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Preliminary Datasheet

Helium 'Atom'

Helium Systems INC., IEEE 802.15.4 Module

OVERVIEW

The Atom is a dual band FCC, ETSI and IC certified IEEE 802.15.4 module. It operates in the 2.4GHz and 915MHz bands in North America and 2.4GHz and 868Mhz bands in Europe. The module is also capable of supporting China frequencies.

The module is designed to provide wireless connectivity to the Helium network infrastructure via modular certification into an end customers application. This allows for ease of integration for connecting devices to the internet. It is perfect as a drop-in module to add certified wireless capability to an end product or as a stand-alone wireless device. The module contains one chip antenna for each operational band within it's allowed region. Those chip antennas for 868MHz/915MHz bands have a gain of -1.0dBi and the chip antenna for 2.4GHz has a gain of -0.5dBi. The Atom also supports U.FL connectors for external antenna connections for use with any choice of antenna provided their performances don't exceed the certified dipole antenna gains of 3dBi (868MHz/915MHz) and 2.3dBi (2.4GHz). The system exhibits -110 dBm sensitivity in the 863MHz-870MHz and 902Mhz-928MHz bands using BPSK modulation at 40kbps and -104 dBm sensitivity in the 2.405GHz-2.480GHz band using O-QPSK at 250kbps. The Atom-AM is FCC/IC certified for TX power up to +25dBm in the 915MHz band offering 10 channels and +14 dBm in the 2.4GHz band offering 15 channels for North America. The Atom-EU is ETSI certified for TX power up to +8 dbm in the 868Mhz band offering 8 channels and +7 dBm in the 2.4Ghz band offering 15 channels for Europe.

The RF sections (IEEE802.15.4 transceivers) of the module are powered by Atmel's integrated Cortex-M0+ ATSAMR21G18A (which integrates an AT86RF233 die), AT86RF212B and SkyWorks FEMs (PA/LNAs). This combination of radios, microcontroller and FEMs marries the best of the available technologies to derive the best RF performance, power, current consumption and cost into a 20x20 mm agency-certified module.

The module comes with pre-programmed firmware, allowing easy setup and deployment on the Helium wireless network. User interface is via standard UART interface, with a well-defined and simple API.

Features

Certifications

Modular certification

- ETSI (this is a different part number from the FCC/IC version)
- FCC (Modular certification)
- IC (Modular certification)
- CE / RoHS compliant

Operational Bands

- 2.4 GHz IEEE802.15.4 (all regions)
- 915MHz IEEE802.15.4 (North America version)
- 868MHz IEEE802.15.4 (European version)
- 780MHz IEEE802.15.4 (China WPAN version)

TX Power

- ETSI
  - TX Power 2.4GHz +10 dBm
  - TX Power 868 MHz +13.9 dBm
- FCC/IC
  - TX Power 2.4GHz +14 dBm
  - TX Power 915MHz +27 dBm

RX Sensitivity

- -104 dBm, 2.4GHz band
- -110 dBm, 868/915MHz bands

Current Consumption

- RX current
  - 39 mA, both radios active
  - 24 mA, 2.4GHz Band only
  - 23 mA, sub-GHz Band only
- TX current
  - 85 mA @ +10 dBm (2.4GHz, ETSI)
  - 155 mA @ +13.9 dBm (868MHz, ETSI)
  - 100 mA @ +14 dBm (2.4GHz, FCC/IC)
  - 380 mA @ +27 dBm (915MHz, FCC/IC)

Voltage Range

- 2.0 to 3.6 V (3.3V typical; 2.4V recommended minimum for full TX power at 915MHz)

Temperature Range

- -40° to +85°C

Interfaces

- UART command interface
- SWD (Serial Wire Debug) for loading user-defined firmware
- One 12-bit ADC channel
- Up to 13 digital GPIO

Table of Contents

1. Introduction 4
    1.1 Module Interface 4
    1.2 Circuit Description 4
    1.3 Power Management 5
2. Pin Configuration 5
3. Specifications 7
4. Product Development 12
5. System Integration 13
6. Electrical Characteristics 14
7. Operating Conditions 15
8. Soldering Information 17
9. Package Drawing - 40LGA 18
10. Placement on the PCB 19
11. Ordering Information 21
Appendix A Additional Information 22
    A.1 Modular Collocation Approval 22
    A.2 End Product Labeling 22
        A.2.1 Countries Covered by ETSI (EU) 22
        A.2.2 USA and Canada 22
        A.2.3 Note 23
    A.3 FCC Interference Statement 24
        FCC Cautions 24
    A.4 IC Statements 25
    A.5 OEM Responsibilities to comply with FCC and Industry Canada Regulations 26
    A.6 RoHS Compliance 27

1. Introduction

The Atom™ is a low cost, easy to use, dual-band RF communication module for IoT-enabled wireless products. It enables designers to easily and quickly add wireless connectivity simply by supplying 3.3V and a UART port, and leveraging the compact Helium Systems API. Since the module is already FCC, ETSI and IC certified, there are no complex RF compliance issues to deal with. Its dual-band support ensures that your product can reach the Helium network under almost all operating conditions.

