User's Manual

WisLink-Cellular™ RAK2011

Version 1.0 | August 2018

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RAK

ABOUT RAKWIRELESS

Rakwireless is a pioneer in providing innovated and diverse cellular and LoRa connectivity solutions for IoT edge devices. It's patented, modularized, simplified design significantly help address diverse IoT applications and accelerate their time-to-market. For any assistance, please contact our company headquarters:

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GENERAL NOTES

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1. Overview

1.1 Introduction

RAK2011is a compact cellular module that supports Low-Power Wide-Area (LPWA) technology for networking Internet-of-Things (IoT). It can simultaneously support 2G, 4G/LTE, NB-IoT and GPS, with additional feature of Voice-over-LTE (VoLTE) for high definition (HD) and uninterrupted voice calls.

These multitude of features allow users the flexibility of advancing from 2G to 4G/LTE without having any hardware change, improve power consumption, system capacity and spectrum efficiency by utilizing the Narrow Band Internet-of-Things, tracking units through GPS and location base services (LBS), stay on the 4G/LTE network even when making or receiving calls and other networking requirements.

It is based on Quectel BG96 module and comes with drivers for Windows, Linux and Android support via AT commands, as well as various network protocols such as PPP, TCP, UDP, SSL, TLS, FTP(S), HTTP(S), NITZ, PING and MQTT. This is useful for facilitating software development and system integration into any IoT applications.

RAK2011 can be used as a development platform in tandem with microcontrollers/microprocessors for IoT applications or can be used as standalone. It is in full compliance with FCC, CE, RoHS and Japan TELEC/JATE.

1.2 Package Content

A full WisLink-Cellular RAK2011 retail package includes:

- BG96 LPWA IoT Cellular Arduino Shield
- Micro USB cable
- Cellular Antenna
- GPS Antenna

1pc BG96 LPWA IoT Cellular Arduino Shield

1pc Micro USB Cable
(Length: 1ft)

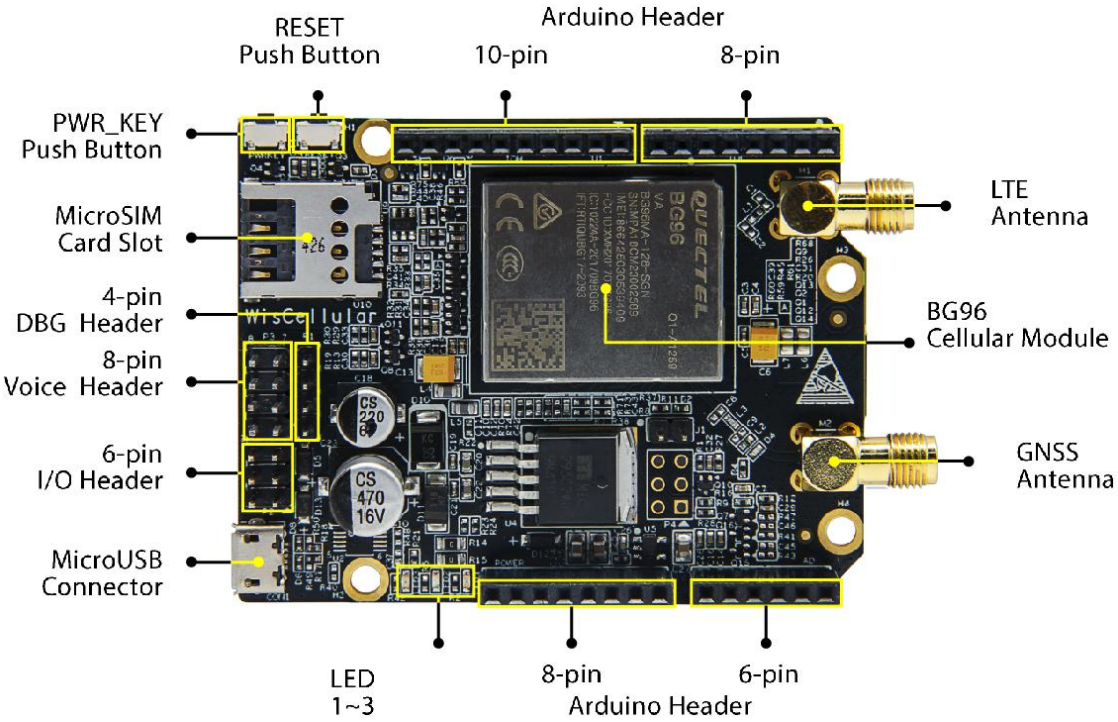
1pc Cellular Antenna

1pc GPS Antenna

2. BG96 LPWA IoT Cellular Arduino Shield

2.1 Overview

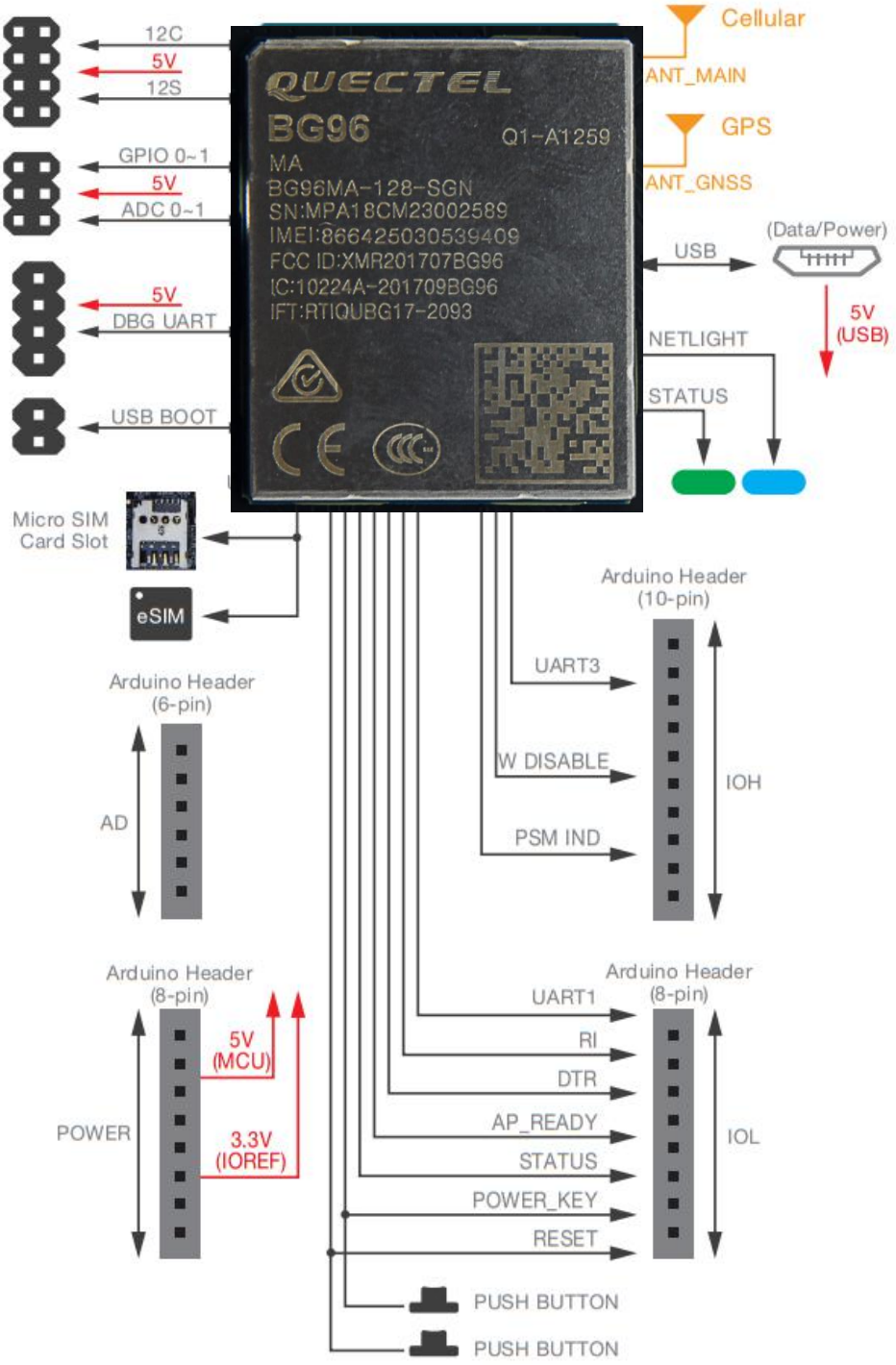
The picture below shows the top view of the BG96 LPWA IoT Cellular Arduino Shield.



The picture below shows the underside of the BG96 LPWA IoT Cellular Arduino Shield.

