCC, there is no need for permissive change; basically, only the verification is sufficient.
- A module that will rely on module integrator to decrease the transmit power of band-edge channels for the end-product to remain compliant:
  - Because criteria No. 7 (for FMA) is not met, this is LMA. The grantee (i.e., the module manufacturer) is responsible for ensuring that the end product is compliant. It is up to the grantee (i.e., the module manufacturer) to figure out, together with the integrator, the best way to ensure that each end product remains compliant. Additional testing with the end product is not required, and permissive change application to add a new host is not needed as long as the design guidelines filed with the original LMA are followed and the final transmit power is not lower than indicated in the guidelines.
- A module without a label:
  - Removing the label from the product always requires pre-approval from the FCC. A module manufacturer can get a pre-approval by submitting a KDB inquiry to the FCC. Provided that the FCC will accept not labeling the module, because criteria No. 6 is not met, this will be an LMA. In this case, the sales package must be labeled instead. However, from the module integrator point of view, there is nothing different compared to MA, and there is no need for testing or permissive changes. The module manufacturer must make sure that the instructions are clear for the module integrator to label the end product correctly.
- A module without voltage regulation for the RF PA (Radio-Frequency Power-Amplifier):
  - Since criteria No.3 (for FMA) is not fully met, this would be LMA and limited to a specific host only. However, a pre-approval (explained below) was requested from the FCC to accept these kinds of modules as MA and FCC accepted with the explained condition that the RF characteristics other than the output power are not dependent on the supply voltage, and we are able to guarantee that the output power will never go beyond what has been certified for the module regardless of the supply voltage.

3.5.16 Countries Following the FCC Standard

United States of America, Anguilla, American Samoa, Bolivia, Cayman Islands, El Salvador, Federated States of Micronesia, Guam, Guatemala, Marshall Islands, Northern Mariana Islands, Palau, Panama, Puerto Rico, and Virgin Islands (U.S.).

3.5.17 Guidance and Useful Links

- Module Certification Guide: KDB 996369
- Labeling Guide: KDB 784748
- RF Exposure Guide: KDB 447498
- Software Control of Non-SDR Devices: KDB 594280
- Permissive Change Guide: KDB 178919
- Software Defined Radio Guidance: KDB 442812
- Test procedures for measuring a Digital Transmission System (DTS): KDB 558074
- Submit tickets, questions to FCC: https://apps.fcc.gov/oetcf/kdb/forms/InquiryForm.cfm
- Browse certified products in FCC: https://apps.fcc.gov/oetcf/eas/reports/GenericSearch.cfm

3.6 ISED

Innovation, Science, and Economic Development (ISED), formerly known as Industry Canada (IC), is the regulatory standard certification in Canada and is similar to the FCC in the U.S.

3.6.1 Full Modular Approval

A module that meets all six criteria set for a module:

1. The radio elements shall have the radio frequency circuitry shielded. Physical/discrete and tuning capacitors may be located external to the shield but must be on the module assembly.
2. If the module has modulation/data input(s), they shall be buffered in order to ensure that the module will comply with the requirements set out in the applicable Radio Standards Specification (RSS) under conditions of excessive data rates or overmodulation.
3. The module shall have its own power supply regulation on the module itself. This is to ensure that the module will comply with the requirements set out in the applicable standard regardless of the design of power supplying circuitry in the host product that houses the module.
4. The module shall comply with the provisions for external power amplifiers and antennas detailed in the applicable RSS. The equipment certification submission shall contain a detailed description of the configuration of highest antenna gain for each type of antenna.
5. The module shall be tested for compliance with the applicable standard in a standalone configuration, i.e., the module must not be inside another product during testing.
6. The module complies or will comply with applicable RSS-102 exposure requirements in its intended configuration/integration in a host.

3.6.2 Limited Modular Approval

A module that does not meet all six criteria for a module described above.

3.6.3 Standards

- http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf06129.html
- Applicable standards for BT and Zigbee are RSS-GEN, RSS-102, RSS-247, and RSP-100.
  - Modular approval requirements: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01130.html#s5.3

3.6.4 Permissive Change

Permissive change policy is similar to FCC and described here: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01130.html#s7.1

If not sure what level change is need, contact a TCB or ISED: ic.certificationbureau-bureauhomologation.ic@canada.ca

3.6.5 Similarity to FCC

ISED is similar to the FCC with a few differences, which are as follows:

- RF exposure requirements in ISED are stricter than those set forth by the FCC. Typically, more separation from a human body is required unless measuring the SAR.
- "Multiple Listing" corresponds to "Change in ID" which is discussed in the FCC section of this application note. Similarly, Silicon Labs' preferred approach in ISED is the "Multiple Listing".
- Labeling requirements are slightly different in ISED than in FCC. In ISED, the particular model of the device has to be labeled in addition to the ID.
- Using a module that is not equipped with a shield, e.g., a BGM121 or BGM122 SiP module, in a new host requires notification to ISED Canada to demonstrate how the module maintains the ISED conditions, which requires notifying ISED with a C4PC.

3.6.6 Practical Examples

- A module without shield:
  - Because the criteria No. 1 (for FMA) is not met, the certification is LMA. The module integrator must go to an accredited test lab to perform radiated emissions testing. Once the test reports are available, the module manufacturer must apply for a Class 2 Permissive Change to approve the new host. In practice, this will happen so that the module manufacturer will authorize an agent to make the application on behalf of the manufacturer. The agent can be the customer or a person in the test lab that the module integrator is using.
- A module that will rely on a module integrator to configure the transmit power of high channels to comply with the band edge:
  - Because criteria No. 3 (for FMA) is not met, this is LMA. The certification is limited to a specific host only, and every new host must submit a C4PC application to ISED. The module integrator must prevent incorrect configuration of the module, regardless of whether it is FMA or LMA.
- A module without a label:
  - The label is not mentioned in the six criteria, so this is FMA. ISED accepts not labeling the IC ID and Model number on the product if there is insufficient space. However, in this case, there must not be any other certification markings either. Using a QR code for the IC ID and HVIN is acceptable, but the QR code must not point to a web site to find the ID; it must read as an HVIN and IC ID in the QR code itself.

3.6.7 Useful Links

Browse certified products in ISED: https://sms-sgs.ic.gc.ca/equipmentSearch/searchRadioEquipments?execution=e1s1&lang=en

3.7 MIC Japan

MIC Japan (previously known as Telec) does not have modular approval. MIC Japan only has generic approval for a radio device. The requirement is that the radio must be able to operate as a standalone. This means, for instance, that even modules without metallic shield, like BGM121A and BGM123A, meet the MIC requirements and can be used as pre-certified components.

- There is no modular certification in Japan, just a generic radio type approval.
- To certify a module, it must operate as standalone.
  - Only the named antennas are approved. Additional antennas must be approved separately.
    - Typically consists only of paperwork and is based on the antenna data sheet.
  - Module integrators (customers or OEM) do not need to “re-certify” with the end product.

3.7.1 Limitations

The radio must operate as a standalone.

PSD limit is similar to EU 10 mW/MHz. However, because of the test procedure, this takes into account the duty cycle relaxation.

3.7.2 Japan-Specific Certifications

- A quality system declaration is required.
- An interference protection mechanism must be provided.
- A construction protection mechanism must be provided.

3.8 KCC Korea

Require in-country testing, so all testing shall take place in Korea.

- For end products, a client must also proceed with KC certification, even if they use certified modules.
  - However, the Radio test is waived and will appear as a KC certification number.
  - For example, in R-CXX, the meaning of C means that the radio test has proceeded.
  - Conversely, the second R in R-RXX signifies a radio test exemption or that the product does not use radio.
- If you are authenticating as a finished product, you will get a KC ID starting with R-RXX because you are using an approved module.

3.8.1 Limitations

A module without a metallic shield cannot be certified. SiP modules without shields, like BGM121 and BGM123, do not have Korean certifications and require RF testing the same as SoCs.

3.9 Brazil (Anatel)

Requires in-country testing and that the certification applicant and holder be companies residing in the country. Contact your test house for more details. Silicon Labs will share the design materials with the test house.

- Anatel ID is provided to the representative who will commercialize the product in Brazil.
- The holder of the Anatel ID will be responsible for warranty, support, and similar activities.
- Module customers do not need an authorization by the local representative to re-use the certification of a certified module. For end-products embedding modules that are not Anatel-certified, the end-product should be certified, and Silicon Labs can share the design material under NDA to the test house if requested.
- If the representative in the Anatel listing changes, it will require a new Anatel ID, and the label of the module must be revised accordingly.
- Anatel certification for modules is valid for two years (Category II).

3.10 China

Requires in-country testing and that the certification grant holder be a company residing in the country. Contact your test house for more details. Silicon Labs will share the design materials with the test house.

4. RF Exposure: Specific Absorption Rate (SAR) and Co-located Radios

Customer designs that use a certified module in co-location with another transmitter or are using a certified module closer to human body than the specific certificate allows must reevaluate the human RF exposure. See Silicon Labs module data sheets (and test reports), which define these in detail.

