

EchoStar Mobile EM2050 Hardware Module Developer's Guide

Version 1.3



Version History

Revision	Date	Description	Changes
1.0	30-08-2022	1 st Draft Document	N/A
1.1	19-10-2022	1 st Release Document	<ul style="list-style-type: none">• Updated images of Final EM2050 Module• Updated mechanical dimensions of EM2050 Module• Clarification of RF Signal Paths when PCB implemented Antenna is used• Updated LED Behaviour descriptions
1.2	12-05-2022	2 nd Release Document	<ul style="list-style-type: none">• Updated Module height to 4mm with conflicts removed•
1.3	17-10-2024	3 rd Release Document	<ul style="list-style-type: none">• Added regulation certifications details• Added chapter 6.3 RF working mode

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List of Abbreviations

Term	Definition
CPU	Central Processing Unit
EML	EchoStar Mobile Limited
ENV	Environmental Requirement
GNSS	Geolocation Requirement / Global Navigation Satellite System
IOT	Internet of Things
LNA	Low Noise Amplifier
LoRa®	Long Range Radio
LoRa®-FHSS	LoRa® Frequency Hopping Spread Spectrum, a new modulation scheme used for uplink
LoRaWAN™	Application protocol, standardized by the LoRa Alliance, which employs LoRa and LoRa-E modulation
LPWAN	Low Power, Wide Area Network
MCU	Micro Controller Unit
MSS	Mobile Satellite Service
NA	Not Applicable
OEM	Original Equipment Manufacturer
PA	Power Amplifier
PCB	Printed Circuit Board
POC	Proof-of-Concept
PWR	Power Supply Requirement
UART	Universal Asynchronous Receiver Transmitter

1 Introduction

This document serves to act as a developer's guide for solution integrators looking to integrate the EM2050 module as part of their new or existing products. It provides an overview of the module and includes all relevant information to allow them to develop solutions with it as the core wireless transmission module. This simplifies the process of partners and system integrators in utilising the EchoStar Mobile Satellite LoRa network as part of their IoT Solutions and allowing them to deliver value to partners and customers.

2 EM2050 Hardware Module Overview

2.1 Features

- **Designed for operation on EchoStar Mobile's Pan European Licensed S-Band LoRa Network**
- **Single CPU Multi Region Application Module**
- **Low Power Consumption:** Typical 320mA Active Transmit, 80mA Receive and 25µA Sleep
- **Small Single Board form factor:** 32 x 47 x 4mm Including RF Shield
- **Multi LoRaWAN and LoRa Frequency Support:** EU 868MHz, USA 915MHz ISM and Licensed S-Band
- **LoRaWAN Class A and C compatible**
- **TX Power of 27dBm in Licensed S-Band**
- **TX Power of 14/22dBm in 868/915MHz ISM Bands**
- **50 Byte Payload size utilising SF12 and LR-FHSS**
- **Built in temperature and supply voltage sensing**
- **Fully Compliant with local certification requirements**

2.2 EM2050 Hardware Architecture

The EM2050 Module incorporates several components in addition to the Semtech LR1120 to enable a complete system in module. This allows the Module to operate on EchoStar Mobile's S-Band LoRa Network as well as the 868/915MHz ISM Bands. This approach allows a simplified product design process for system integrators allowing the module to handle the complexities of the Satellite S-Band Network.

2.3 Hardware Variants

There is currently only one variant of the EM2050 module available, this is outlined below. The options available will evolve long term based on customer feedback and demand.

- EM2050-0 – Base version not equipped with U.FL antenna connectors and utilising STM32WB15 MCU

2.4 Software Revisions

Software Version	Changes	Accompanying Document
V1.0	No Changes – First Version	EchoStar Mobile OEM Module Software Guide V1.0

2.5 Applications

The EchoStar Mobile OEM Module is a perfect fit for many industries and use cases, its wide range of operation, flexible operating structure and low power consumption allow it to be utilised in a wide range of use cases such as below.