2.2 Functional Diagram

Block diagram below shows internal architecture and external interfaces:



2.3 Interfaces

It is built around Quectel BG96 LPWA IoT cellular module and provides the following interfaces, headers, jumpers, buttons and connectors:

- Micro-B USB
- Micro SIM Card Slot
- Arduino Headers (UART1, UART3, RESET, PWRKEY, STATUS, AP_READY, DTR, RI, PSM_IDC, W_DISABLE, 5V, 3.3V)
- 2x4 PCM Voice Headers (I2C, I2S)
- 2x3 Digital/Analog I/O Headers (ADC0, ADC1, GPIO0, GPIO1)
- 1x4 Debug UART Header (UART2)
- 1x2 USB BOOT Jumper

It has two push buttons to allow the user to power on/off and reset the board:

- POWER_KEY – Power on/off the BG96 module
- RESET – Reset the BG96 module

It has two SMA antenna connectors:

- Cellular (LTE/GSM) Antenna (3GPP Bands) – UART1
- GPS Antenna (1575.42±1.023 MHz) – UART3

2.4 Operating Modes

BG96 LPWA IoT Cellular Arduino Shield can operate in the following modes:

Normal Operation

Idle - Software is active. The BG96 module has registered on network, and it is ready to send and receive data.
Talk/Data - Network connection is ongoing; the power consumption is decided by network setting and data transfer rate.

Extended Idle Mode DRX (e-I-DRX) - BG96 module and the network may negotiate over non-access stratum signaling the use of e-I-DRX for reducing power consumption, while being available for mobile terminating data and/or network originated procedures within a certain delay dependent on the DRX cycle value.

Airplane Mode - AT+CFUN command or W_DISABLE# pin can set the module into airplane mode. In this case, RF function will be invalid.

Minimum Functionality Mode - AT+CFUN command can set the BG96 module into a minimum functionality mode without removing the power supply. In this case, both RF function and (U)SIM card will be invalid.

Sleep Mode - In this mode, the current consumption of the BG96 module will be reduced to a lower level. During this mode, the BG96 module can still receive paging message, SMS and TCP/UDP data from the network normally.

Power Saving Mode (PSM) - The BG96 module may enter into Power Saving Mode for reducing its power consumption. PSM is similar to power-off, but the BG96 module remains registered on the network and there is no need to reestablish PDN connections.

Power OFF Mode - In this mode, the power management unit shuts down the power supply. Software is not active. The serial interfaces are not accessible, but operating voltage remains applied.

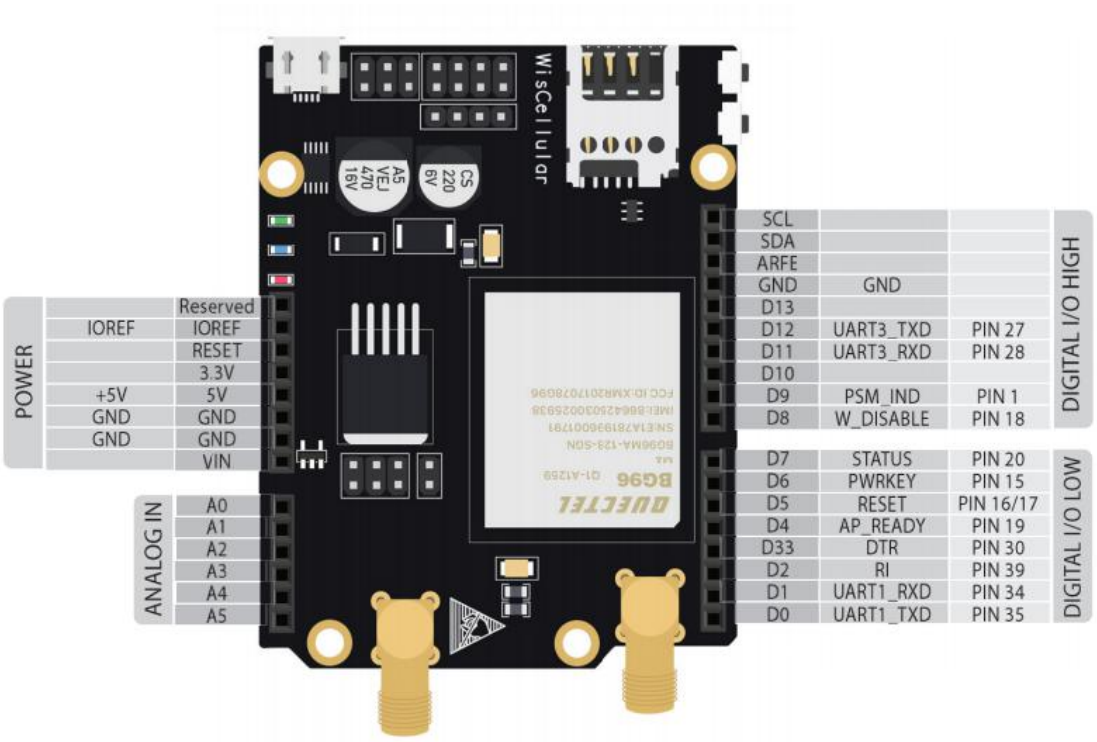
2.5 Cellular (LTE/GSM) Operating Frequency

The table below lists all the supported cellular (LTE/GSM) operating frequency:

3GPP Band	Transmit (MHz)	Receive (MHz)
B1	1920 ~ 1980	2110 ~ 2170
B2 (PCS1900)	1850 ~ 1910	1930 ~ 1990
B3 (DCS1800)	1710 ~ 1785	1805 ~ 1880
B4	1710 ~ 1755	2110 ~ 2155
B5 (GSM850)	824 ~ 849	869 ~ 894
B8 (GSM900)	880 ~ 915	925 ~ 960
B12	699 ~ 716	728 ~ 746
B13	777 ~ 787	746 ~ 757
B18	815 ~ 829.9	860 ~ 874.9
B19	830 ~ 844.9	875 ~ 889.9
B20	832 ~ 862	791 ~ 821
B26	814 ~ 848.9	859 ~ 893.9
B28	703 ~ 748	758 ~ 803
B39	1880 ~ 1920	1880 ~ 1920

2.6 Arduino Header

The mapping of Arduino headers on BG96 LPWA IoT Cellular Arduino Shield is shown below:



BG96 LPWA IoT Cellular Arduino Shield Arduino header signal definition is shown below:

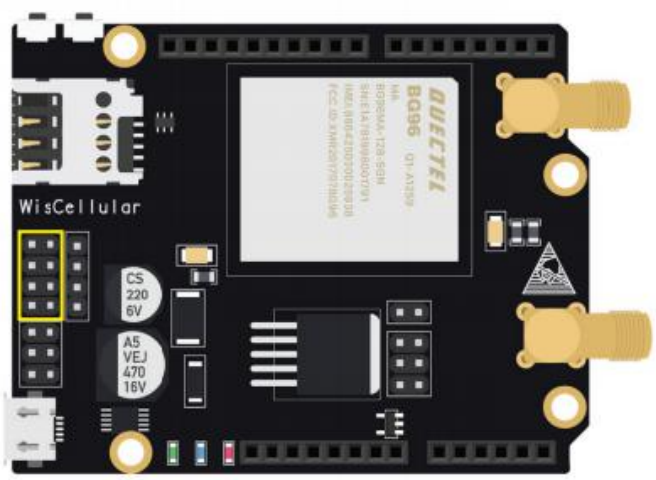
Name	Pin#	I/O	Description
UART1_TXD	D0	D0	UART3_TXD
UART1_RXD	D1	D1	Receive cellular (LTE/GSM) data
R1	D2	D0	Ring indicator
DTR	D3	D1	Data Terminal Ready (sleep mode control)
AP_READY	D4	D1	Application processor sleep state detection
RESET	D5	D1	Reset signal of the BG96 module
PWRKEY	D6	D1	Turn on/off the BG96 module
STATUS	D7	D0	Indicate the BG96 module's operation status
W_DISABLE	D8	D1	Airplane mode control
PSM_IND	D9	D0	Power saving mode indicator
UART3_RXD	D11	D0	Transmit GPS data
UART3_TXD	D12	D1	Receive GPS data

UART1 interface supports 9600, 19200, 38400, 57600, 115200, 230400, 460800 and 921600 baud rates, and the default is 115200bps. It is used for cellular (LTE/GSM) data transmission and AT command communication.

UART3 interface supports 115200bps baud rate. It is used for outputting GPS data and NEMA sentences.