Different certifications have different SAR requirements. For example, the SAR exclusion thresholds are described in detail in FCC KDB 447498. ISED exclusion thresholds are described in RSS-102 Issue 5. RF exposure restrictions for each module are described in detail in relevant data sheets. If the end product does not meet the criteria described in the data sheet, customers must reevaluate the RF exposure with the end product, which may require SAR testing. The FCC and ISED must be notified, and C2PC is required to allow either co-location or use of the transmitter closer to a human body than what the module certificate allows.

4.1 RF exposure for FCC and ISED

Mobile devices

- More than 20 cm from any user.
- Typically, a calculation based on output power.
- A general calculation assessment based on power and distance.

Portable devices

- Less than 20 cm from a person.
- This is an exact measurement of a specific product.
- Antenna, enclosure, configuration-specific.

4.1.1 Most Modules are Therefore Mobile Devices

- Maximum Permissible Exposure (MPE) assessment at 20 cm. MPE limits are derived from the SAR limits in terms of free-space field strength and power density.
- Calculation based on output power and antenna gain.
  - With modules, antenna gain may not be known.
  - Worst-case values may be used.
- Grant Notes state that the module is “Mobile.”
  - More than 20 cm from users.
    - There is a power threshold to trigger a SAR assessment.
  - Must not co-locate with other transmitter antennas.
    - "Except in accordance with FCC procedures."
    - Common use of a C2PC.
- Modules may be co-located in real installations.
  - Transmit antennas within 20 cm of each other.
  - Transmit at the same time.
- Co-location can theoretically be handled at the time of Module certification.
  - Even if future co-locations are not known.
  - Typical co-location scenarios.
  - Grant notes state “No co-location, except as detailed in filing.”
- Any co-location that has been calculated at certification time does not require a Permissive Change.

4.1.2 It is Possible to Certify a Module as Portable

- If the output power of the module is below the power threshold to allow Portable use without SAR testing.
  - Section 4.3 of KDB 447498.
- Based on maximum transmitter output power, antenna distance from the user, and transmitter frequency.
  - This could allow Portable use in any host.
  - May require installation control and/or professional installation.
    - Power to be added to other modules for co-location.
- If the output power of the module is above the power threshold to allow portable use without SAR testing.
  - Then SAR testing of the module may be possible.
- SAR testing of the module with an antenna: Limitations are based on SAR result.
- Lower SAR result allows greater flexibility.
  - <0.4 W/kg = any host.
  - <0.8 W/kg = any range of suitable hosts.
  - <1.2 W/kg = single platform type.
  - <1.4 W/kg = re-test for any host.
- SAR is specific to antennas: Only certified for use with tested antenna(s). Other antennas can be approved through C2PC.
- Grant notes list SAR and hosts.

4.1.3 Mobile Module in a Portable Host

- Module certified as Mobile at >20 cm.
- Installer wishes to put the module in a Portable Host.
  - The Grant notes might say “more than 20 cm.”
- Is the output power above the threshold?
  - If not, then SAR is not required.
- If power is above threshold, then SAR testing is needed.
  - Perform SAR test on a host and module combination.
  - Module Grantee to complete a C2PC.
- If the host uses proximity sensors, the module will require new FCC certification with that host and agreements with OEM.

4.2 RF Exposure for CE

If transmit power is higher than +13 dBm (20 mW), RF exposure needs to be evaluated.

- Typically requires SAR testing.
- Depends however on the end product and use case, such as proximity to a human body.
- RF exposure evaluation should be sought from a suitable test laboratory if the product’s TX power exceeds 13 dBm.

Multiple radios used in a single end product:

- If co-located radios are transmitting simultaneously, RF exposure must be reevaluated.
- If co-located radios are not transmitting simultaneously, RF exposure should be evaluated independently for each radio.

5. RF Module Certification FAQ

5.1 Why do I Need to Test at All? Can't I Just Rely on Silicon Labs Certification?

Radiated measurements as spot-checks are recommended for products intended to be sold in regions with modular certifications (USA, Canada, Japan, etc.). The FCC especially emphasizes this. Based on module grant limitations, further SAR measurements might also be needed. For regions in the EU using the CE DoC approach, it is always recommended that the OEM check the radiated performance of the module in its final product (given that the end-manufacturer is ultimately responsible for the compliance of their end-product and for their signed DoC), while the conducted results can be inherited from the module CE test reports.

5.2 Where Do I find Silicon Labs Certificates and Test Reports?

Certificates, DoC, and test reports are available in zipped format files under the technical resource search of our public webpage at https://www.silabs.com/support/resources.ct-module-certifications.

5.3 For What Regions or Countries Does Silicon Labs Typically Certify?

Europe (CE), USA (FCC), Canada (ISED), Japan (MIC), and South Korea (KCC), and, occasionally, according to customer-based demand, Taiwan (NCC) and Brazil (Anatel).

5.4 What is the Process if a Customer Wants to Certify on Their Own for a Country or Region for which We Have Not Certified?

The customer needs to contact a test house and/or TCB of their choice for further guidance and to guide them through the certification process.

5.5 Are Silicon Labs Modules SRRC or CCC Certified?

No, our products are not certified for China. For China certification, the customer must contact their test house for further guidance and might have to provide some documentation when applying for the radio approval. We are ready to sign any module manufacturer document that the test house might require.

5.6 Do I Need to Do My Own Certification if I Use a Different External Antenna?

See the product's FCC grant (this should be available under www.silabs.com); any limitations are described there. If those cannot be met, then the grant requires a permissive change to extend its validity to a new host. External antenna change is a typical case of C2PC. However, if documentation of the same antenna type as that planned to be used can prove that it has similar in-band and out-of-band characteristics with non-higher gain and emissions compared to the antenna the module is currently certified with, then it will only be C1PC, which does not require application to the FCC. A different antenna type requires C2PC in any case. Using a different antenna with higher gain will typically lead to a change in FCC ID, so please consult your test house and/or TCB for the required path to compliance.

For the FCC, it is a C2PC according to KDB 996369 and KDB 178919. Silicon Labs favors applying and getting authorized for "Change in ID" in FCC (or "Multiple Listing" in ISED) before the actual C2PC for new antennas to ensure a free and more flexible approach and processes for the integrator of the Silicon Labs module. See 3.5.3 Permissive Changes in this document.

For the CE, the end product manufacturer must have all the test evidence that is needed to show compliance. Having a new antenna means radiated emissions testing. The conducted test can still be inherited from the module test reports.

5.7 What External Antenna are Modules Typically Certified with by Silicon Labs?

We typically certify modules using a standard +2.14 dBi dipole. According to the FCC, any antenna of the same type with equal or less gain and the same in-band and out-of-band characteristics can be used without notifying the FCC since it is a C1PC only. If using an antenna of a different type, it will be C2PC (recommend signing for "Change in ID" before the actual C2PC). Silicon Labs will provide an authorization letter so that the customer can apply for "Change in ID" and then C2PC on their own (preferred approach) or for the C2PC on behalf of Silicon Labs. To do this, the module must be tested with that particular antenna. It can either be tested in the host or as a standalone with just the module. Once the test report is available, the customer (or the authorized agent in the test lab) will make a TCB application. Often, the TCB is a person in the test lab or a third-party company, who can be used for the TCB application. The TCB will provide the C2PC grant, and the listing will then be visible in the FCC listings, and the new FCC ID will be added in the FCC database. The cost is approximately ~4–6k USD. In Japan, only certified antennas listed in the MIC database may be used, but the module Grantee is authorized to add new antennas to the certificate based on data sheet review of the new antennas (with keeping the max EIRP, max conducted power + max antenna gain, under the regulation limits).

5.8 If We Use an External Antenna with BGM121, Will the Existing Silicon Labs Approvals Still Apply?

With CE, our customers will reuse our test reports for what concerns conducted test, while their end product will, in any case, have to undergo retesting for radiated tests regardless of the antenna in use. This is valid for all modules. Customers should not have surprises during testing if using one of the approved antennas mentioned in the data sheet, basically, all dipole antennas with gain equal to or less than +2.14 dBi. With FCC and ISED, we only have limited modular approval for the BGM12x. For example, the FCC grant states that “This module is not shielded and therefore requires radiated emission tests in each new host product” meaning that, as with CE, the customer will anyway have to perform the radiated tests and then apply for a permissive change to use our FCC ID. For other countries, we have no certifications, except for Japan, but only for the BGM12xA version because, at the time of certification in Japan, the radio device had to be capable of operating standalone, and this was not the case for the BGM12xN with an external antenna.

5.9 What Are the Steps for Regulatory Compliance with CE?

- Contact an accredited test laboratory for CE testing services.
- EN300328 conducted test cases can be inherited from the module test report.
- All radiated test cases of EN300328 and EN301489 must be tested with the end product in an accredited test laboratory.
- Safety/RF exposure (if needed) must be tested with the end product in an accredited test laboratory.
- Write a DoC based on the passed test reports. The person who signs must be traceable, and the test reports with the technical information must be saved in a TCF.
- Label the end product with the CE logo.