1.1 Module Interface

The primary interface to the embedded designer is through the UART. The UART settings are 115.2K baud, 8N1. Set up your UART for either polling or interrupt on data, and the module will effortlessly deliver received frames to your host processor.

When powered on, the module will automatically establish a secure connection to the Helium network. No commissioning procedure is needed, and security is hardware-based for robustness.

1.2 Circuit Description

The Atom™ incorporates the Atmel SAM R21 processor, which is an ARM Cortex-M0+ class processor running at up to 48MHz. This processor includes a stacked-die Atmel AT86RF233 2.4GHz IEEE 802.15.4 radio. An external SkyWorks front-end chip (PA/LNA/switch) is used to permit internal/external antenna selection and to boost RF performance. An Atmel AT86RF212B 780/868/915MHz IEEE 802.15.4 radio chip is also connected to the processor, along with an additional SkyWorks front-end chip. On-board chip antennas are supplied for each band, as well as U.FL connectors for external antennas. All controllable aspects of radio performance are managed by firmware in the processor. Several I/O signals are available for interfacing to the user's system, primarily for communicating commands and data but also permitting general-purpose analog and/or digital interfacing. No control signals that could directly affect the radios are available externally.

A separate hardware security chip is also available to the processor. This chip securely stores encryption keys as well as permanent device configuration details (serial number, operating bands, model number, MAC addresses, etc.) and also provides secure authentication and random number generation.

1.3 Power Management

There are a number of factors which contribute to power consumption by the module. Almost all of these can be controlled via firmware in order to minimize power consumption. Here is a list of the factors:

- Transmit power setting
- LNA enable/disable (may not be needed if the received signal is strong)
- Both vs only one radio being active
- Use of external antenna(s) (potentially higher gain than the chip antennas)
- Use of module I/O signals (no pins left floating, not driving high-current loads, etc)
- CPU power management (bus/clock speeds, peripheral use, Sleep mode use, etc)

Helium-supplied firmware endeavors to minimize power consumption both in the CPU configuration choices and by automatically managing the radio system power, taking advantage of the network's ability to monitor and adjust both inbound and outbound RF path characteristics.

2. Pin Configuration

There are several GPIO signals available to the embedded designer. The figure below shows a top side view of the module with the relative placement of the major IO and components. (Note: the pads shown below indicate relative position, but are on the bottom of the PCB.)

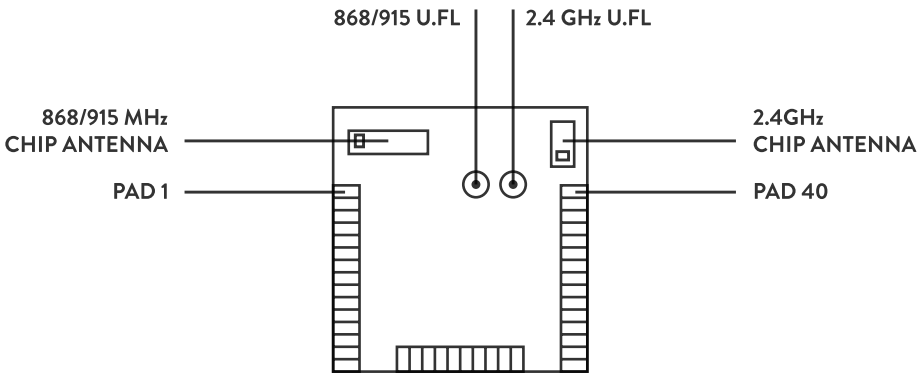


Table 1: Pin Functions

Pin	Function	Comments
1	GND	All GND pads are from the same plane in the module.
2	3.3 V	All 3.3V pads are from the same plane in the module.
3—6	Reserved	No Connect
7	User I-O 7	
8	User I-O 8	
9	User I-O 9	
10	User I-O 10	
11	Reset	
12	SWCLK / User I-O 12	Serial Wire Debug
13	SWDIO / User I-O 13	Serial Wire Debug
14	3.3 V	
15	GND	
16	GND	
17—24	Reserved	No Connect
25	GND	
26	GND	
27	3.3 V	
28	User I-O 28	
29	User I-O 29	
30	User I-O 30	
31	User I-O 31	
32	User I-O 32	
33	User I-O 33	
34	User I-O 34	
35—38	Reserved	No Connect
39	3.3V	
40	GND	

3. Electrical and RF Summary

The RF and DC specifications here are based on bench characterization at VDD=3.3V, 21°C. Note that in all cases the transmitters are capable of higher power, but the values shown are the maximum settings that meet regulatory agency limits for their respective regions.