2.7 PCM Voice Header

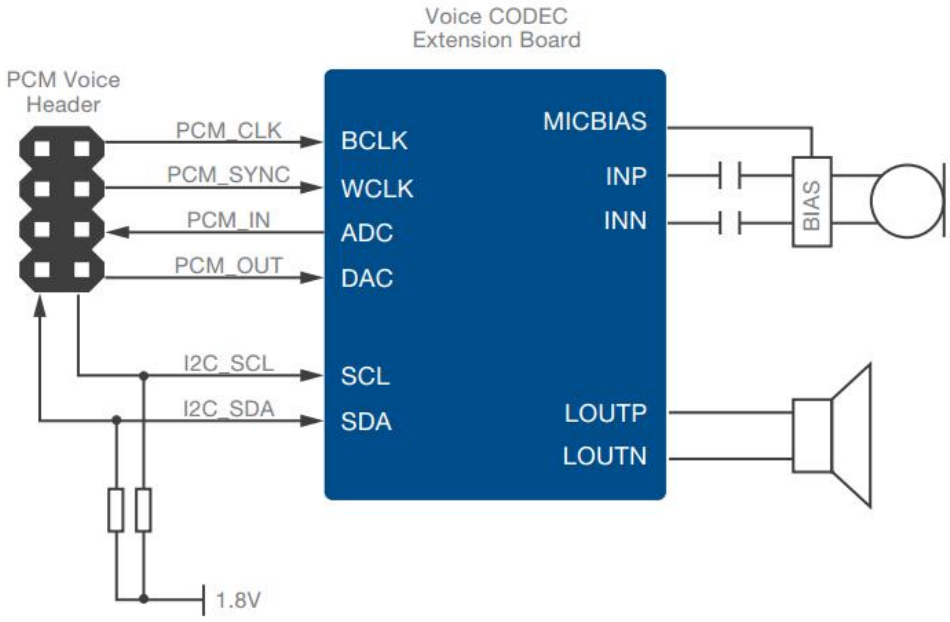
A standard 2x4 (2.54mm) male header is used to provide one Pulse Code Modulation (PCM) digital interface and one I2C interface to external CODEC extension board. PCM voice header pin definition is shown below:



PCM voice header signal definition is shown below:

Name	Pin#	I/O	Description	Comments
I2C_SCL	1	OD	I2C serial clock	External pull-up resistor is required. 1.8V only. If unused, keep it open.
I2C_SDA	2	OD	I2C serial data	
PCM_SYNC	3	DO	PCM frame sync output	1.8V power domain. If unused, keep it open.
PCM_CLK	4	DO	PCM clock output	
PCM_IN	5	DI	PCM data input	
PCM_OUT	6	DO	PCM data output	

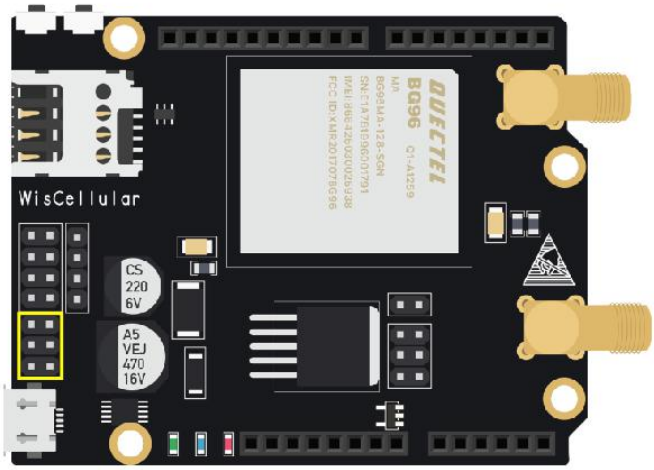
Reference design for external CODEC extension board is shown below:



2.8 Analog Input / Digital I/O Header

A standard 2x3 (2.54mm) male header is used to provide 2x analog input (ADC0 and ADC1 and 2x digital input and output (GPIO0 and GPIO1) to external extension board for additional features that will take advantage of these analog Input and digital I/O. Analog input and digital I/O header pin definition is shown below:

GPIO0	1		2	GPIO1
ADC0	3		4	ADC1
GND	5		6	VCC_5V

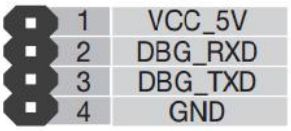


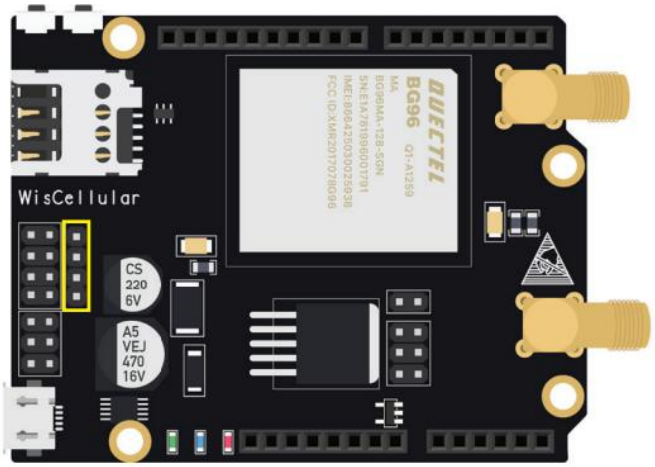
Analog Input/Digital I/O header signal definition is shown below:

Name	Pin#	I/O	Description	DC Characteristics	Comments
GPIO0	1	IO	General Purpose Input/Output	VOLmax=0.45V, VOHmin=1.35V VILmin=0.3V, VILmax=0.6V VIHmin=1.2V, VIHmax=2.0V	1.8V power domain. If unused, keep it open.
GPIO1	2				
ADC0	3	AI	General Purpose analog to digital converter	Voltage range: 0.3V to 1.8V 15-bit resolution	If unused, keep it open.
ADC1	4				

2.9 Debug Header

A standard 1x4 (2.54mm) male header is used to provide a serial port (UART2) interface for debug and log output at 115200bps baud rate. Debug header pin definition is shown below:



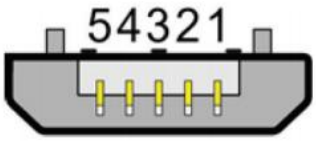


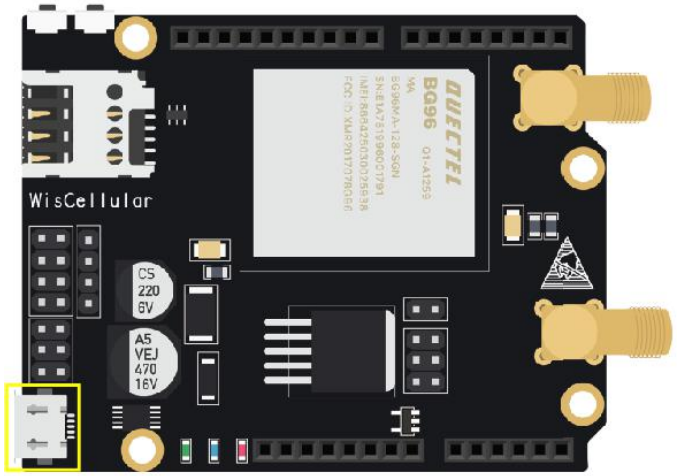
Analog Input/Digital I/O header signal definition is shown below:

Name	Pin#	I/O	Description	DC Characteristics	Comments
DB_G_RXD	2	DI	Receive data	VILmin= 0.3V, VILmax=0.6V VIHmax=1.2V, VIHmax=2.0V	1.8V power domain. If unused, keep it open.
DBG_TXD	3	DO	Transmit data	VOLmin=0V, VOLmax=0.45V VOHmin=1.35V, VOHmax=1.8V	1.8V power domain. If unused, keep it open.

2.10 Micro-B USB Interface

A Standard Micro-B USB compliant with USB 2.0 standard specification is used to provide an interface to connect to a PC for control of BG96 cellular modem and firmware upgrade.



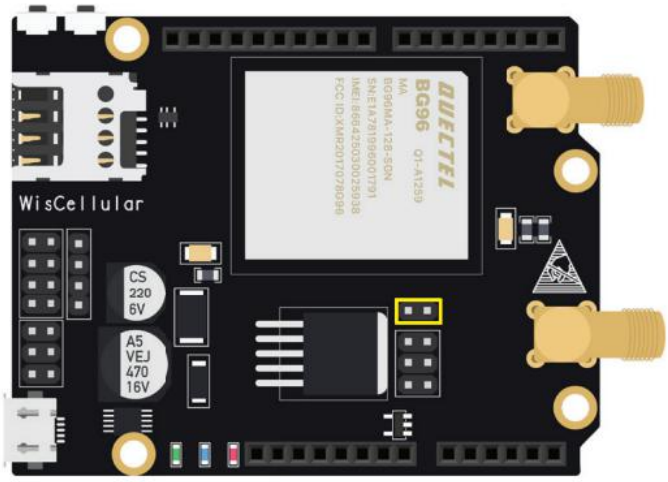


The Micro-B USB pin definition is shown below:

Pin#	Description
1	USB_VBUS (+5V)
2	USB_DM
3	USB_DP
4	N/C
5	GND

2.11 USB Boot Jumper

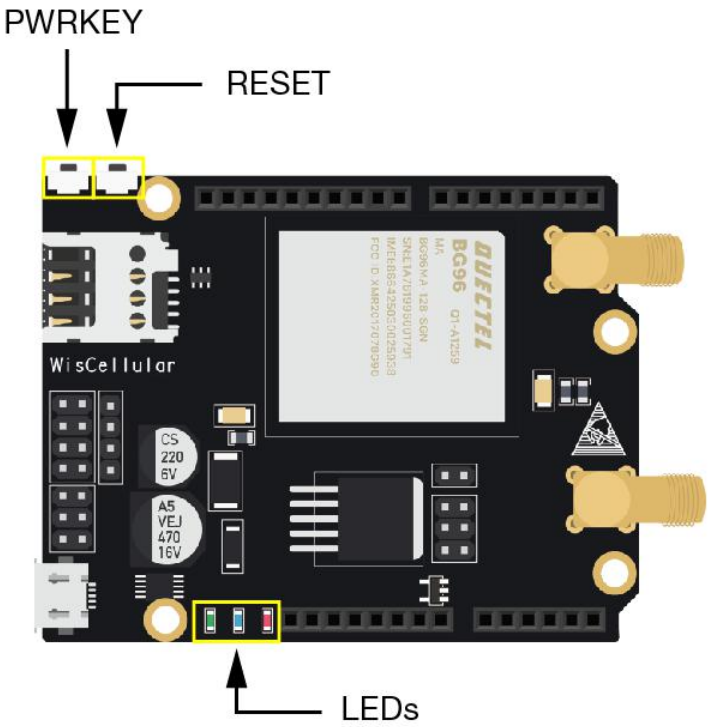
A Standard 1x2 USB Boot header (once closed) is used to force BG96 LPWA IoT Cellular Arduino Shield to boot from USB port for firmware upgrade.