5.10 What Are the Steps for Regulatory Compliance with FCC/ ISED?

- Read the FCC grant and the FCC info in the module data sheet if there are restrictions that must be taken into account with the end product.
- If there are no restrictions that concern the end product, the labeling of the end product with ”Contains FCC ID: QOQ....” is all that is necessary.
- If there are any restrictions that concern the end product (co-location or RF exposure limit), contact your local test laboratory for services to remove the restrictions.
- The FCC also recommends that OEMs perform spot checking via radiated measurements of the final product as well.

5.11 What Are the Steps for Regulatory Compliance in Japan and Korea?

No further RF testing is needed when using a certified module in Japan or South-Korea.

5.12 What Are the Steps for Regulatory Compliance in Australia and New Zealand?

- Contact your local representative / importer. The local representative or importer is to be registered by the regulatory authority; must be aware of the local regulations, and is ultimately responsible for compliance by holding the evidences and signing the DoC.
- CE test reports can be used as evidence of compliance, either directly or as a basis for generating official test reports, depending on the corresponding ACMA standards.

5.13 What Test Houses Do You Recommend?

SGS, Bureau Veritas, Dekra, Element, TUV-SUD, and NCC Certificacoes do Brasil are some of the most frequently used certification houses.

5.14 In FCC, Does an RF Layout Change Require a Complete New Certification or Only C2PC?

It depends on the type of layout change. For example, we were able to make C2PC with a balun that required a new layout because the new balun was not pin-to-pin compatible with the original. C2PC KDB says: “changes that result in a non-electrically equivalent device require a new grant of certification”. What is considered electrically equivalent can be taken up with the TCB or FCC directly. A test lab will most likely say that it requires full testing with a new FCC ID (they cannot speculate), so it might be better to instead ask the FCC by submitting a ticket here: https://apps.fcc.gov/oetcf/kdb/forms/InquiryForm.cfm. If the FCC says it is acceptable, then any TCB will also accept it.

5.15 How Long Do the Certification Process and Paperwork Take?

Roughly 7–14 weeks, based on the availability of the accredited test house.

5.16 For Battery-Powered Devices, Can a Lab Power Supply Substitute for the Battery in Conducted Tests?

Testing is typically carried out with a laboratory power supply.

5.17 Can You Recommend Useful Links for KCC Korea Certifications?

- FAQ page: https://www.rra.go.kr/ko/notice/D_e_faq2_4.do
- Radio Waves Act / Enforcement Decree / Regulation
  - http://www.law.go.kr/lsSc.do?tabMenuId=tab18&query=%EC%A0%84%ED%8C%8C%EB%B2%95#undefined
- English Version of Radio Waves Act
  - http://www.law.go.kr/engLsSc.do?tabMenuId=tab45&query=%EC%A0%84%ED%8C%8C%EB%B2%95#
- English Version of Enforcement Decree of Radio Waves Act
  - http://www.law.go.kr/engLsSc.do?tabMenuId=tab45&query=%EC%A0%84%ED%8C%8C%EB%B2%95#
- Notification on Indication of Radio Conformity from National Radio Research
  - http://www.law.go.kr/conAdmrulByLsPop.do?&lsiSeq=204681&joNo=0077&joBrNo=05&datClsCd=010102&dguBun=DEG&lnkText=%25EA%25B3%25BC%25ED%2595%2599%25EA%25B8%25B0%25EC%2588%25A0%25EC%25A0%2595%25EB%25B3%25B4%25ED%2586%25B5%25EC%258B%25A0%25EB%25B6%2580%25EC%259E%25A5%25EA%25B4%2580%25EC%259D%25B4%2520%25EC%25A0%2595%25ED%2595%2598%25EC%2597%25AC%2520%25EA%25B3%25A0%25EC%258B%259C%25ED%2595%259C%25EB%258B%25A4&admRulPttninfSeq=9102#J1962784

5.18 What External Antennas Can be Used with a Certified Module in the USA/Canada and Japan?

In Japan, only the external antennas listed in the MIC database can be utilized under the original certification of module. If antennas other than the basic dipole antenna are in the list, we will describe them in the public archive containing the certificate(s) and test report(s).

In the USA and Canada, besides the listed antennas, any antenna of the same type with equal or less directional gain (and with similar in- and out-of-band characteristics) can be utilized under the original module certification with C1PC only.

5.19 Is CW (Continuous Wave Tone) Mode Required for Compliance Testing, or Is It Only Something "Nice to Have" Since it Makes Some Measurements Easier?

CW is required in Korea. In any other region, CW is not required in any testing.

5.20 What Software Should I Use for Testing? How Do I Enter Test Modes for Testing in a Lab?

- Need to provide the test house with: test modes and test guidance.
- Powering of the module directly from a laboratory power supply.
- TX modes
  - Fixed frequency:
    - Modulated output with maximum duty cycle / maximum data rate; all modulation types selectable.
    - Unmodulated carrier.
- Frequency hopping:
  - Modulated output with maximum duty cycle/maximum data rate; all modulation types selectable.
- RX mode
  - Data connection between EUT and reference module with the capability to monitor the link quality (preferably PER).
  - ESD immunity
  - EM field immunity
  - Adaptivity
- **Note:** Test modes can be configurable and do not need to be restricted to remain compliant. As long as the instructed test modes represent the normal operational mode, then it is OK. CW mode is only required in Korea; other regions do not require CW mode capability.

- **Note:** Module integrators are recommended to test the products in their normal operational mode (for example by setting up a link with maximum data throughput to an access point).

5.21 What is the ITSS Standard and Do Silicon Labs Modules Support It?

ITSS is the European standard for Intelligent Transport System, which is meant to standardize the exchange of information between road users and roadside infrastructure and is achieved by a regular exchange of information from vehicle to vehicle (V2V) and between vehicles and roadside infrastructure (V2I and I2V) based on wireless networks. This is not related to regulatory radio approvals; it is more of an application matter, and hence marketing people should be consulted.

5.22 What is the Typical Process if I Need to File C2PC with a Silicon Labs Module?

For C2PC, our general approach is to sign an authorization letter for the customer to do that on our behalf with the help of their TCB (Telecommunication Certification Body). Their TCB will have a template of an authorization letter that the customer will pass to us via the Salesforce system, and then we will review it; fill in our letterhead, and sign it.

Please be aware that Silicon Labs prefers authorizing for "Change in ID" or "Multiple Listing" for antenna changes before the actual C2PC. "Change in ID" or "Multiple Listing" allows a more flexible approach for the module integrator for additional future changes. See 3.5.3 Permissive Changes.

5.23 Do Silicon Labs Modules Satisfy UL Conformity Requirements?

It is not a requirement for the modules to conform to UL, as this is not an official regulatory matter (UL standards are more like private standards for safety). In fact, there is no test and/or certification on our side with regards to meeting UL safety requirements. In general, it applies to the end product, and there is no reason why a product with one of our modules embedded in it would not be capable of obtaining a UL certification because of the module itself.

5.24 Can Silicon Labs Prepare and Sign an Authorization Letter for a Customer?

Yes. The preferred method is to communicate this through the Salesforce system. Silicon Labs is open to reviewing, filling in, and then signing authorization letters for customers.

5.25 Does the Customer Need to Retest the End Device with the Silicon Labs Module Inside It, or Is a DoC (Declaration of Conformity) from Silicon Labs Enough in CE?

Even if the end device has a Silicon Labs module inside it, it is the customer's ultimate responsibility to make sure that their end product is compliant with that particular standard. Such conformance must be supported by evidence, i.e, test reports showing that the end-product as a whole is compliant, not just the module. This is valid for all modules, not just the SiP. It is recommended to at least perform radiated measurements with the final end product, whereas the conducted measurement test results can still be used from our test reports. If the customer's HW is not different from our EVB and the customer is confident that they have not changed anything from an RF perspective, they can take the risk of writing the DoC by themselves based on our module's test reports without additional testing being performed.

5.26 Do Customers Need to File for C2PC and Retest Their End Product with a Module that Has Limited Modular Approval (LMA), e.g., BGM12x?

- As BGM12x does not have a shield, it has Limited Modular Approval (LMA). Thus, customers should always verify that their end product is still compliant and that there are no additional emissions. Whether filing C2PC is mandatory or not, it depends upon the regulatory body's requirements.
- In FCC, if the end product is using an LMA module (due to lack of shield), it is not necessary to do a C2PC if the host manufacturer verifies that there are no additional spurious emissions.
- In the grant, we read "Limited Modular Approval: This module is not shielded and therefore requires radiated emission tests in each new host product", and, in addition, the new KDB 996369 D04 requires spot checking for any module's host. So, a verification of the final product must be done by spot checking emissions from the device while operating the host as a complete system. This testing is performed with the host product configured in typical operational modes to check the fundamental frequency and spurious emissions for compliance with all applicable rules.
- If the spot checking result suggests that the TX limits are under regulations, then the customer might just have to do a C1PC, or nothing, whatever is appropriate based on the result.
  A C2PC is required only if there are additional spurious emissions detected by spot checking of the final end product.
- In ISED, if the end product uses an LMA module (due to lack of shield), the customer must test their final product and provide the test results to the TCB for a C2PC change.
- If the customer is getting their end product certified for both FCC and ISED, since the customer has a test report for the ISED's C2PC, the customer may still do an FCC C2PC (to be on a safe side), but it is not mandatory as long as there are no additional spurious emissions.