- Remote Asset Tracking
- Fixed Asset monitoring
- Battery Powered remote devices

3 Regulatory Certification

The EM2050 module is a regulatory approved transceiver that meet CE, FCC and ISCED requirements according to the following table:

Regulatory	EMC	Radio	Safety & health
FCC	FCC CFR47 part 2,15 and 25		
ISED	RSS-GEN, RSS-247 and RSS-170		
CE	EN 301 489-1	ETSI EN 300 220-1	EN 62368-1
	EN 301 489-3	ETSI EN 300 220-2	EN IEC 62311:2020
	EN 301 489-20	ETSI EN 302 574-3	RoHS

Certification and Declaration of Conformity can be shared on demand.

3.1 FCC warning statement

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

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

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

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

The module complies with FCC radiation exposure limits for uncontrolled environment.

Note:

The modular transmitter is only FCC and ISSED authorized for FCC Part 15C and 25 and ISSED RSS-GEN, RSS-247 and RSS-170. The host product manufacturer is responsible for compliance to any other FCC rules or ISSED standards that apply to the host not covered by the modular transmitter grant of certification.

Additional Testing, Part 15 Subpart B Disclaimer:

the final host product still requires Part 15 Subpart B compliance testing with the modular transmitter installed.

3.1.1 EMI Consideration

A host manufacture is recommended to use D04 Module Integration Guide recommending as "best practice" RF design engineering testing and evaluation in case non-linear interactions generate additional non-compliant limits due to module placement to host components or properties For standalone mode, reference the guidance in D04 Module Integration Guide and for simultaneous mode7; see D02 Module Q&A Question 12, which permits the host manufacturer to confirm compliance.

3.2 Industry Canada warning statement

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

This radio transmitter has been approved by Innovation, Science and Economic Development Canada to operate with the antenna types listed below, with the maximum permissible gain indicated. Antenna types not included in this list that have a gain greater than the maximum gain indicated for any type listed are strictly prohibited for use with this device.

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

Le présent émetteur radio a été approuvé par Innovation, Sciences et Développement économique Canada pour fonctionner avec les types d'antenne énumérés ci dessous et ayant un gain admissible maximal. Les types d'antenne non inclus dans cette liste, et dont le gain est supérieur au gain maximal indiqué pour tout type figurant sur la liste, sont strictement interdits pour l'exploitation de l'émetteur.

ICES-003 Class B Notice -Avis NMB-003 Classe B:

This Class B digital device complies with Canadian ICES-003

Cet appareil numérique classe B est conforme à la norme Canadien NMB-003.

CAN ICES-3(B) / NMB-3(B)

4 Mechanical Characteristics

4.1 Module Dimensions and Weight

The OEM Module is assembled on a single sided 1mm thick PCB with castellated pins, ready to be soldered on an existing PCB developed by the system integrator. The mechanical drawings, step file and footprint to be imported into Altium can be found in this document's complementary components. A summary of the mechanical characteristics can be found below in [Table 1 - Mechanical Characteristics](#)

Width	Height	Depth	Weight
47mm	32mm	4mm	6 Grams

[Table 1 - Mechanical Characteristics](#)