Table 2: Specifications

Typical DC Characteristics	Value	Comments
Deep Sleep Current	TBD	With active watchdog timer
Module TX current	155mA @ +13.9dBm @ 868MHz (ETSI) 85mA @ +10dBm @ 2.4GHz (ETSI) 380mA @ +27dBm @ 915MHz (FCC/IC) 100mA @ +14dBm @ 2.4GHz (FCC/IC)	TX power measured at U.FL connector with unmodulated CW signal; 3.3V, 21°C; CPU active at 48MHz
Module RX current	39mA with both radios active; 23mA with only low-band radio active; 24mA with only 2.4GHz radio active	CPU active at 48MHz, LNA active
Typical RF Characteristics	**Value**	**Comments**
Receive sensitivity	-110dBm @ 915MHz using 40Kbps BPSK modulation (FCC/IC)	Measured using PER test described in IEEE802.15.4 section 6.5.3.3 (note 1) at the respective U.FL connector
	-110dBm @ 868MHz using 40Kbps BPSK modulation (ETSI)	
	-TBDdBm @ 868MHz using 20Kbps BPSK modulation (ETSI)	
	-104dBm @ 2.4GHz using 250Kbps O-QPSK modulation (all regions)	
Radio TX power		
Peripherals	**Comments**	
UART		
ADC		
GPIO		
Serial Debug Wire		

Table 3: Operating Frequencies and TX Power, Low-band radio (868MHz) - AT-OM-EU

Channel	Frequency (MHz)	PA TX Max Power (dBm - 100% duty cycle)
65	863.7	8
66	864.5	8
67	865.3	8
68	866.1	8
69	866.9	8
70	867.7	8
71	868.5	8
72	869.3	8
0*	868.3	8

- Approved for BPSK-40 (Approved to run if OBW < 20MHz)
- Europe (ETSI)
- Absolute MAX TX Power = +13.9dBm
- This gives a +3.9dBm margin for antenna gains (both chip antenna and dipole antenna)
- Current Consumption = 155mA
- * Europe (alternate IEEE 802.15.4 single channel)

Table 4: Operating Frequencies and TX Power, Low-band radio (915MHz) - AT-OM-AM

Channel	Frequency (MHz)	PA TX Max Power (dBm - 100% duty cycle)
1	906	27
2	908	27
3	910	27
4	912	27
5	914	27
6	916	27
7	918	27
8	920	27
9	922	27
10	924	27

- Approved for BPSK-40
- North America (FCC/IC)
- Absolute MAX TX Power = +36dBm (includes 30 + 6dbi antenna allowance)
- This gives a + 9dBm margin for antenna gains (both chip antenna and dipole antenna)
- Current Consumption = 380mA

Table 5: Operating Frequencies and TX Power, High-band radio (2.4GHz) - AT-OM-EU

Channel	Frequency (MHz)	PA TX Max Power (dBm - 100% duty cycle)
11	2405	7
12	2410	7
13	2415	7
14	2420	7
15	2425	7
16	2430	7
17	2435	7
18	2440	7
19	2445	7
20	2450	7
21	2455	7
22	2460	7
23	2465	7
24	2470	7
25	2475	7
26	2480	7

- Approved for O-QPSK-250 (Approved to run if OBW < 20MHz)
- Europe (ETSI)
- Absolute MAX TX Power = +10dBm
- This gives a +3dBm margin for antenna gains (both chip antenna and dipole antenna)
- Current Consumption = 85mA

Table 6: Operating Frequencies and TX Power, High-band radio (2.4GHz) - ATOM-AM

Channel	Frequency (MHz)	PA TX Max Power (dBm - 100% duty cycle)	PA TX Max Power (dBm - 35% duty cycle)
11	2405	14	19
12	2410	14	19
13	2415	14	19
14	2420	14	19
15	2425	14	19
16	2430	14	19
17	2435	14	19
18	2440	14	19
19	2445	14	19
20	2450	14	19
21	2455	14	19
22	2460	14	19
23	2465	14	19
24	2470	14	19
25	2475	12	19
26	2480	NA	2 *Only 20% duty cycle allowed

- Approved for O-QPSK-250
- North America (FCC/IC)
- Absolute MAX TX Power = +36dBm (includes 30 + 6dbi antenna allowance)
- This gives a +22dBm margin for antenna gains (both chip antenna and dipole antenna) depending on duty cycle being used.
- Current Consumption = 100mA

4. Product Development

When used with the Helium network, the Atom firmware handles all aspects of the wireless protocol services transparently to the end user. Helium's services also provide the ability to configure and use all of the User I/O pins of the Atom module directly from Helium's servers. In situations where the end application requires simple I/O, it may be possible to implement the application without needing an additional CPU. For example, small sensors for light, temperature, voltage, switch closures, etc. could be implemented directly.