5.27 What Additional Tests Are Required for a Module-Based Product Using a Silicon Labs Module with Single/Full Modular Approval in FCC?

No complete RF testing (nor permissive change) is needed for the host system, as long as the limitations in the grants are respected, such as the co-location requirement that modules in the same PCB do not transmit at the same time; otherwise, it is true that additional testing is required. However, spot checking in radiated measurements is recommended by the FCC. They will also have to consider the minimum distance from a human body at which the host (the end-product) will normally operate. Analysis for the FCC exemption of the SAR evaluation may be required.

5.28 My Test House Needs Design Files of Silicon Labs Modules for Certification Purposes. Where Can I Find These?

- Module design files are not to be shared with any end customer, since these are Silicon Labs IP, and design files can only be shared under NDA, preferably directly and only with the test house (or notified/certification body).
- So, if module design files are requested for certification purposes, please make sure you have an NDA in place with us via local Silicon Labs Sales representative and/or Regional Field Marketing. Then, the files can be shared through a Salesforce case.
- Here is the procedure for a test house (or notified/certification body) to obtain the confidential documentation needed to certify a product embedding one of our modules/SoCs on behalf of a customer:
  1. NDA exists between the test house (or notified/certification body) and Silicon Labs, signed by the respective legal representatives.
  2. A test engineer from the test house (or notified/certification body) opens a new Salesforce case at http://www.silabs.com/support using the “Request Support” button. No end customer's email should appear in the cc list.
  3. The test engineer from the test house (or notified/certification body) attaches the NDA to the newly created Salesforce case and adds a comment with the request for the exact documentation required while referring to the end customer, the end product, and the embedded module.
  4. Silicon Labs technical support team provides the requested documentation as attachment(s) via the Salesforce case.
- The steps described above are normally communicated by the customers to their test house (or notified/certification body), and again, if needed, the customers are supposed to pass to their test house (or notified/certification body) the details of their direct Silicon Labs Sales contact, because, ultimately, it is Sales personnel who assist with NDAs.

5.29 Are All Modules Certified for Worldwide Operation?

The modules are typically certified for Europe (CE), USA (FCC), Canada (ISED), Japan (MIC), and South Korea (KCC). Occasionally, based on customer demand, we may certify for Taiwan (NCC) and Brazil (Anatel). For the radio approval of end-products in other regions, please consider the GMA (Global Market Access) services provided by the global test houses.

5.30 What are the TX Power Limitations of Silicon Labs Modules for Regulatory Compliance in the USA and EU?

Due to the Power Spectral Density (PSD) and band edge limits of FCC and CE regulatory standards, the maximum allowed TX power also needs limitations as described in the KBA here: https://www.silabs.com/community/wireless/bluetooth/knowledge-base.entry.html/2019/03/26/using_afh_considerin-emyv.

5.31 How Do Adaptive Frequency Hopping (AFH) and FCC Band-Edge Limits Affect the Max Power of a Module?

When applying AFH, the maximum allowed TX power of a module can be higher, and the limitations are described in the same KBA here: https://www.silabs.com/community/wireless/bluetooth/knowledge-base.entry.html/2019/03/26/using_afh_considerin-emyv.

5.32 I Need to Fill Annex E Section of EN300328 Standard, but Silicon Labs CE Test Reports Are Missing this Info. Where Can I Find the Information Needed for this Purpose?

It is typically not provided for our modules for Zigbee or BLE, etc., since these are well-known standards, and this application form (not a technical document) is only intended to help the test houses in preparation, but most test houses are aware of these standards.

5.33 When is SAR Testing Required?

- In case of co-location, only RF exposure needs to be reevaluated to define the minimum separation distance to human body when combining the RF output power of the two radios.
- If the radios are not transmitting simultaneously or are at least 20 cm apart, then they are not considered to be co-located. SAR testing is only needed if the calculations shown in KDB 447498 result in minimum separation distance, which is more than what the application requires.
- If radios are co-located, you simply add their transmit powers and calculate again to see whether SAR is needed.
- In general, Silicon Labs does not provide SAR reports, except for RF Exposure assessments with the minimum distances from human body for the exposure testing exemption. If a customer needs to place the transmitter closer, then they will have to test the SAR themselves with the end-product and apply for a C2PC with the FCC.

5.34 We'd Like to Use an Antenna that Is Not Covered by the FCC Certificate, So We Need C2PC to Get Our Product FCC-Approved. What Should We Do?

- We typically do not do C2PC ourselves for our customers, but we let our customers do the C2PC on our behalf. Furthermore, Silicon Labs prefers and recommends getting the Silicon Labs module integrator authorized for "Change in ID", and the C2PC can be done by the module integrator. This requires an extra small step for the integrator of the original module (i.e., Silicon Labs module customer) before the actual C2PC as follows. Basically, the TCB will issue a new grant to the authorized grantee, based on Silicon Labs' existing grant and following the Silicon Labs authorization. This is a quick procedure by the TCB, just the time to write the grant and file it to the FCC database. The cost should not be more than a couple of hundred USD. Then, the new grantee will be fully responsible for the module and will be performing the following steps for C2PC in the below list and able to do any further changes independently from Silicon Labs.
- Contact your TCB and discuss your case with them (if you are not yet in touch with a TCB, we can recommend www.acbcert.com, as we use them, and they are familiar with our products).
- They will recommend the proper permissive change and indicate what, if any, test(s) to perform.
- They will provide you with the template of a letter of authorization that you will forward to us via a Salesforce case.
- We will sign the letter to authorize you and the TCB to make the permissive change.
- You will perform any required test(s) and finally provide the test report(s), the signed letter, and any other form that you will have filled out to the TCB for them to finalize the permissive change.

5.35 What Is the Correct Test Method for Band-Edge Measurements in FCC?

- Marker-Delta method based on whitepaper, measuring with lower RBW and then compensating back for RBW = 1 MHz: https://www.fcc.gov/Bureaus/Engineering_Technology/Public_Notices/2000/da000705.doc
- AVG detector (i.e., VBW = 10 Hz) + DCCF (duty-cycle correction factor, average in a 100 ms moving window) can simultaneously be applied. Acceptance can typically be obtained from the FCC by submitting a ticket here: https://apps.fcc.gov/oetcf/kdb/forms/InquiryForm.cfm
  - FCC pre-approval may be necessary at 388624 D01 Pre-Approval Guidance v11r01
    - EXAMPLE: Official FCC guidance clearly states that duty cycle relaxation is not allowed on band edge testing. However, the FCC silently accepts it, and not all test labs are aware that it is accepted for BLE and Zigbee. The formal route to apply for permission to use duty cycle relaxation at the band edges is as follows:
      - Prior to testing, submit a KDB inquiry to the FCC.
      - The FCC will respond with the tracking number.
      - Let the test lab know that you have FCC permission to test with duty cycle relaxation.
      - The FCC certification application form has a field "is there KDB inquiry associated with this application?". When applying the certification, check the box and include the tracking number for the FCC response where the FCC states that the duty cycle is accepted.
- Silicon Labs modules tested with TX packets with maximum duty cycle.

5.36 What is the Guidance If a Customer Has Multiple Radios in Their Product?

- If the grant doesn't allow colocation, you can find the grant conditions here: https://apps.fcc.gov/oetcf/eas/reports/GenericSearch.cfm
- Usually, the multi-transmitter procedure means only reevaluation of RF exposure.
- For the details, you can find the FCC KDBs here: https://apps.fcc.gov/oetcf/kdb/forms/AdvancedExternalSearch.cfm
- The RF exposure guide is KDB 447498.
- We recommend that you contact a TCB or FCC test lab for details about your product. The co-location can be a C1PC with a simple calculation, or it may require C2PC with SAR testing.
- In case of co-location, only RF exposure needs to be reevaluated to define the minimum separation distance to human body when combining the RF output power of the two radios.
- If the radios are not transmitting simultaneously, then they are not considered to be co-located. SAR testing is needed only if the calculations shown in KDB 447498 result in a minimum separation distance that is more than what the application requires.
- If radios are co-located, you simply add their transmit powers and repeat the calculation to see whether SAR is needed.

5.37 What Kind of Transmitter Operation Should be Supplied for FCC Tests?

- Conditions
  - Transmitter supplied for the tests shall be a representative type of a production version.
- Output power
  - Transmitter shall deliver maximum achievable output power.
  - The power measured during the tests is declared as a maximum allowable power in the FCC Grant.
  - Transmitter adjusted to produce the nominal output power plus tolerance following tuning procedure shall be provided for tests.
  - Transmitter sample, which yields maximum output power within batch, shall be provided for testing if output power is fixed.
- Operating frequency
  - Lowest, highest, and middle band frequency.
- Modulating (baseband) signal
  - Transmitter shall be able to produce each type of modulation it supports.
  - Unmodulated carrier is useful for frequency tolerance tests.
- Data rate
  - Minimum and Maximum
- Duty cycle
  - Maximum available under normal conditions.
  - Continuous transmission (100% duty cycle) of modulated carrier.
  - Transmitters operated intermittently shall be modified to provide repetitive transmission, preferably at a repetition rate of at least 20 Hz.