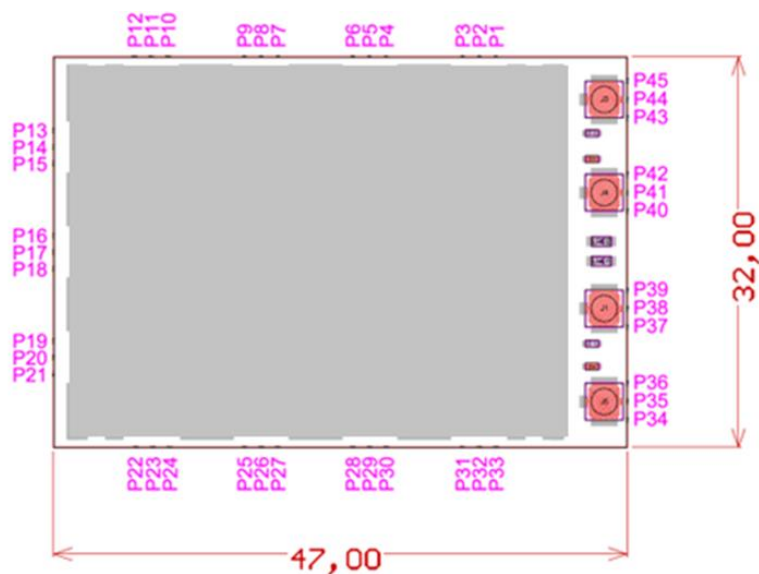


Figure 1 - Mechanical Dimensions and Pin assignments

4.2 Environmental Conditions

The module conforms to the following environmental conditions

Metric	Value
Operating Temperature Range	-30 to 70 Degrees Celsius
Operating Humidity Range	Up to 90% relative humidity non-condensing
Storage Temperature Range	-40 to 85 Degrees Celsius
Storage Humidity Range	Stored to MSL 3 Standards

4.3 Reflow Profile and Soldering Process

The EM2050 module is designed to be surface mounted with castellated terminations utilising gold plated solder lands, the module employs a lead-free manufacturing process with lead free soldering paste. EM2050 module is compatible with the industrial reflow profile for common SAC type RoHS solders and a No-clean soldering paste is recommended.

As with any reflow profile it is dependent on the thermal mass over the entire area of the host PCB, the heat transfer from the oven and the type of solder paste utilised. The optimal soldering profile must be tweaked slightly depending on the PCB layout and specific soldering process.

The parameter values shown in the table below are guidelines that we recommend for mounting the EM2050 modules to your PCBs using a Pb-free process.

Process Stage	Parameter	Unit	Value
Pre-Heat	Ramp up rate to T_{SMIN}	K/s	3
	T_{SMIN}	°C	150
	T_{SMAX}	°C	200
	T_S (from +25°C)	S	150
	T_S (Pre-heat)	S	60 - 120
Peak	T_L	°C	217
	t_L (time above T_L)	S	40 - 60
	T_P (absolute max)	°C	245
Cooling	Ramp-down from T_L	K/s	4
	Allowed soldering cycles	-	1