2.12 PWRKEY Push Button

PWRKEY push button is used to turn on/off the BG96 module. To turn on the BG96 module, push PWRKEY button for at least 100ms. STATUS pin from Arduino header will output HIGH.

To turn off the BG96 module, push PWRKEY button for at least 650ms. STATUS pin from Arduino header will output LOW.



2.13 RESET Push Button

RESET push button is used to reset the BG96 module. To reset the BG96 module, push RESET button between 150ms and 460ms.

2.14 LEDs

Three LEDs are used to indicate operating status. The table below lists their detailed functions:

GREEN: **STATUS** - indicates module operation status.
BLUE: **NETLIGHT** - indicates network activity status.
RED: **Power ON** - indicates power status.

2.15 Power Requirements

BG96 LPWA IoT Cellular Arduino Shield can be powered by +5V coming out of MCU baseboard via Arduino header (POWER) if used as an Arduino Shield.

BG96 LPWA IoT Cellular Arduino Shield can also be powered by +5V out of Micro-B USB if used as a standalone modem.

Parameter	Min.	Max.
Power Supply Voltage	3.7V	5.5V
Current Consumption		500mA
Digital Inputs Voltage	0V	IOREF
Digital Outputs Voltage	0V	IOREF

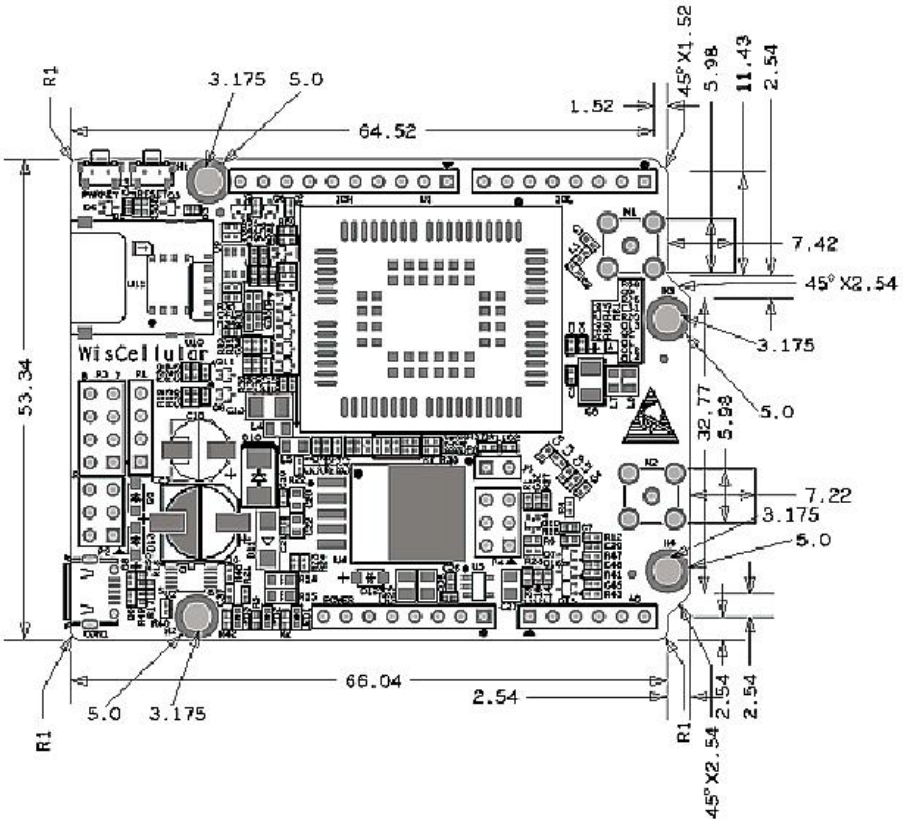
2.16 Environmental Requirements

The table below lists the operation and storage temperature requirements:

Parameter	Min.	Typical	Max.
Operation Temp. Range	-35˚C	+25 ˚C	+75 ˚C
Extended Temp. Range	-40 ˚C		+85 ˚C
Storage Temp. Range	-40 ˚C		+90 ˚C

2.17 Mechanical Dimensions

The mechanical dimension of BG96 LPWA IoT Cellular Arduino Shield can be found here:



3. Antenna

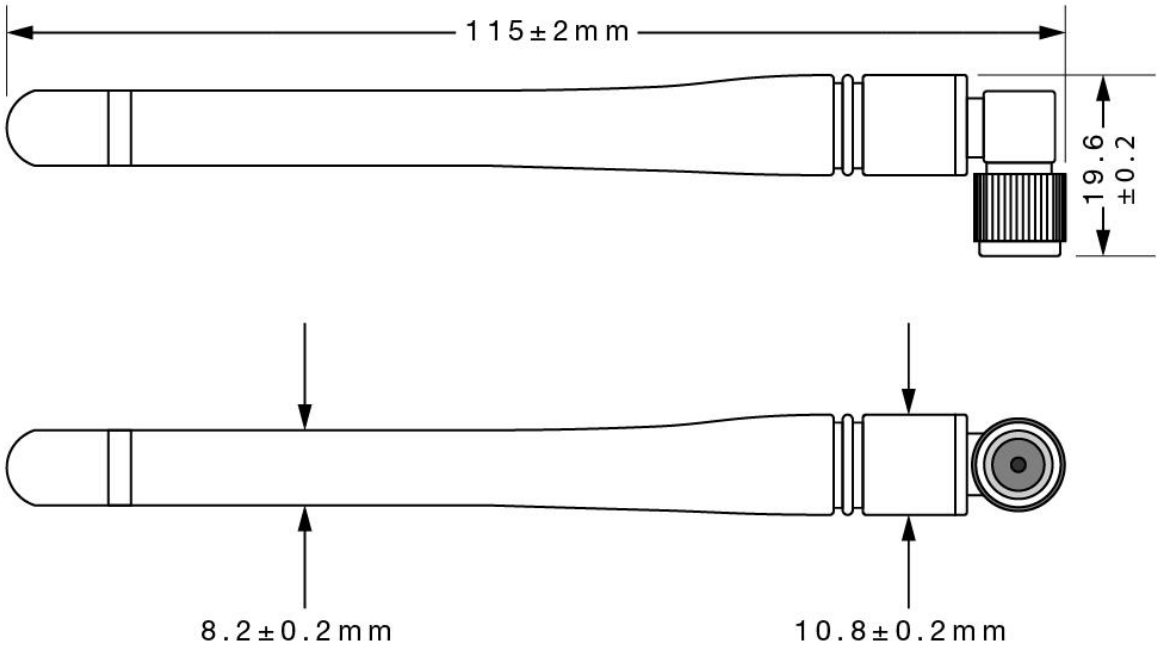
3.1 Cellular (LTE/GSM) Antenna

3.1.1 **Overview**

The cellular (LTE/GSM) antenna for BG96 LPWA IoT Cellular Arduino Shield covers working frequency band from 824MHz to 2690MHz.