If the application requirements exceed the direct capabilities of the module, then the end application system can use the module simply as a data communication pathway, using UART to handle communication between their application processor and the Atom module. Additional details are available in application notes at helium.com.

It is also possible to create custom firmware for using the module independently from Helium's network. In this case, the developer is responsible for handling not only application requirements, but also all aspects of regulatory agency compliance for the RF signaling. More information on this will be provided at helium.com in the future.

5. System Integration

The Atom™ dual-band wireless module is designed to be simple to integrate into your product. When using the module with Helium-supplied standard firmware, all Regulatory Agency limiting requirements are managed automatically. Even so, there are a few system integration guidelines you should be aware of to help meet those requirements. If you decide to implement your own firmware, the module can be operated under Helium's FCC/IC/ETSI approval, as long as you ensure that the module is never operated outside of the Regulatory limits (as detailed in this Atom™ datasheet). Here are a few pointers to help you meet those requirements.

- The Atom™ module must be operated within its **specified voltage and temperature limits**.
- **Variations in voltage and temperature have a small effect of transmitter efficiency**, and hence on transmitter power. Highest power output occurs at the low temperature / high voltage corner, and lowest power is seen at the high temperature / low voltage corner.
- **Power supply filtering is included on-board,** and no special external filtering has been needed in our testing. As always, good engineering practices will help ensure final product RF compliance, particularly as regards having good circuit ground connections.
- Do not have 'planes' (ground or power) or any other circuit traces under the antenna section of the module (the area where the chip antennas and U.FL connectors are located). **The antenna section should be in free space** (hanging off the edge of the carrier PCB, or over a routed-out area) for best RF performance.
- When using external antennas, the **antenna cables should route directly off the board**, rather than having them cross over the chip antennas or the shielded section.
- **Transmit power limits must be observed in all frequency bands**, per applicable Regulatory limits. Since each antenna has its own characteristics, those gains (or losses) must be taken into account to ensure that transmit power does not exceed the tested limits. The test conditions for the external antennas included a U.FL-to-SMA cable that exhibited a 0.5dB loss, and the gain figures for the tested antennas are listed in this Atom™ datasheet.
- The Atom™ module certification does not currently permit simultaneous transmission from both radios; as a result, **there is no antenna co-location requirement**. Of course, if the end product includes additional transmitters, any applicable co-location requirements will need to be addressed.
- **The Helium-supplied label must remain in place**, per Regulatory requirements. End-Product documentation must also contain applicable regulatory notices.

6. Electrical Characteristics

Voltage Range
2.0 to 3.6 V (3.3V typical; 2.4V recommended minimum for full TX power at 915MHz)

Temperature Range
-40° to +85°C

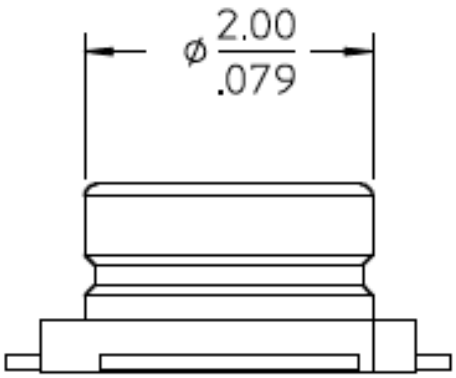
7. Operating Conditions

7.1 Hardware

The module supports various types of antenna configurations based on the frequency band of interest and the application range desired. In order to best optimize the right antenna for the application, the following notes describe how to best setup the module based on the antenna selected for the application. Both connectors support 50ohm matched antennas.

7.1.1 U.FL Antenna Configuration

The module supports 1 U.FL coaxial connector for the subGhz band (UFL1) and 1 U.FL coaxial connector for the 2.4GHz band (UFL2). Both of these connectors are standard U.FL form factors which is shown below. The part number for the U.FL connector is Molex - 73412-0110. There are several mating connector options in the same Molex family like 73116-0000 or 73116-0010.