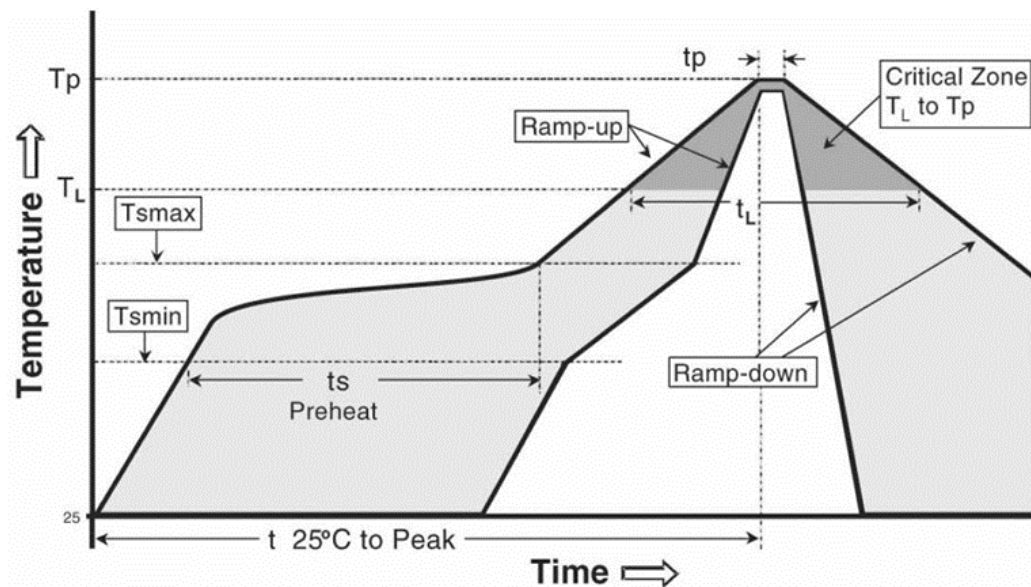


Figure 2 - Reflow Profile for EM2050 Module

5 Electrical Characteristics

5.1 Pinout

The table below defines the module pinout available at the castellated connections surrounding the PCB.

Pin	Pin Name	Pin Type	Direction	Description
P1	UART_RX	DIG	Input	UART RXD input from external application MCU
P2	GND	PWR	NA	
P3	UART_TX	DIG	Output	UART TXD output to external application MCU
P4	TX_2G_CE	DIG	Output	H=TX S-BAND active L=TX S-BAND inactive
P5	GND	PWR	NA	
P6	LNA_GPS_ON	DIG	Output	H=Enable External GPS LNA L=Disable External GPS LNA

P7	SW_ON	DIG	Output	H=Enable External S-BAND Switch L=Disable External S-BAND Switch
P8	GND	PWR	NA	
P9	VCC	PWR	NA	3.3V DC supply +/- 10%
P10	MCU_RSTn	DIG	Input	Apply an external GND level to reset the radio MCU. Internal 10Kohm pullup.
P11	MCU_PH3	DIG	Bidirectional	Reserved, internal 10K pulldown
P12	DNC			
P13	DNC			
P14	DNC			
P15	GND	PWR	NA	
P16	VCC	PWR	NA	3.3V DC supply +/- 10%
P17	GND	PWR	NA	
P18	DNC			
P19	MCU_BUSY/CTSn/E N_BOOTLOADER	DIG	Bidirectional	H=OEM Module in sleep mode L=OEM Module in active mode Internal 100K pullup Sampled after reset for bootloader activation
P20	RTSn	DIG	Bidirectional	H=Application MCU in sleep mode L=Application MCU in active mode 100K pullup for low power operation
P21	GND	PWR	NA	
P22	GND	PWR	NA	
P23	I2C_SDA	DIG	Bidirectional	I2C bus, SDA line. Internal 1K8 pullup
P24	I2C_SCL	DIG	Bidirectional	I2C bus, SCL line. Internal 1K8 pullup
P25	GND	PWR	NA	
P26	GND	PWR	NA	
P27	GND	PWR	NA	
P28	VCC	PWR	NA	3.3V DC supply +/- 10%
P29	GND	PWR	NA	
P30	GND	PWR	NA	
P31	GND	PWR	NA	
P32	GND	PWR	NA	
P33	VCC_PA	PWR	NA	3.3V DC for Power Amplifier, 500mA Maximum
P34	GND	PWR	NA	
P35	TX_S-BAND_ANT	RF	Output	S-Band TX output port
P36	GND	PWR	NA	
P37	GND	PWR	NA	
P38	RX_GPS_ANT	RF	Input	RF input for GNSS signal
P39	GND	PWR	NA	
P40	GND	PWR	NA	
P41	RX_S-BAND_ANT	RF INPUT	Input	S-Band RX input port
P42	GND	PWR	NA	
P43	GND	PWR	NA	
P44	868_915_RF	RF.I/O	Bidirectional	TX/RX port for sub-GHz ISM bands (868 / 915MHz)
P45	GND	PWR	NA	

Table 2 – EM2050 Module Pinout Table

There are two configurations possible for breaking out the RF signal paths, by default the paths are connected to the OEM Module pinouts as described below in **Table 3 - Default RF Signal Paths**. In this configuration the RF path must be broken out to the antenna by the system integrator along a 50-ohm impedance trace.