5.38 When is "Recertification" Needed?

- Any changes to the existing grant are called Permissive Changes.
  - FCC guidance for permissive changes: KDB 178919
  - Permissive changes are allowed within 1 dB margin of the original reported output power.
- When is Permissive change needed?
  - If the end product assembly does not meet the module grant conditions, a permissive change is needed to remove the restrictions from that particular assembly.
  - Module HW / FW changes that have an impact on originally reported RF characteristics.
  - Adding a new antenna type or adding an antenna with higher gain than the previously listed antenna.
- Who will do the Permissive Changes?
  - The original grantee (the manufacturer who owns the FCC ID) is responsible for all permissive changes.
  - A module integrator can apply for a permissive change with an authorization of the original grantee.
  - A module integrator can take ownership of the certification by applying Change of ID.
- What changes will require a completely new FCC ID?
  - If the change results in higher power than allowed in the original grant, it will require a new FCC ID.
  - Changing active RF components requires a new FCC ID.
  - Making changes that result in a design that can no longer be considered electrically identical to the original will require a new FCC ID.
- If you are not sure what level change is needed, contact the FCC: https://apps.fcc.gov/oetcf/kdb/forms/InquiryForm.cfm

5.39 Why Is the Wi-Fi Use Case Unique?

- Wi-Fi modulation can be affected by matching issues.
  - 802.15.4 and BLE are constant-envelope modulation where a bad match does not typically cause issues with modulation and spectral emissions (it only affects range).
  - Wi-Fi modulation is not constant-envelope, and, therefore, a bad match can cause much worse Error Vector Magnitude (EVM) and Spectral Emission Mask (SEM) performance and spurious spectral content issues and can fail regulatory limits (in addition to affecting range).
    - For example, amplitude-modulated information can become seriously degraded due to PA distortion, which can be caused by an antenna or PA mismatch.
- PA sensitivity to VSWR.
  - The PA of integrated radio chips embedded into wireless modules is typically sensitive to VSWR magnitude and phase.
  - If the recommended layout and design guide is not followed, the resulting antenna VSWR may be higher than 2:1 (return loss of 9.5 dB), which degrades performance and requires power back-off to avoid PA distortion.
  - Typically, RF/antenna performance strongly depends on the host board.
- For a Silicon Labs Wi-Fi module example of WFM200 SiP, please see *UG395: WFM200 Hardware Design User's Guide* for additional details.
  - "If the hardware design guide is not properly followed, the resulting VSWR may be higher than 2:1 over operating conditions, which would require Tx Output Power to be reduced using PDS file Back Off, and possibly agency approval."

5.40 Assume a Customer is Using a Module that Doesn't Have a Shield, which We Didn't Certify, and For which the Customer Applies Their Own Certification. If We Change the BOM, Does it Trigger Recertification for the Customer?

Since the customer is fully responsible for the certification in this case, they should use their own judgement or check with relevant certification bodies or authorities about the need for permissive changes based on the PCN information that we give to them. In general, parts that are not within the RF path and do not affect the RF/EMC characteristics can be changed to be similar to the same footprint without notifying authorities.

5.41 If the PCB is Changed to Widen the Solder Mask Opening to Enable Better Soldering of the Device, the Part Revision Changes. Does this Cause Recertification for the Customer?

This would be a change that does not affect RF/EMC characteristics, so this change can be made without notifying authorities.

5.42 If We Own Certification for the Module and We Apply for a Permissive Change Due to Some Change in the Module, Does this Activity Happen with No Impact to the Customer? If We Do Not Have a Precertified Module, and We Change Something in the Module, Can the Customer Apply for a Permissive Change Based On Information From Us?

This is correct. Our permissive changes do not cause any impact to our customers. Yes, if we change a non-certified module so that it would require filing a permissive change, the customer should apply for the permissive change based on the information that we give to them.

5.43 Which Regions in the World Recognize Certified Modules?

This is a question that is difficult to answer in just few sentences. Even if some authorities don't recognize Modular Approval, it doesn't mean that a module can't be certified or that the customer doesn't get any benefit from the certification of a module. A good example is Japan. Japan doesn't recognize Modular Certification. A module is subject to the same type approval as any other radio product. When a module is certified, the module integrator can install it into the host product without a need for "recertification". The difference between the Modular Certification in FCC and the type approval in Japan is that, in the case of FCC approval, the customer can install the module into the end product with certain conditions, which are stated in the module's FCC grant. In Japan, there are no specific installation conditions. It is simply a certified radio that the customer will use as-is. Another good example is CE. Since CE is not a certification in the first place, obviously, there is no Modular Certification either. However, the module integrator can still inherit most of the module's test results into the test report of the end product.

5.44 Does the Definition of Certified Modules Always Include a (Metallic) Shield?

The shield is required for module certification in South-Korea and for Single/Full Modular Certification for FCC/ISED/NCC/SRRC. There are no shield requirements in MIC/CE/ACMA.

6. Technical Resource Search for Test Report, DoC, and Certificate

Compliance tests reports, DoC and certificate documents for all Silicon Labs modules are publicly available under the “Technical Resource Search” page of www.silabs.com.

Direct link for module certification documents: https://www.silabs.com/support/resources.ct-module-certifications

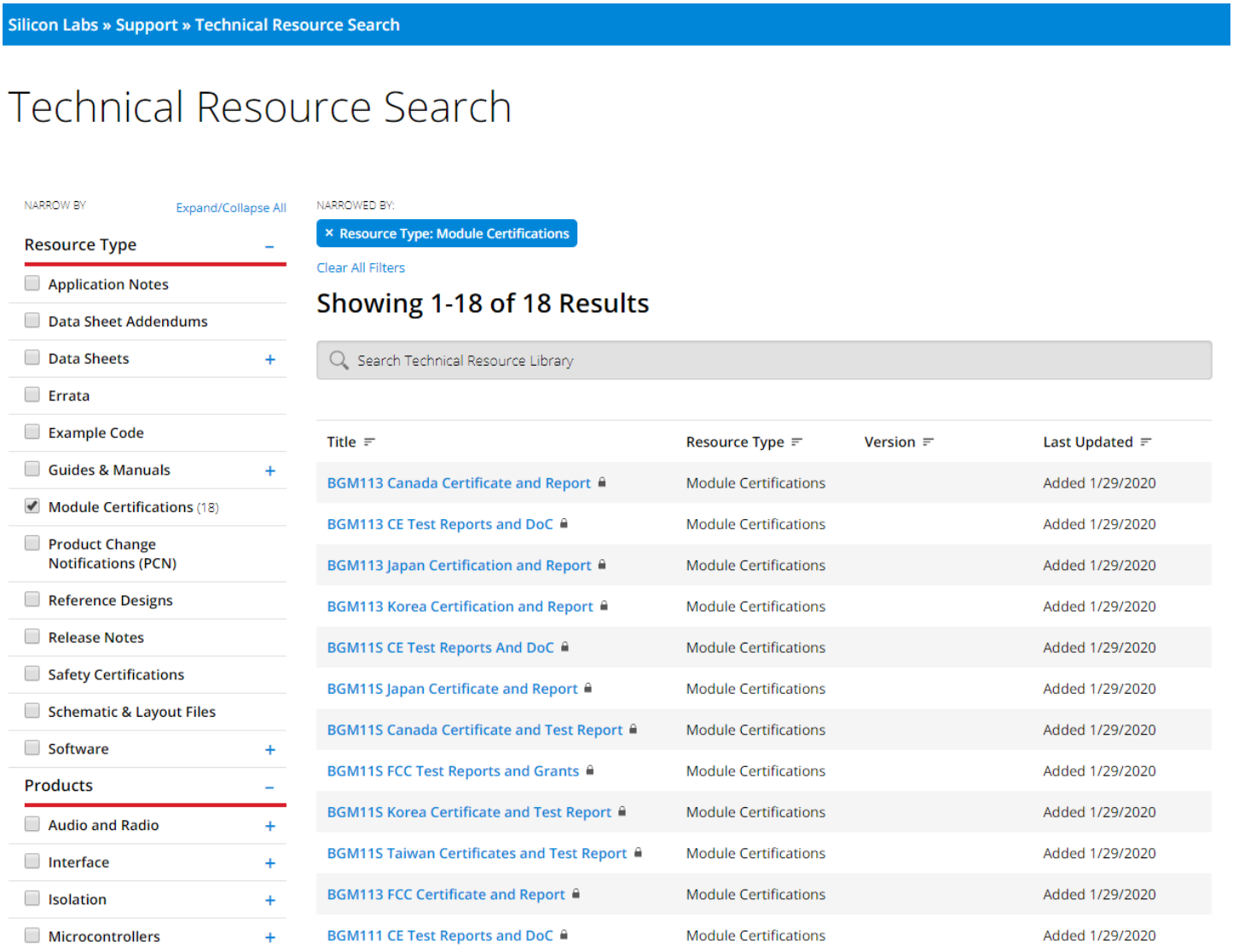


Figure 6.1. Technical Resource Search for Module Certifications Documents

7. Appendix 1: FCC Part 15.247 Requirements in the 2.4 GHz Band

7.1 This FCC Part Covers Wide Bandwidth Applications

- Frequency Hopping Spread Spectrum (FHSS)
- Wideband digital modulation (6 dB modulation BW > 500 kHz)
- Intent of this specification is to spread out the power.
  - The more the power is spread out, the more TX power is allowed.