Dimensions = mm/inch

When making the connections to either U.FL connector, it is recommended to have the mating cable assemblies oriented in the direction shown in the figure below. This will allow the coaxial cable to stay as isolated away from the chip antennas to avoid any kind of forced crosstalk on the U.FL connected RF transmission path. If the coaxial cable is directly run over the top of the chip antennas, there is higher chance of RF transmission leakage into the U.FL path.

The U.FL to SMA cable that was used during FCC/IC/ETSI testing was a Taoglas CAB.011 cable assembly. This provides a direct SMA connection (for external antennas) to the module via the U.FL connector.

The recommended antennas for external antenna support that were used with the Taoglas CAB.011 cable assembly are:

> 2.4GHz - MobileMark PSKN3-2400S - +2.3dBi
> SubGHz - MobileMark PSKN3-700/2100S - +3.0dBi

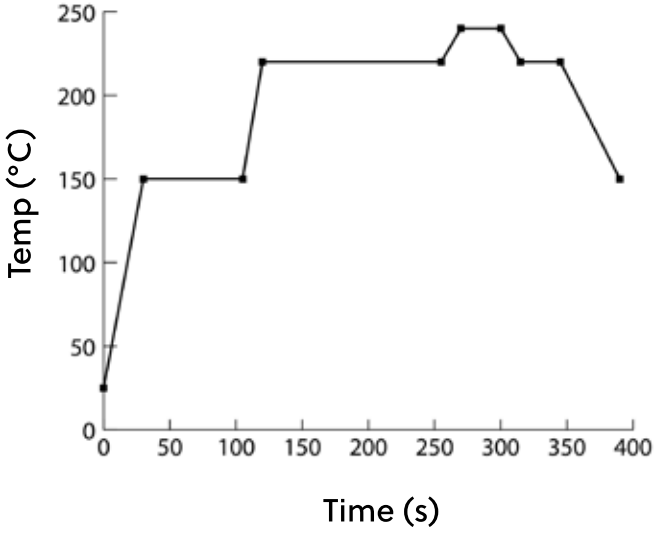
NOTE: See the FCC/IC/ETSI statement Appendix A section for full details of the required compliance with external antennas in order to prevent voiding the modular approval of the module.

8. Soldering Information

The following graph shows the typical reflow curve for the placing of the module on the desired PCB design. The standard reflow oven doesn't apply air pressure therefore the maximum temperature limit the module can withstand without air pressure is 300°C.

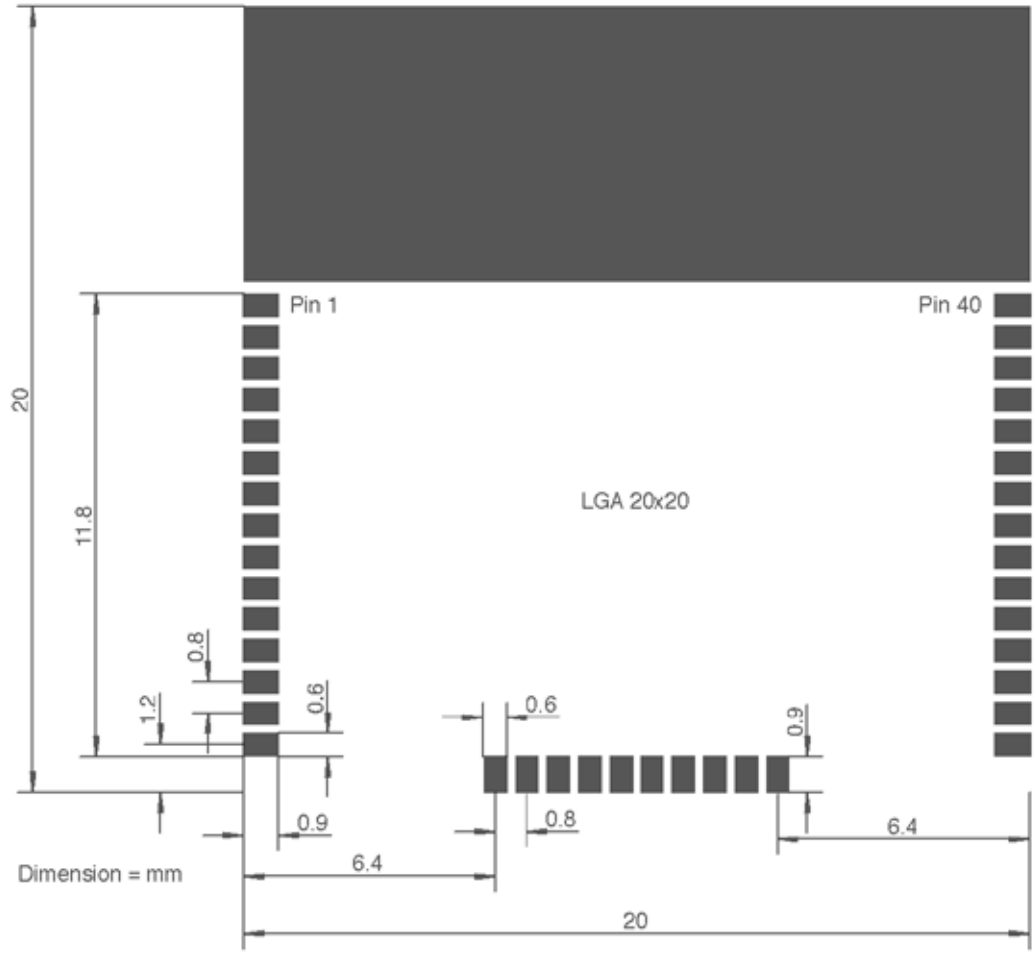
Rework may need to occur in various circumstances with a rework hot air machine using air pressure. In this case, the module has a tolerance of the same 300°C if the air pressure is very low; however, the absolute maximum temperature limit should not exceed 280°C under 5.5 PSI at a distance of 1" away from the heat source.