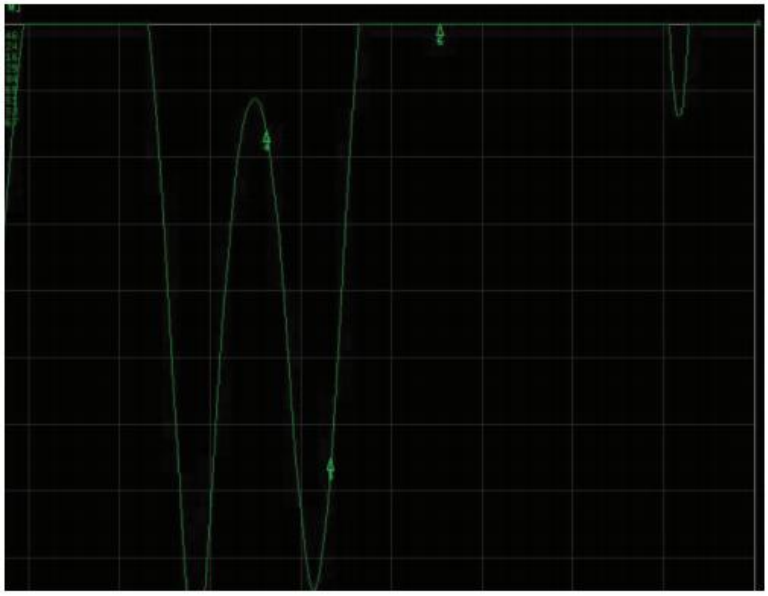
3.1.2 **Cellular (LTE/GSM) Antenna Dimension**

The antenna's mechanical dimension is shown below:



3.1.3 **Cellular (LTE/GSM) Antenna Parameter**

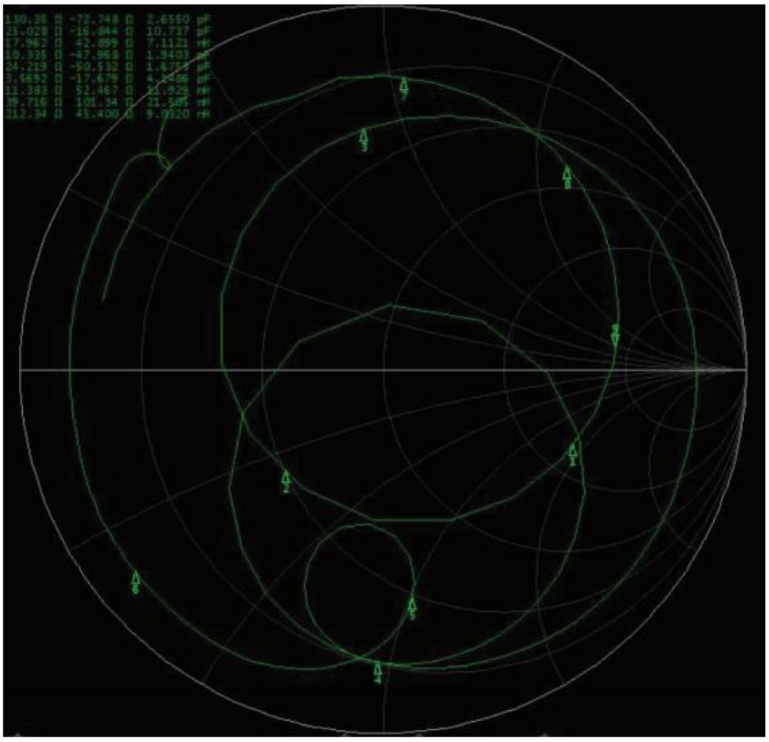
Voltage Standard Wave Radio (VSWR) plot is shown below:



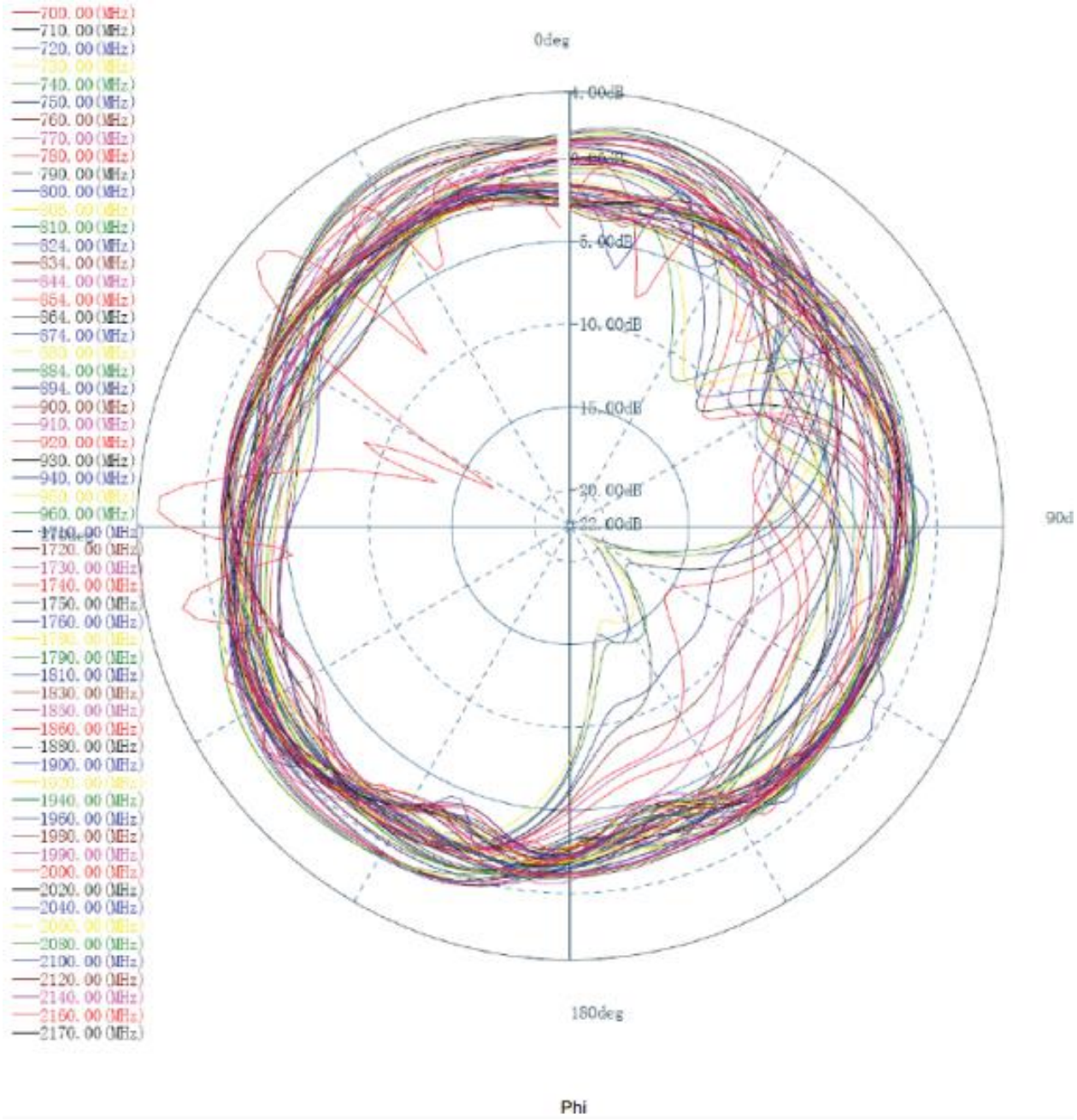
Freq. (MHz)	VSWR
700	9.3
800	4.6
880	3.6
960	4.9
1710	9.3
1880	4.4
2170	15

3.1.4 **Smith Plot**

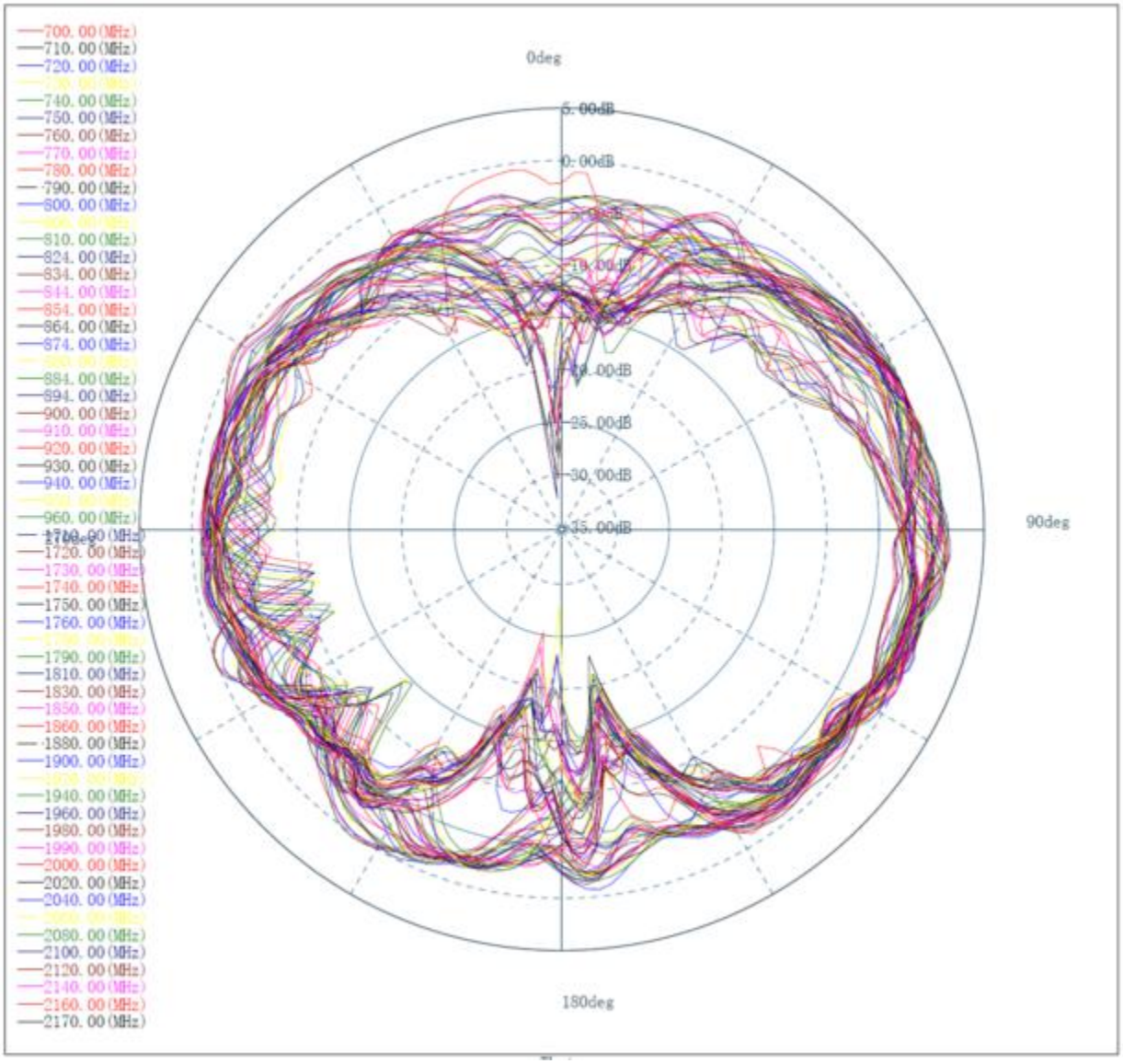
Smith Plot is shown below:



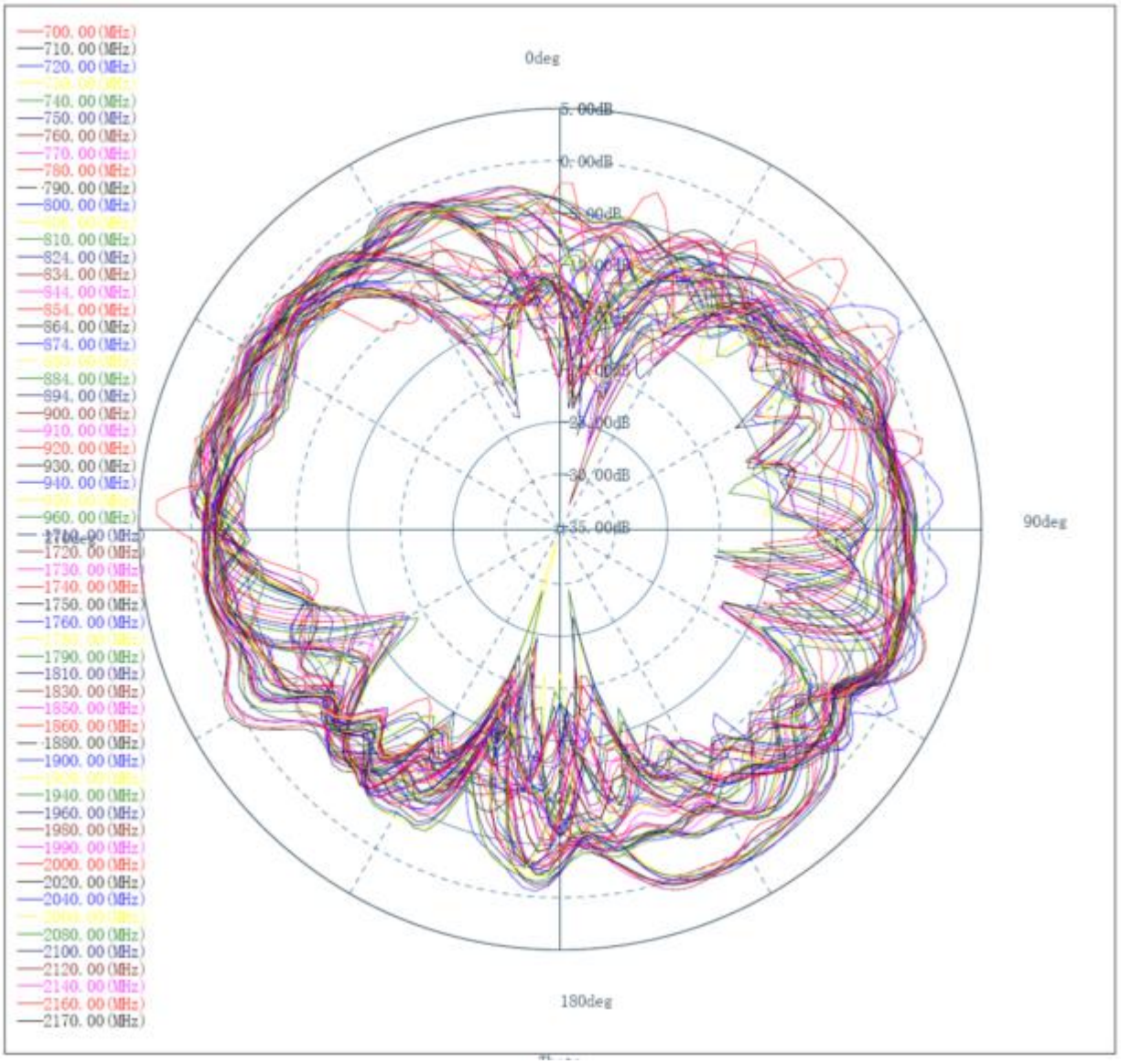
3.1.5 **Radiation Pattern on H-Plane**



3.1.6 **Radiation Pattern on E1-Plane**



3.1.7 **Radiation Pattern on E2-Plane**



3.1.8 **UGain and Efficiency Table**

Frequency (Hz)	Efficiency	Gain (dBi)
7.00E+08	49%	1.632948
7.10E+08	51%	1.826395
7.20E+08	49%	1.833288
7.30E+08	44%	1.600659
7.40E+08	46%	1.896142
7.50E+08	50%	1.936788
7.60E+08	50%	1.721112
7.70E+08	46%	1.406281
7.80E+08	45%	1.491829
7.90E+08	47%	1.8309
8.00E+08	45%	1.843967
8.06E+08	41%	1.714366
8.10E+08	45%	2.215538
8.24E+08	42%	1.97312
8.34E+08	44%	1.890023
8.44E+08	42%	1.407188
8.54E+08	42%	1.453714
8.64E+08	47%	2.111646
8.74E+08	46%	1.93289

8.80E+08	48%	1.960958
8.84E+08	46%	1.930333
8.94E+08	52%	2.347337
9.00E+08	50%	2.192946
9.10E+08	50%	2.265394
9.20E+08	49%	2.081987
9.30E+08	48%	2.005751
9.40E+08	49%	2.128994
9.50E+08	49%	2.305449
9.60E+08	48%	2.233022

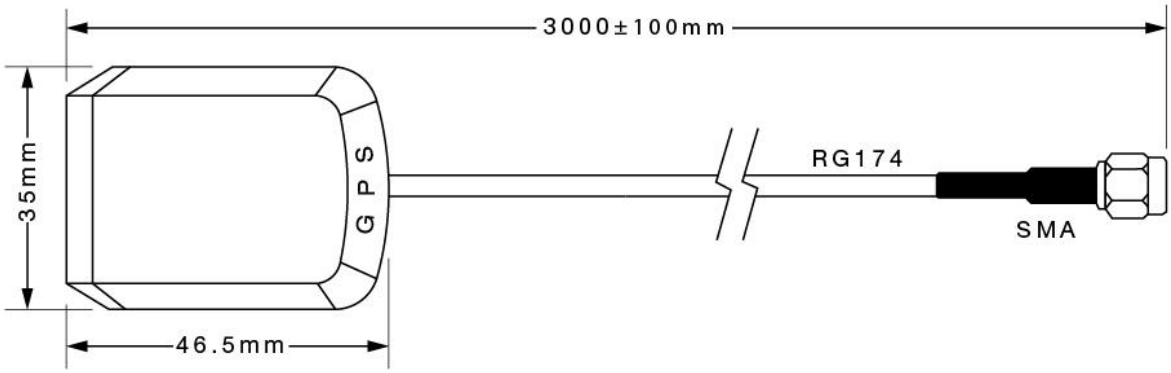
Frequency (Hz)	Efficiency	Gain (dBi)
1.71E+09	35%	0.02584
1.72E+09	35%	0.0088
d1.73E+09	36%	0.647356
1.74E+09	44%	0.806863
1.75E+09	35%	0.03676
1.76E+09	46%	0.549059
1.78E+09	34%	0.14522
1.79E+09	35%	0.41562
1.81E+09	36%	0.35094
1.83E+09	34%	0.30882
1.85E+09	38%	0.430313
1.86E+09	35%	0.33059
1.88E+09	37%	0.008792
1.90E+09	43%	0.479122
1.92E+09	40%	0.111459
1.94E+09	46%	0.407999
1.96E+09	44%	0.037526
1.98E+09	48%	0.405617
1.99E+09	48%	0.112167
2.00E+09	47%	0.144104
2.02E+09	46%	0.14634
2.04E+09	47%	0.033818
2.06E+09	45%	0.112366
2.08E+09	51%	0.672779
2.10E+09	48%	0.291807
2.12E+09	54%	0.939911
2.14E+09	54%	1.161325
2.16E+09	59%	1.631935
2.17E+09	59%	1.967355