7.2 Basic Rules of FHSS

- Must hop by the greater of: 25 kHz or 20 dB bandwidth of the signal (15.247.a.1).
  - Can be reduced to (2/3) x 20 dB BW, if Pout < 125 mW
- Maximum allowed 20 dB bandwidth = not specified
- You must hop over a minimum number of channels (15.247.a.1.iii).
  - Min = 15 channels → allowed TX power limited to 125 mW (+21 dBm)
  - At least 75 channels → allowed TX power increased to 1 W (+30 dBm)
- You must visit each channel with equal probability (15.247.a.1).
- The list of channels must be pseudo-randomly ordered (15.247.a.1).
  - The list of channels may be heuristic or adaptive (but not required) (15.247.h).
  - That is, if one channel is blocked, you may substitute another channel in the list.
- Transmitters cannot stay on any one channel for longer than 400 msec (15.247.a.1.iii).
- Receiver bandwidth must correspond to transmitter bandwidth (15.247.a.1).
- The receiver must hop in synchronization with the transmitter (15.247.a.1).

7.3 Basic Rules of Wideband Digital Modulation

- Maximum allowed conducted power is 1 watt (+30 dBm) (15.247.b.3).
- Any form of modulation is allowed (FSK, GFSK, BPSK, QPSK, etc.).
  - Direct Sequence Spread Spectrum (DSSS) is allowed but not required.
- The 6 dB bandwidth of the signal must be ≥ 500 kHz (15.247.a.2).
- The power spectral density (PSD) must be ≤ +8 dBm/3 kHz (15.247.e).
  - That is, the FCC desires the power to be “spread” over a wide bandwidth and not concentrated in a few spectral peaks.
- This constraint on PSD may limit the output power level to < 1 watt.
  - Maximum power is possible when each 3 kHz “bin” contains equal power.
  - That is, a flat power spectral density across the bandwidth.
- Modulation spectral shape is highly dependent upon data rate and deviation.
  - Some combinations have relatively flat PSDs.
  - Other combinations have fairly high spectral peaks.
  - Flat power spectral density modulations for BLE (MSK, FSK with H=0.5) and Zigbee (OQPSK + DSSS).

7.4 Limits on Spurious Emissions Fall into Two Basic Categories

- Strict limits apply to emissions in “restricted bands”.
  - Restricted bands are frequencies where important radio services exist (bands defined in Part 15.205).
  - Radiated emission limits in these bands defined in FCC Part 15.209.a
    - Spurious falls below 960 MHz = -49.2 dBm EIRP (max).
    - Spurious falls above 960 MHz = -41.2 dBm EIRP (max).
- Weak limits apply outside of restricted bands.
  - Spec is only –20 dBc.
- Restricted bands at 2nd, 3rd, 5th, 6th, 8th, 9th and 10th harmonics of 2.4 GHz.

7.5 Spurious Emission Measurements are Radiated Measurements

- Spec is actually in terms of field strength (µV/meter), not power (dBm)
  - Can back-calculate to an equivalent conducted output power by assuming a particular type of antenna (e.g., typically an isotropic or dipole antenna).
  - Most common to calculate Equivalent Isotropic Radiated Power (EIRP) or Effective Radiated Power (ERP)
- End module must be verified in an accredited, calibrated antenna chamber (e.g., an approved FCC or ETSI Test Facility).
- TX Power: Peak vs. Average Measurement
- Output power of desired signal is a PEAK conducted measurement (15.247.b)
- Radiated spurious emissions (e.g., harmonics) above 1 GHz are AVERAGE measurements
  - Covered under FCC Part 15.35.b
- Thus average power using short bursts or TDD packets appears lower.
  - Example: if you transmit with only 10% duty cycle, your average power appears less.
- Benefit from use of short packets and averaging is limited to 20 dB (i.e., you can't use an extremely small duty cycle and claim a huge benefit).
  - Your packet must be less than 100 ms to use averaging (15.35.c)
    - Longer packets must be measured during strongest 100 ms part of packet (i.e., same results as measuring CW signal).
- Thus high data rate → short packets → lower average harmonics → easier to meet specs
  - May allow for meeting FCC spec without shielding or special board layout
- RX Requirements under FCC Part 15.247 = NONE
  - Except: the unit must still comply with Radiated Spurious Emission limits while in RX mode.
  - This is covered by FCC under "FCC Part 15.109 Unintentional Radiators".
  - Limits for any unintentional radiation are same as for intentional radiators in a restricted band.
    - Spurious falls below 960 MHz = –49.2 dBm EIRP (max) (15.209.a)
    - Spurious falls above 960 MHz = –41.2 dBm EIRP (max) (15.209.a)

8. Appendix 2: FCC Part 15.249 Requirements in the 2.4 GHz Band

8.1 This FCC Part Covers Much Lower Power Applications

- Proprietary applications
- TX output power specified as radiated field strength
  - 50 mV/meter @ 3 meters → -1.2 dBm EIRP (max) (15.249.a)
  - Measured using quasi-peak detector below 1 GHz (15.35.a) (i.e., not measured with averaging) or with an averaging detector above 1 GHz (15.35.b).

8.2 Harmonics Also Specified as Radiated Field Strength

- 500 µV/meter @ 3 meters → -41.2 dBm EIRP (max) (15.249.a)
- Applies to all harmonics (not just restricted bands)
- Measured using averaging above 1 GHz (15.35.b)
  - Harmonics may benefit from using short packets (see Part 15.247 discussion)

8.3 All Other Spurious Emissions (Other than Harmonics)

Must be < –50 dBc or below restricted band limits (whichever is easier to meet).

8.4 Question: Why Operate under Part 15.249?

After all, max allowed output power is relatively low (–1.2 dBm EIRP) compared with up to +30 dBm under Part 15.247.

Answer: There are no restrictions on bandwidth or frequency hopping.

For such low power, the FCC doesn't care if energy isn't "spread out."

8.5 Continuous Transmissions are Allowed

- Either modulated or unmodulated (CW)
- Allows for "beacon" channels

8.6 No Minimum Bandwidth Requirement

Allows for the use of low data rates and low deviations (i.e., narrow receive bandwidth → good RX sensitivity).

8.7 RX Requirements under FCC Part 15.249 = NONE

- Except the unit must still comply with Radiated Spurious Emission limits while in RX mode.
- This is covered by FCC under "FCC Part 15.109 Unintentional Radiators".
- Limits for any unintentional radiation are the same as for intentional radiators in a restricted band.
  - Spurious falls below 960 MHz = –49.2 dBm EIRP (max) (15.209.a)
  - Spurious falls above 960 MHz = –41.2 dBm EIRP (max) (15.209.a)

9. Appendix 3: ETSI EN 300-328 Requirements in the 2.4 GHz Band

9.1 Covers Wide Bandwidth Applications

- Frequency Hopping Spread Spectrum (FHSS)
- Wideband digital modulation
- “Umbrella” specification over Bluetooth and Zigbee operation in 2.4 GHz band

9.2 Blocking

- Desired signal at –30 dBm, Interferer at –30 dBm (CW) (Section 4.3.1.11.2)
  - Relative blocking level much easier than BTLE spec
  - Absolute blocking level slightly harder than BTLE spec
- But not applicable for systems with TX EIRP < +10 dBm (i.e., not applicable to BTLE)

9.3 RX Spurious Emissions

- 30-1000 MHz, –57 dBm ERP, BW = 100 kHz (Section 4.3.1.10.2)
- 1-12.75 GHz, –47 dBm EIRP, BW = 1 MHz (Section 4.3.1.10.2)

9.4 TX Output Power

Maximum of +20 dBm EIRP (Section 4.3.1.1.2)

9.5 Occupied Channel Bandwidth

- Defined as bandwidth containing 99% of the power
- For FHSS systems:
  - For equipment with EIRP ≤ +10 dBm, OCBW is simply declared by the supplier (Section 4.3.1.7.2)
  - For equipment with EIRP > +10 dBm, OCBW declared by the supplier, but less than 5 MHz (Section 4.3.1.7.2)
- For wideband digital modulation systems:
  - For equipment with EIRP > +10 dBm, OCBW declared by the supplier, but less than 20 MHz (Section 4.3.2.6.2)

9.6 TX Power Spectral Density

- Applies only to wideband digital modulation systems and not FHSS systems
- PSDMAX ≤ +10 dBm / MHz (Section 4.3.2.2.2)

9.7 TX Unwanted Emissions in Out-of-Band Domain

- OOB Domain defined for “nearby” signals (relative to edges of frequency band)
- Within 2*BW of 2.400-2.4835 GHz band edges, where BW = Occupied Channel Bandwidth
- At greater frequency offsets, the Spurious Domain limits apply
- OOB Domain Limits:
  - –10 dBm/MHz EIRP, within 1*BW offset from band edge (Section 4.3.1.8.2)
  - –20 dBm/MHz EIRP, within 1*BW to 2*BW offset from band edge (Section 4.3.1.8.2)