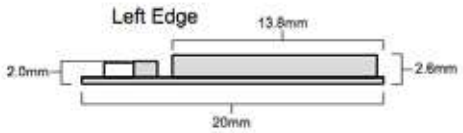
Chart 1: Module Soldering Profile

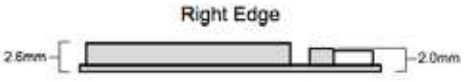


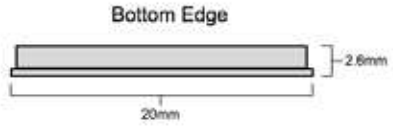
9. Package Drawing - 40LGA

9.1 Actual Module Pad Dimensions (Top View)

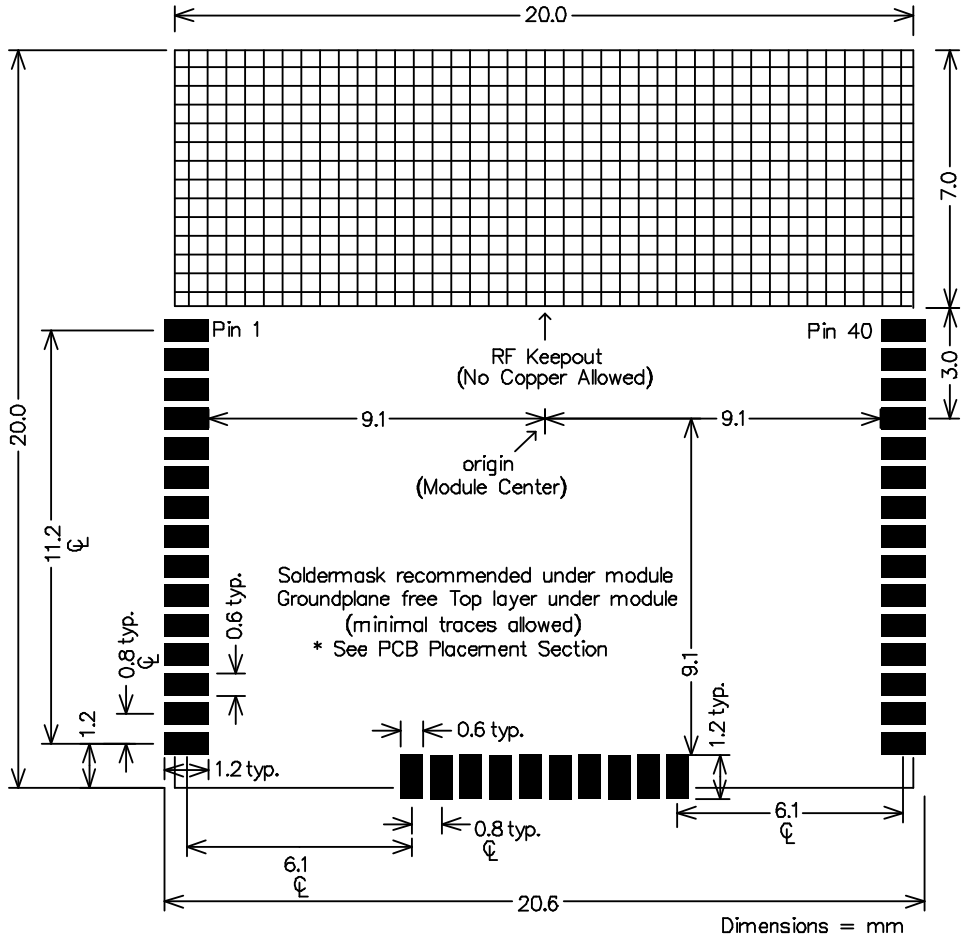








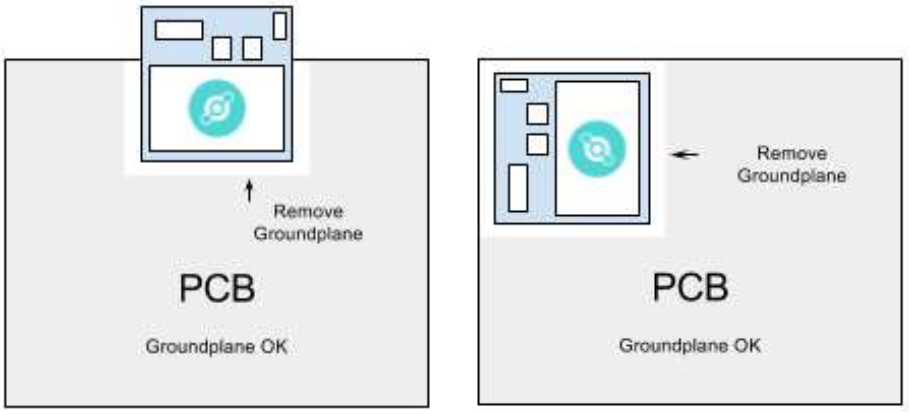
9.2 Recommended Pad Layout (Top View)



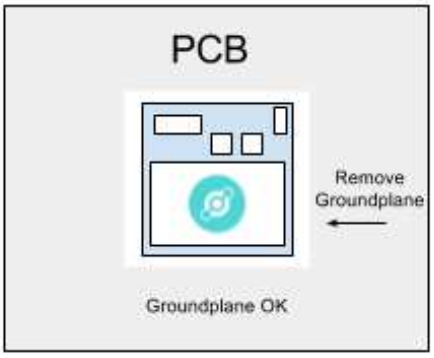
10. Placement on the PCB

The design of the host base board needs to keep in mind that the modules RF characteristics can be affected substantially by any groundplanes within the chip antenna section of the module. The recommended placement is to have the module placed near an edge or over the edge to provide the best RF performance from the chip antennas. This will give the best radiation pattern especially when the module is also placed within an enclosure.

The following figures give recommendations for the best placement.



Based on the above recommendations, there may be situations where you cannot place the module near an edge. This may force the module to buried within the center groundplane of the host base board. Even though this is not recommended due to the dramatic decrease in chip antenna performance, the U.FL connections will still provide adequate RF performance to the external antenna of choice. As long as the ground plane can be minimized under the module as shown in the following figure.



In all cases, the requirement to run traces under the module may arise. This is allowed provided there are no traces run through the RF KEEPOUT area described in the Recommended Pad Layout section above. Beware that high speed data lines running under the module is not recommended as there might be interference in both directions (host to module and module to host) especially when the module executes a transmission.

11. Ordering Information

11.1 Countries Covered by ETSI (EU)