RF port	Default configuration
868_915_RF	P44
RX_S-BAND_ANT	P41
RX_GPS_ANT	P38
TX_S-BAND_ANT	P35

Table 3 - Default RF Signal Paths

It is also possible to remove the 0 Ohm resistors and solder U.FL connectors on the OEM module board to take advantage of alternative RF signal paths as seen in **Table 4 - Alternative RF Signal Paths**.

RF port	Alternate configuration (requires removal of 0 Ohm resistors and soldering of U.FL connectors)
868_915_RF	J3
RX_S-BAND_ANT	J4
RX_GPS_ANT	J1
TX_S-BAND_ANT	J5

Table 4 - Alternative RF Signal Paths

5.2 Power Requirements

The OEM Module requires a stabilised 3.3V DC Power Supply capable of delivering 500mA for 2 second intervals when operating at full power. If powered via a battery with a high internal resistance it is recommended that stabilisation of the supply voltage is implemented to ensure stable operation of the EM2050 Module.

The table below provides some examples of typical current draw of the EM2050 module during normal modes of operations.

Operating Mode	Current @ 3.3VDC
Sleep	20µA
RX ISM-Band	40mA
TX ISM-Band @14dbm	80mA
RX S-Band	130mA
TX S-Band @ 27dbm	320mA Typical, 500mA Max

Table 5 - Module Current Consumption

In **Figure 3 - Transmit and Receive Window at Full Power (27dBm)** you can see the EM2050 Module's typical power consumption during the transmission of a packet and then the power consumption during the RX window after this. Further detailed information and a whitepaper on the power consumption of the EM2050 module will be available in due course across a range of power levels. Only approved Antenna designs should be used, the module's current consumption is highly dependent on the exact implementation of these.