9.8 TX Unwanted Emissions in Spurious Domain

- Spurious Domain defined for “far-away” signals (relative to edges of frequency band)
- More than 2*BW away from band edges
  - Where “BW” is the Occupied Channel Bandwidth (but minimum value of 1 MHz)
- At lesser frequency offsets, the Out-of-Band Domain limits apply
- Spurious Domain Limits: (Section 4.3.1.9.2): 1-12.75 GHz, -30 dBm EIRP, RBW=1 MHz

10. Appendix 4: BLE 4.1 Requirements

10.1 Frequency Band = 2.400 to 2.4835 GHz

- RF Channels at F = 2402 + k*2 MHz, k = 0,1,…39
- Frequency hopping is required (to combat interference and fading)

10.2 TX Output Power

- Specs on both average and peak power (e.g., due to ramp transients)
- PAVG = 0.01 mW (-20 dBm) minimum, to 10 mW (+10 dBm) maximum (Section 3)
- PPK < PAVG + 3 dB (RF-PHY.TS 4.0.0 Section 6.2.1)

10.3 Modulation

- DR=1 Mbps ±50 ppm, 2GFSK, B*T=0.5 (Section 3.1)
- Modulation index H=0.5 (nominal, 0.45 to 0.55 worst case, → MSK) (Section 3.1)
  - Eye closure for "1010…" sequence > 80% of deviation for "00001111…" sequence
  - Minimum frequency deviation > 185 kHz
- Zero-crossing error < 0.125*Tb (Section 3.1)

10.4 Modulation Bandwidth

- FCC Part 15.247: BW6dB ≥ 500 kHz (with RBW = 100 kHz) (Section 3.2.1)
  - No upper limit under Part 15.247
- ETSI EN 300-328: BW99% = as declared by supplier
  - BW99% < 5 MHz limit only applies for EIRP > +10 dBm (i.e., not BTLE)
  - No minimum limit under EN 300-328, but BWMIN = 1 MHz for the purpose of defining TX Out-of-Band Spurious Domain

10.5 In-Band Spurious Emissions (Adjacent Channel Power)

- Measured as total integrated power in a 1 MHz bandwidth (Section 3.2.2)
  - RBW = 100 kHz, using average detector but with MAXHOLD (RF-PHY.TS 4.0.0 Section 6.2.3)
  - Per Bluetooth Test Spec, tested while transmitting packets
    - e.g., effects of splatter due to ramping transients are captured
    - Also, MAXHOLD → ~10 dB tougher requirement on phase noise
  - Thus, PA ramp time is implicitly specified by this requirement.
- Measured at frequency offsets of (M-N)*1 MHz (Section 3.2.2)
  - M = TX channel center frequency
  - N = Adjacent channel measurement frequency
  - |M-N| ≥ 2 (i.e., closest measurement channel is 2 MHz away)
- Limits are as follows:
  - –20 dBm, for |M-N| = 2 (Section 3.2.2)
  - –30 dBm, for |M-N| ≥ 3 (Section 3.2.2)
- Exceptions allowed on up to three frequencies, but absolute power must be less than –20 dBm.

10.6 Out-of-Band TX Spurious Emissions

Controlled by spurious emission requirements in intended countries of sale (Section 3.2.3).

10.7 TX Spurious Emissions under FCC Part 15.205 / 15.209

- Radiated measurement.
- Using averaging (above 1 GHz) or quasi-peak (below 1 GHz).
- Spurious emissions falling in restricted bands.
  - -41.2 dBm EIRP (above 960 MHz), RBW = 1 MHz.
  - -49.2 dBm EIRP (below 960 MHz).
- -20 dBc in non-restricted bands.
- Restricted band starts at 2.4835 GHz, just above BTLE band.
  - May limit output power or operation on upper channels in band.
  - Max Ch39 = 2.480 GHz → 3.5 MHz from band edge.

10.8 TX Spurious Emissions under ETSI EN 300-328

- Two different domains defined:
  - OOB Domain = nearby signals = within 2*BW of 2.400-2.4835 GHz band edges.
  - Spurious Domain = far-away signals = more than 2*BW away from band edges.
    - BW = occupied channel bandwidth (but minimum value of 1 MHz).
- OOB Domain Limits:
  - -10 dBm/MHz EIRP, within 1*BW offset from band edge.
  - -20 dBm/MHz EIRP, within 1*BW to 2*BW offset from band edge.
- Spurious Domain Limits:
  -
  - 30-47 MHz, 74-87.5 MHz, 118-174 MHz: -36 dBm ERP, BW=100 kHz.
  - 47-74 MHz, 87.5-118 MHz, 174-230 MHz: -54 dBm ERP, BW=100 kHz.
  - 230-470 MHz, -36 dBm ERP, BW=100 kHz.
  - 470-862 MHz, -54 dBm ERP, BW=100 kHz.
  - 862-1000 MHz, -36 dBm ERP, BW=100 kHz.
  - 1-12.75 GHz, -30 dBm EIRP, BW=1 MHz.

10.9 Transmit Radio Frequency Tolerance

- Maximum frequency error during a packet = ±150 kHz (Section 3.3).
  - Includes both drift and initial offset.
- Maximum frequency drift during a packet = ±50 kHz (Section 3.3).
  - QED, max initial frequency offset = ±100 kHz.
- Maximum frequency drift rate during a packet = 400 Hz/µs (Section 3.3).

10.10 RX Sensitivity Level

- PRX = -70 dBm (max) for BER = 0.1% (Section 4.1).
- Easy to meet, but tested against “dirty” packets with any combination of (Section 4.1).
  - Initial frequency offset
  - Frequency drift
  - Symbol rate variation
  - Frequency deviation variation
- Various combinations of dirty packets listed in Bluetooth Test Spec (RF-PHY.TS 4.0.0 Section 6.3.1).

10.11 Adjacent or Co-Channel Selectivity (Section 4.2)

- Desired signal at -67 dBm (3 dB above reference sensitivity).
- Interferer at ±N * 1 MHz offset (N=0,1,2…), modulated with reference signal.
- Maintain BER ≤ 0.1% for the following C/I levels and frequency offsets:
  - N=0 (co-channel), C/I = 21 dB
  - N=1 (adjacent channel), C/I = 15 dB
  - N=2, C/I = -17 dB
  - N=3, C/I = -27 dB
  - Image channel, C/I = -9 dB
  - Image channel ±1 MHz, C/I = -15dB
- Applies only to interferers falling within the 2400-2483.5 MHz band.
  - Out-of-band blocking requirements apply to signals outside the band.
- Up to five violations allowed.
  - Frequency offset must be ≥2 MHz.
  - Excluding the image channel, or image channel ±1 MHz.
  - Must meet limit of C/I = –17 dB.

10.12 Out-of-Band Blocking Requirements (Section 4.3)

- Desired signal at –67 dBm (3 dB above reference sensitivity).
- Desired signal fixed at single test frequency = 2426 MHz.
- Interferer is unmodulated.
- Maintain BER ≤ 0.1% for the following interference levels and frequencies:
  - 30 MHz – 2000 MHz (step 10 MHz), PINT = -30 dBm
  - 2003 MHz – 2399 MHz (step 3 MHz), PINT = -35 dBm
  - 2484 MHz – 2997 MHz (step 3 MHz), PINT = -35 dBm
  - 3000 MHz – 12.75 GHz (step 25 MHz), PINT = -30 dBm
- Up to 10 violations allowed.
  - At least seven violations must meet –50 dBm or better; maximum of three violations may be worse.

10.13 Other Controlling Documents?

- FCC: no requirements on RX (except RX spurious radiation).
- ETSI EN 300-328: -30 dBm blocking spec (more stringent).

10.14 Intermodulation Requirements (Section 4.4)

- Desired signal at F0 at –64 dBm (6 dB above reference sensitivity).
- Interferers at –50 dBm: F1 = CW (unmodulated), F2 = modulated with reference signal.
- Maintain BER ≤ 0.1% for the following conditions:
  - F0 = 2* F1 – F2
  - |F2 – F1| = N * 1 MHz
  - N = 3, 4, or 5 (must meet at least one)

10.15 Maximum RF Input Level (Section 4.5)

- Max RF input level at least –10 dBm.
- Must maintain BER ≤ 0.1% at –10 dBm input level.

10.16 Reference Signal Definition (Section 4.6)

- Bit Rate = 1 Mbps ±1 ppm, 2GFSK, B*T = 0.5 ±1%, Mod index = 0.5 ±1%.
- Modulation data = PRBS9 (desired signal), PRBS15 (interfering signal).
- Frequency accuracy better than ±1 ppm.