ATOM-EU (this module cannot be used in FCC/IC countries)

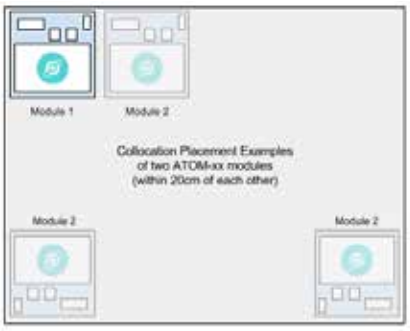
11.2 USA and Canada

ATOM-AM (this module cannot be used in ETSI countries)

Appendix A – Additional Information

A.1 Modular Collocation Approval

Collocation approval is required for any two transmitters located with a separation of less than 20cm from each other in the end product. The ATOM-xx modules have been approved for collocation operation with one other ATOM-xx module of the same type within an end product (2 modules total). The operation of both frequency bands and both collocated modules have been approved for simultaneous transmissions on all antenna configurations. This allows the module to be oriented in any configuration as shown in the the figure below.



For collocation operation with any other transmitting devices (i.e. - Wifi, Bluetooth, Cellular), it is required that the end product manufacture has the completed product evaluated for compliance with simultaneous transmission requirements. This can be completed by the following:

1. If using an already certified module (Wifi, Bluetooth, Cellular), the end product manufacture must obtain permission from either Helium or the other module vendor company to do a Change of Identification on the original grantee filing number (proper form).
   i) This is to create a duplicate FCC Grant from the original number over to the end product manufactures control.
2. Once the Change of Identification is complete, the end product manufacture can submit a permissive change request to the certification authority (FCC or IC) on behalf of the end product manufacture describing the changes from the original grantee filing description (i.e. ATOM-xx module now collocated with Wifi module).
3. Once this permissive change is approved, this new filing number can be used on the end product for collocation operation.