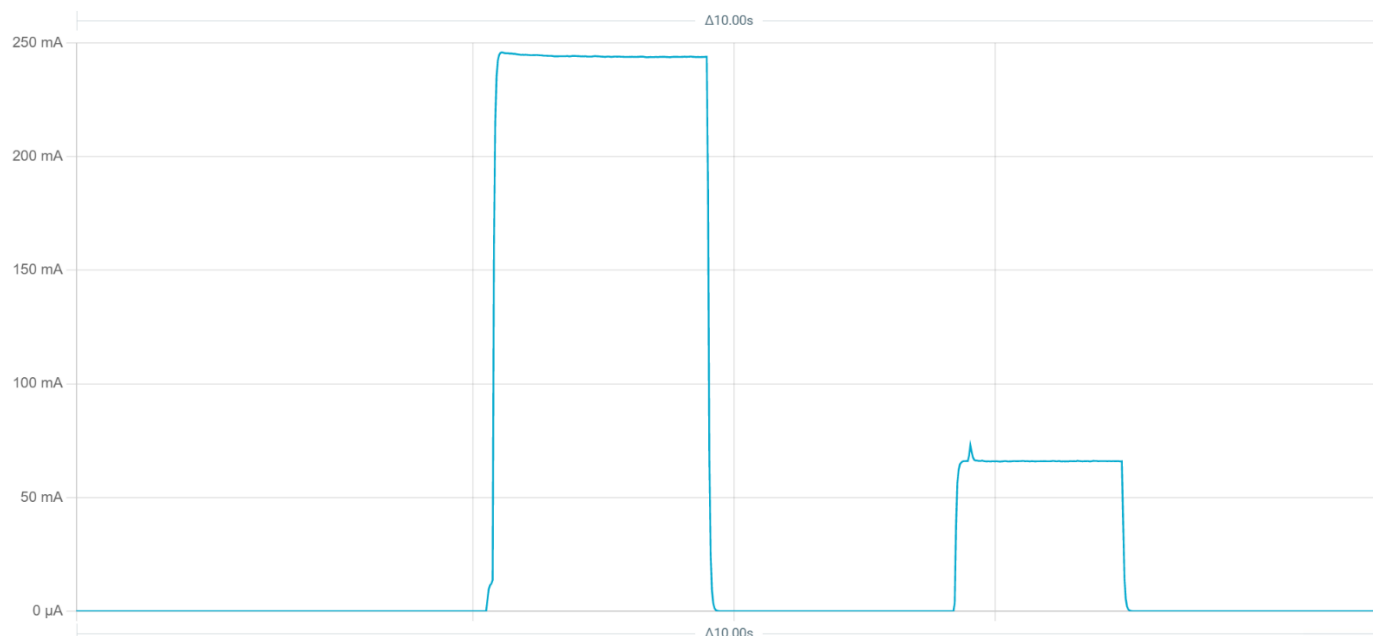


Figure 3 - Transmit and Receive Window at Full Power (27dBm)

6 Radio Frequency Overview

6.1 S-Band RF Characteristics

There are two discrete S-Band RF ports on the OEM module to allow narrowband antennas to be utilised for the TX and RX of signals as they operate on different frequencies.

6.1.1 S-Band TX P35

In the default configuration the S-Band TX Port is broken out on P35 or J5(non-default config) and has a typical maximum output power of +27dBm with a frequency range of 1980-2010MHz, an antenna centred on this frequency should be used for optimal performance. EchoStar Mobile will provide a list of approved antennas for use with the module. The output power can be reduced if sufficient link budget is available and detected by the application MCU using the ADR feature of the EM2050 Module.

6.1.2 S-Band RX P41

In the default configuration the S-Band RX Port is broken out on P41 or J4(non-default config) and includes all necessary circuitry for external noise rejection on the frequency range of 2170-2200MHz, an antenna centred on this

frequency should be utilised for optimal performance. EchoStar Mobile will provide a list of approved antennas for use with the module.

6.2 ISM-Band RF Characteristics

When operating in the ISM 868/915MHz bands there is a single signal path broken out from the OEM Module on P44 in default configuration or J3 if a U.FL connector is utilised. This input is then multiplexed internally by an RF switch to ensure that the signal path is connected to the relevant RF port on the LR1120 based on the current action being performed. The OEM module incorporates all relevant filtering necessary to meet harmonic and emissions limits when operating in the 868 and 915MHz bands at the relevant legal power levels. These power levels are 14dBm in the 868MHz band and 22dBm in the 915MHz bands.

6.3 RF working mode

The heart of the EM2050 module is the LR1120 radio transceiver from Semtech. It is a very powerful chip with the following features:

- A high frequency PA (HF PA), optimized for +13dBm operation in the 2.4GHz band and used for S-Band operation (2.1Ghz) in LoRa® and LoRa-FHSS up to 11.5dBm
- A low power PA (LP PA), optimized for +14dBm operation working on Sub-GHz operation on 868 / 915MHz ISM bands
- High power PA path +22dBm in the Sub-GHz band, only available when operating in the 915MHz ISM band
- GNSS reception of raw pseudo-range data for low-power position determination
- SPI interface to MCU

The following figure shows the LR1120 block diagram:

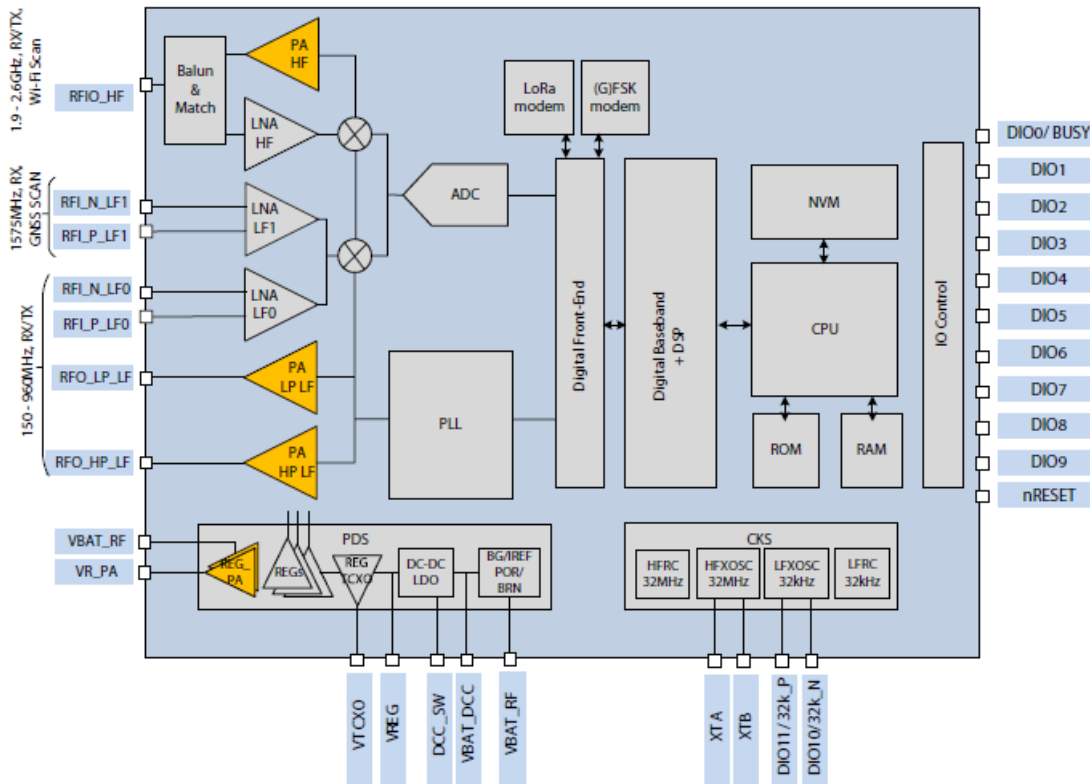


Figure 4 – LR1120 Power Amplifier block diagram

LR1120 has one single transmitter modulator that can be used in one of the following 3 RF output ports (one at a time, not simultaneously):

- the RFO_HF port has been enabled in TX and operates in the S-Band: 1980-2010MHz for TX. Operation up to 2020MHz for US band is supported.
- The RFO_HP_LF port is the high-power sub-GHz TX port, connected to the sub-GHz TX switch U4, port 2. This port is able to operate up to +22dBm power output (US 915MHz only).
- The RFO_LP_LF port is the low-power sub-GHz TX port, connected to the sub-GHz TX switch U4, port 3. This port is able to operate up to +14dBm power output.

LR1120 has also 3 RF input ports used in Rx:

- the RFI_HF port is available but is not used in RX mode.
- The RFI_LF0 port is the sub-GHz RX input port and is connected to the sub-GHz RF switch matrix U5. This port is used to receive from ISM band or from S-Band through a Fixed IF downconverter (U10 PLL + U7 Mixer).
- The RFI_LF1 port is connected to the internal GNSS antenna and is therefore capable of autonomous, low-power geolocation in addition or in alternative to an external GNSS receiver (if provided by the system integrator).

Note for more details on LR1120 please refer to Semtech [LR1120 user manual](#)

EchoStar has developed a dedicated firmware for EM2050, derived by Semtech, to configure and control the frequency band in use, identified in LoRaWAN as Region;

Below the details of AT command to be used to set the active LoRa Region to use

```
AT+REGION LoRaWAN Region Select: sets the active LoRaWAN region.  
AT+REGION=? displays  
AT+REGION: Show/set current LoRaWAN Region. Supported regions: MSS-S, EU868, US915  
AT+REGION? displays current value  
AT+REGION?  
Current Default Region: MSS-S  
OK
```

To change the active region enter AT+REGION=<region> which can be one of the following values: MSS-S, EU868, US915; The device will automatically save the new configuration in Flash and restart a new Join procedure with the new regional parameters, e.g.:

```
AT+REGION=MSS-S  
New Default Region: MSS-S  
Saving and applying new configuration...  
OK  
INFO: LoRaMac stack initialized @ 01/01/1970 02:21:43  
WARNING: Restarting LoRaWAN stack with new region MSS-S, rejoining network. @ 01/01/1970 02:21:43
```

As shown in the commands above, only one region can be active at a time, therefore the device cannot operate simultaneously on more than one band.