10.17 RX Spurious Emissions

- Controlled by spurious emission requirements in intended countries of sale.
- Performance often limited by RX LO leakage out of the antenna.
- FCC Part 15.109 (Unintentional Radiator).
  - Radiated measurement
  - Using averaging (above 1 GHz) or quasi-peak (below 1 GHz)
  - 30-88 MHz = 100 µV/meter @ 3 m (–55.2 dBm EIRP)
  - 88-216 MHz = 150 µV/meter @ 3 m (–51.7 dBm EIRP)
  - 216-960 MHz = 200 µV/meter @ 3 m (–49.2 dBm EIRP)
  - Above 960 MHz = 500 µV/meter @ 3 m (–41.2 dBm EIRP)
- ETSI EN 300-328
  - 30-1000 MHz, –57 dBm ERP, BW=100 kHz
  - 1-12.75 GHz, –47 dBm EIRP, BW=1 MHz

11. Appendix 5: Zigbee 2.4 GHz requirements

11.1 Frequency Band

- 2.400 to 2.8435 GHz (802.15.4 Section 8.1.1).
- RF Channels at 2405 + 5*(k-11) MHz, k=11,12,…36 (802.15.4 Section 8.1.2.2) (i.e., 16 channels spaced 5 MHz apart).

11.2 Frequency Tolerance

±40 ppm max (802.15.4 Section 10.3.9).

11.3 Modulation

- O-QPSK with half-sine pulse shaping, using DSSS (802.15.4 Section 10.3.1).
- 4-bits of data maps to 1-of-16 (nearly) orthogonal 32-chip symbol sequences.
  - Data rate = 250 kbps, symbol rate = 62.5 ksps, chip rate = 2000 kcps.
- Symbol rate tolerance = ±40 ppm (802.15.4 Section 10.3.3).

11.4 TX Output Power

- The maximum TX output power “shall conform with local regulations” (802.15.4 Section 8.1.5), but at least -3 dBm (802.15.4 Section 10.3.10).
- Potentially different allowed limit in each country.
  - U.S.: 1 watt (FCC Part 15.247)
  - Canada: 1 watt (GL-36)
  - Europe: 100 mW EIRP or 10mW/MHz peak power density (ETSI EN 300-328)
  - Japan: 10 mW/MHz (ARIB STD-T66)

11.5 TX Power Spectral Density

- |F – FC| > 3.5 MHz: -20 dBc (relative), -30 dBm (absolute) (802.15.4 Section 10.3.2).
  - Measured using averaging with RBW = 100 kHz.

11.6 RX Sensitivity

–85 dBm or better for PER < 1% (PSDU length = 20 octets) (802.15.4 Section 10.3.4).

11.7 RX Adjacent/Alternate Channel Selectivity

- Adjacent Channel = ±1 channels away from Desired Channel (±5 MHz).
  - Adjacent Channel rejection limit: 0 dB (802.15.4 Section 10.3.5).
- Alternate Channel = ±2 channels away from Desired Channel (±10 MHz).
  - Alternate Channel rejection limit: 30 dB (802.15.4 Section 10.3.5).
- Test performed with Desired Signal at –82 dBm (3dB above RX Sens).
  - Performance metric is PER < 1%.

11.8 RX Max Signal Handling

> –20 dBm, while maintaining PER < 1% (802.15.4 Section 10.3.11).

11.9 Additional RX Functionality Requirements

- ED: Energy Detection (802.15.4 Section 10.3.12)
- LQI: Link Quality Indication (802.15.4 Section 10.3.13)
- CCA: Clear Channel Assessment (802.15.4 Section 10.3.14)

11.10 Spurious Emissions (both TX and RX)

- Out-of-Band spurious emissions “shall conform with local regulations” (802.15.4 Section 8.1.6). Potentially different limit in each country.
- Summary of major countries and frequency bands:
  - U.S.:
    - 216-960 MHz: –49.2 dBm EIRP.
    - >960 MHz: –41.2 dBm EIRP.
  - Europe:
    - 30-1000 MHz: –30 dBm EIRP/100 kHz (TX), -57 dBm EIRP/100 kHz (RX or Standby)
    - 1-12.5 GHz: –30 dBm EIRP/1 MHz (TX), -47 dBm EIRP/1 MHz (RX or Standby), except
    - 1.8-1.9 GHz: –47 dBm EIRP/1 MHz (TX), -47 dBm EIRP/1 MHz (RX or Standby), and
    - 5.15-5.3 GHz: –47 dBm EIRP/1 MHz (TX), -47 dBm EIRP/1 MHz (RX or Standby).
  - Japan:
    - 2387 to 2400 MHz or 2483–2496.5 MHz: –16 dBm (TX).
    - <2387 MHz or >2496.5 MHz: –26 dBm (TX).
    - <1000 MHz: –54 dBm (RX), >1000 MHz: –47 dBm (RX).

11.11 Turn-Around Time

- TX-to-RX Turnaround Time: 12 symbol periods max (192 µs) (802.15.4 Section 8.2.1).
- RX-to-TX Turnaround Time: 12 symbol periods max (192 µs) (802.15.4 Section 8.2.2).

11.12 Error Vector Magnitude

< 35%, measured across 1000 chips (802.15.4 Section 10.3.8).

12. Revision History

Revision 0.3

February, 2021

- Added mentions to FCC's "Change in ID" and ISED's "Multple Listing" options allowing independent Permissive Change procedures.

Revision 0.2

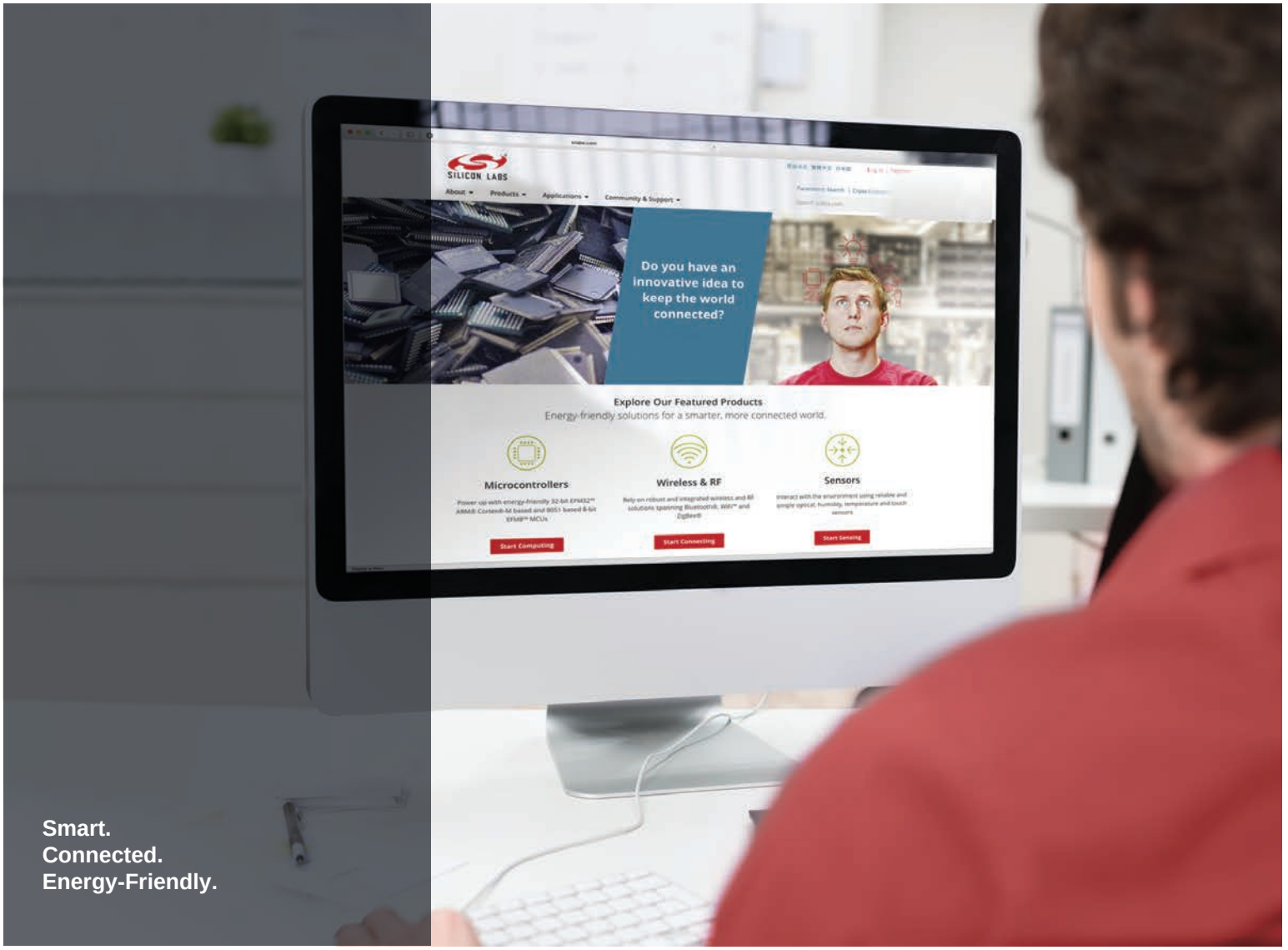
March, 2020

- Renamed the application note to *AN1048: Regulatory RF Module Certifications*.
- Made the application note more general and comprehensive.

Revision 0.1

January, 2017

- Initial release of application note focusing on BGM121/BGM123 SiP module example certifications.



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