3.2 GPS Antenna

3.2.1 **Overview**

The GPS antenna for BG96 LPWA IoT Cellular Arduino Shield is shown below:

3.2.2 **GPS Antenna Dimensions**



3.2.3 **GPS Environmental Requirements**

The antenna environmental requirements are listed in the table below:

Conditions	Temperature	Humidity
Working	-35ºC ~ +80ºC	0% ~ 95%
Storage	-40ºC ~ +85ºC	0% ~ 95%

3.2.4 **GPS Antenna Parameter**

Antenna specifications are listed in the table below:

Item	Specifications	Post Environmental Tolerance
Range of Receiving Frequency	1575.42±1.1	±2.5
Center Frequency (MHz) w/ 30mm^2 GND plane	1575.42	±3.0
Bandwidth (MHz) (Return Loss ≤ -10dB)	≥10	±0.5
VSWR (in Center Frequency)	≤2.0	±0.5
Gain (Zenith) (dBi Typ) w/ 70mm^2 GND Plane	4.5	±0.5
Axial Ratio (dB) w/ 70mm^2 GND Plane	3.0	±0.2
Polarization	Righ-Handed Circular	-
Impedance (Ω)	50	-
Frequency Temparature Coefficient (ppm/ºC)	0±10	-

Amplifier Specifications are listed in the table below:

Item	Specifications
Frequency Range	1575.42MHz
Gain	27dB
VSWR	≤2.0V
Noise Coefficient	≤2.0dBm
DC Voltage	3 ~ 5V
DC Current	5 ± 2mA

Environmental test performance specifications are listed below:

Item	Normal Temperature	High Temperature[1]	Low Temperature[2]
Amplifier Gain	27dB ± 2.0	27dB ± 2.0	27dB ± 2.0
VSWR	≤ 2.0	≤ 2.0	≤ 2.0
Noise Coefficient	≤ 2.0	≤ 2.0	≤ 2.0

1. High temperature test: soap in temperature (85º C) and humidity (95%) chamber for 24-hour and return to normal temperature (at least for 1-hour) without visual shape change.
2. Low temperature test: soap in temperature (-40º C) chamber for 24-hour and return to normal temperature (at least for 1-hour) without visual shape change.

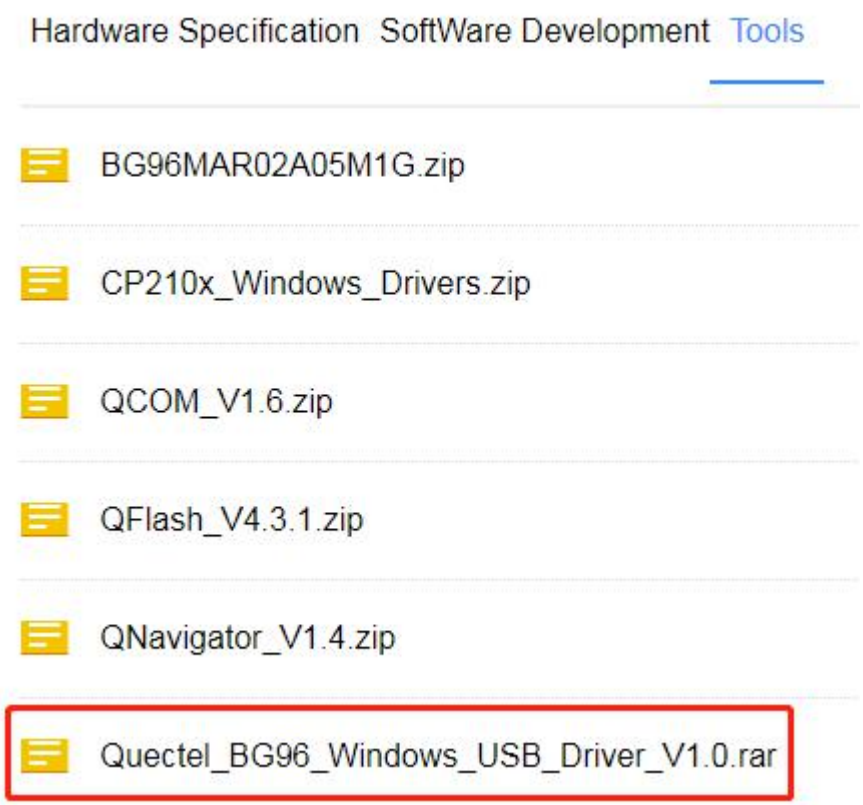
4. Usage Model by Interface

4.1 User USB Interface

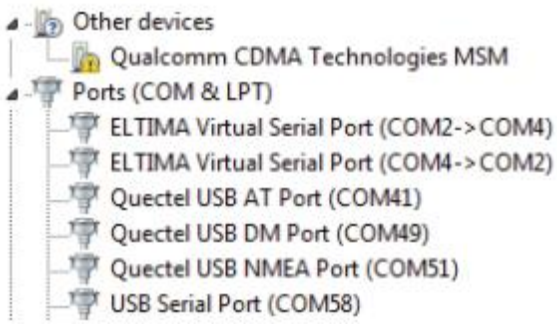
4.1.1 **Install USB Driver**

If it is the first time to connect BG96 LPWA IoT Cellular Arduino Shield to a Windows PC, install the BG96 USB driver first. The driver can be downloaded from:

https://www.rakwireless.com/en/download/Cellular/WisLTE



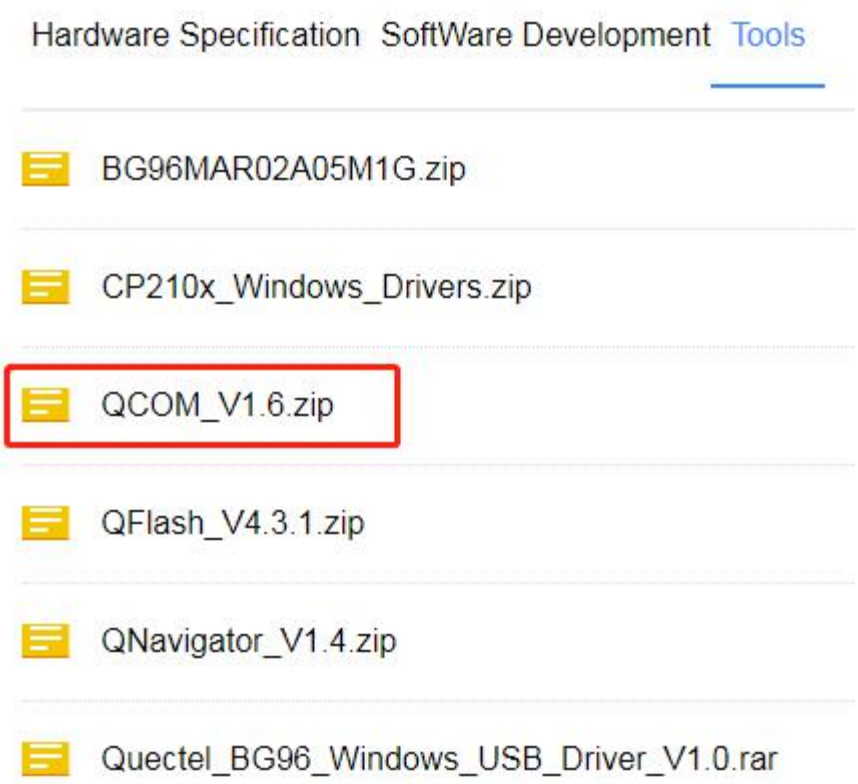
After the Windows USB drive installation is complete, connect BG96 LPWA IoT Cellular Arduino Shield to a PC via a Type A to Micro B USB cable. Open Windows' Device Manager and it will show the following under Ports (COM & LPT):



4.1.2 **Send AT Commands**

Select Quectel USB AT Port corresponding to the COM port, then open the serial port tools like shown on the screenshot.The tools can be downloaded at:

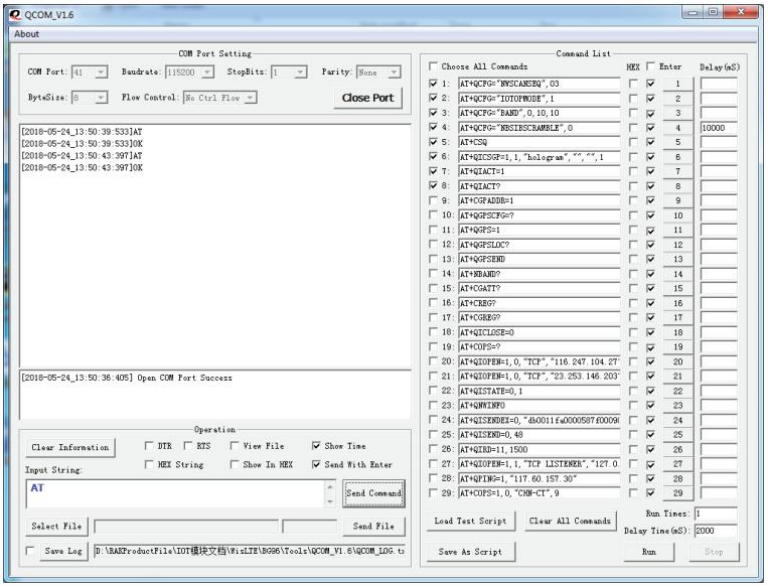
https://www.rakwireless.com/en/download/Cellular/WisLTE



After sending AT\r\n, The module will return AT\r\nOK, this means the BG96 module is working normally.