6.4 Antenna characteristics

For FCC Max allowed antenna gain for sub-GHz Band is 10dBi and max allowed antenna gain for S-Band is 7.5dBi with a Duty cycle 100%, as reported in the filing.

For ISCED Max allowed antenna gain for sub-GHz Band is 10dBi and max allowed antenna gain for S-Band is 6.7dBi with a Duty cycle 100%, as reported in the filing.

Recommended antenna for S-Band is the PCB omnidirectional antenna type EMAS100 made by EchoStar Mobile Ltd. with a transmission gain of 0 dBi

Recommended antenna for terrestrial ISM bands are any commercially available antennas with gain lower than 10dBi and impedance 50 Ohm.

7 Operating the OEM Module

7.1 LED Indicators

The EM2050 Module is equipped with two LED indicators to provide visual feedback on the current state of the EM2050 Module Radio MCU, these can be disabled if required to further reduce the power consumption of the EM2050 Module by issuing the command **AT+LED=0**.

LED Number and Colour	Behaviour
LED 1 Green	<p>During bootup the Green LED will illuminate for 1 second, it will then blink again briefly to indicate that bootup has been successful.</p> <p>In Normal operation the Green LED indicates that the OEM Module is in RX Mode.</p> <p>During bootloader operation the Green LED will blink alternately with the Red LED.</p>
LED 2 Red	<p>During Bootup the Red LED will blink briefly alongside the Green LED to indicate the bootup has been successful.</p> <p>In Normal Operation the Red LED indicates that the OEM Module is current in TX Mode.</p> <p>During bootloader operation the Red LED will blink alternately with the Green LED.</p>

Table 6 - LED Behaviour

7.2 Communicating with the OEM Module

By default, the application MCU should communicate with the OEM Module via P1 for RX and P3 for TX utilising the following serial port parameters as defined below.

Parameter	Value
Bit Rate	115200
Data bits	8
Stop bits	NA
Parity	None

Table 7 - Serial Port Parameters

In addition to the RX and TX lines there are two additional handshake lines used for communicating with the OEM module available on P19 and P20, these are used to signal to the application MCU that the OEM module is asleep and cannot receive or send commands, this also works in reverse from the application MCU to the OEM module.

7.2.1 Communication Flow

RTS is a signal from the Application MCU to the OEM board. It must be configured as an open-drain I/O with internal pullup on the Application MCU.

When the Application MCU is in active mode and ready to receive data, RTS signal P20 must be driven LOW, and the pullup may be switched off to reduce power consumption.

When the Application MCU is in sleep mode, this signal must be configured as an interrupt-generating input with internal pullup. The Radio MCU will wake up the Application MCU by driving P20 signal LOW for approx. 10 usec, then the signal will be floated and pulled up by the Application MCU.

When the Application MCU has woken up and is ready to receive data, it will drive RTS LOW.

On the opposite side, the CTS signal P19 behaves in the same way.

CTS is a signal from the OEM board to the Application MCU. It is configured as an open-drain I/O with internal pullup R11 on the OEM Board.

When the OEM Board is in active mode and ready to receive data, CTS signal P19 will be driven LOW.

When the OEM Board is in sleep mode, this signal is configured as an interrupt-generating input with internal pullup R11. The Application MCU will wake up the OEM Board by driving the CTS/P19 signal LOW for at least 10 µsec, then the signal must be floated and will be pulled up by the OEM Board, R11.

When the OEM Board has woken up and is ready to receive data, it will drive CTS/P19 LOW.