WARNING: This collocation approval does not warrant use of this ATOM-xx module within 20cm of any human body / mobile application (i.e. body wearables) without the proper SAR testing.

A.2 End Product Labeling

A.2.1 Industry Canada:-

For Industry Canada, the following statements must be included in the end-product documentation:

> Contains Industry Canada ID IC: 12590A-1
> Comprend le numéro d'identification de l'industrie canadienne ID IC: 12590A-1

A.2.2 United States:-

The final 'end product' should be labelled in a visible area with the following:

> Contains FCC ID: 2ADMK-1

A.2.3 Note:-

An OEM integrator must not provide information to the end user regarding how to install or remove this RF module or change RF related parameters in the user manual of the end product.

The user manual for the end product must include the following information in a prominent location:

This device has been granted Modular approval for use in mobile applications. OEM integrators for host products may use the module in their final products without additional FCC / IC (Industry Canada) certification if they meet the following conditions. Otherwise, additional FCC / IC approvals must be obtained.

- If additional transmitters are present in the end product, that product must be evaluated for compliance with simultaneous transmission requirements.
- External antennas must not exceed 2.3dBi gain (2.4GHz band) or 3.0dBi gain (900MHz band), including cable loss.
- A label must be affixed to the outside of the host product with the following statements:

  > Contains FCC ID: 2ADMK-1
  > Contains Industry Canada ID IC: 12590A-1

L'intégrateur OEM doit être conscient de ne pas fournir des informations à l'utilisateur final quant à la façon d'installer ou de supprimer ce module RF ou RF changer les paramètres liés au mode d'emploi du produit final.

Le manuel d'utilisation pour le produit final doit comporter les informations suivantes dans un endroit bien en vue:

Cet appareil a reçu l'agrément modulaire pour une utilisation dans des applications mobiles. Les intégrateurs OEM pour des produits susceptibles d'utiliser cet appareil peuvent l'utiliser dans leurs produits finaux sans certification complémentaire de FCC/IC (Industry Canada) s'ils remplissent les conditions suivantes. A défaut, un agrément complémentaire de FCC/IC doit être obtenu.

- Si des émetteurs supplémentaires sont présents dans le produit final, ce produit doit être évalué pour valider qu'il respecte les normes en matière de transmission simultanée.
- Les antennes externes ne doivent pas dépasser un gain de 2.3dBi (2.4GHz de fréquence) ou de 3.0dBi gain (900MHz de fréquence), y compris la perte de signal propre au câble.
- Une étiquette doit figurer sur l'extérieur du produit accueillant l'appareil avec la mention suivante :

  > Contient FCC ID: 2ADMK-1
  > Contient Industry Canada ID IC: 12590A-1

A.3 FCC Interference Statement

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. If not installed and used in accordance with the instructions, this 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 measures listed below.

- 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/television technician for help.

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

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

FCC Cautions

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

A.4 IC Statements

Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that permitted for successful communication.

This device has been designed to operate with none, one or both of the antennas listed below, having a maximum gain including cable loss of 2.3dBi gain (2.4GHz band) or 3.0dBi gain (900MHz band). Antennas not included in this list or having a gain greater than specified above are strictly prohibited for use with this device. The required antenna impedance is 50 ohms.

> 2.4GHz: MobileMark PSNK3-2400S
> 900MHz: MobileMark PSKN3-700/2100S

Son fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne peut pas provoquer d'interférences et (2) cet appareil doit accepter toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositif.

Pour réduire le risque d'interférence aux autres utilisateurs, le type d'antenne et son gain doivent être choisies de façon que la puissance isotrope rayonnée équivalente (e.i.r.p) ne dépasse pas celle admise pour une communication réussie.

Cet appareil a été conçu pour fonctionner sans, ou avec une, ou les deux antennes mentionnées ci-après, avec un gain maximum y compris la perte de signal propre au câble de 2.3dBi (2.4GHz de fréquence) ou 3.0dBi (900MHz de fréquence). Les antennes non comprises dans cette liste ou ayant un gain supérieur à celui qui est spécifié plus haut sont strictement interdites d'utilisation avec cet appareil. L'impédance requise pour l'antenne est de 50 ohms.

> 2.4GHz: MobileMark PSN3-2400S
> 900MHz: MobileMark PSKN3-700/2100S