You can send more AT commands to control the module. For more AT commands, please read the documents BG96 AT Commands Manual. It can be downloaded at:

www.quectel.com/support/downloadb/TechnicalDocuments.htm



4.1.3 **NB-IoT UDP Communication Test**

1. Plug in NB-IoT SIM card.
2. Connect WisLink-Cellular RAK2011 to a Windows PC.
3. Select Quectel USB AT Port corresponding to the COM port.
4. Open the serial port tools.
5. Send the AT commands listed below to have the BG96 module find a NB-IoT network;

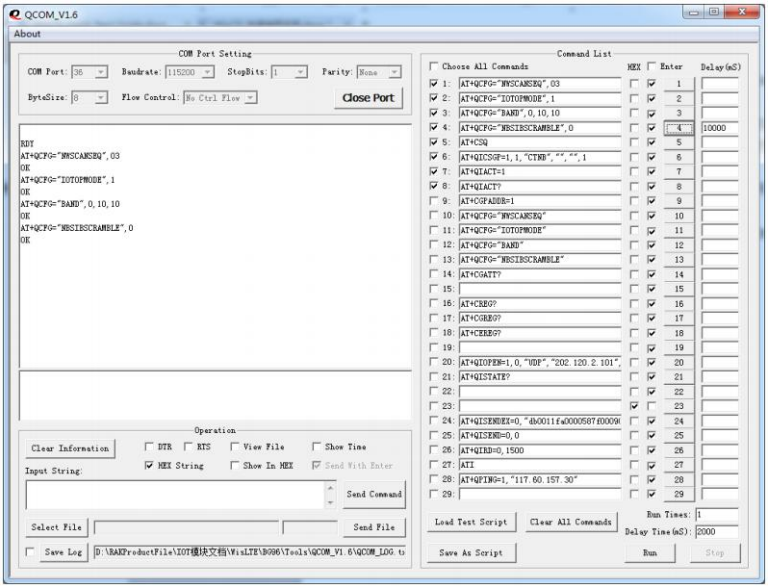
(China Telecom's NB-IoT SIM card is used in this test. Please adjust accordingly for NBIoT network you connect in your regions. For more information on AT commands, please refer to: Quectel BG96 Network Searching Scheme Introduction)

```
AT+QCFG="NWSCANSEQ",03      // Set the scanning network to NB-IoT network
AT+QCFG="IOTOPMODE",1
AT+QCFG="BAND",0,10,10      // Set the scan channel to BAND5
AT+QCFG="NBSIBSCRAMBLE",0
```

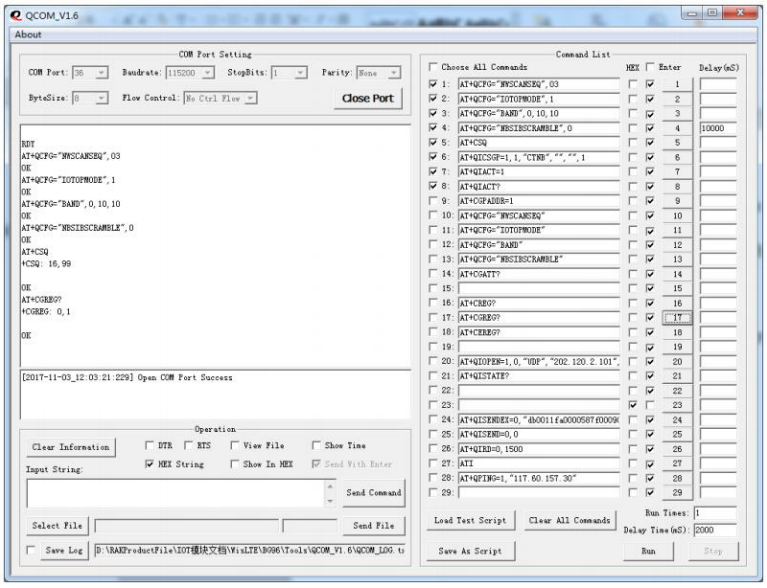
Or you can manually search the current network and connect manually.

```
AT+COPS=?                   // Manually search the current network
AT+COPS=1,0,"CHN-CT",9      // Manually connect NB-IoT network
```

(These command reference come from: Quectel BG96 AT Commands Manual)

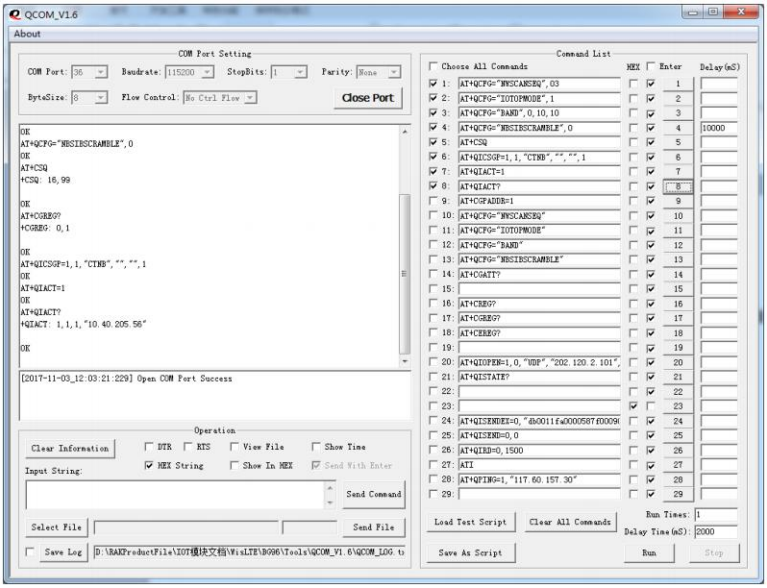


6. After setting, send AT + CSQ to check network signal strength, if there is a signal value, it indicates that it has connected to NB-IoT network. You can also send AT + CGREG? to check the connection status of the network to determine whether to connect to the network:



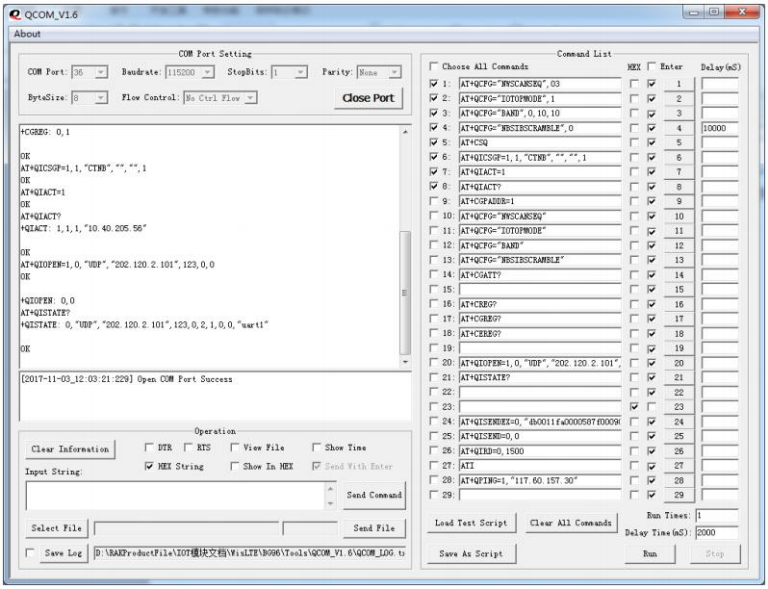
7. After connecting to the network, you need to set up the APN and activate the APN network. You can set the APN by sending the following commands; (For command details, please refer to Quectel BG96 TCP (IP) AT Commands Manual)

```
AT+QICSGP=1,1,"CTNB","","",1        // Set APN parameters
AT+QIACT=1                          // Activate APN
AT+QIACT?                           // Query the APN assigned IP address
```



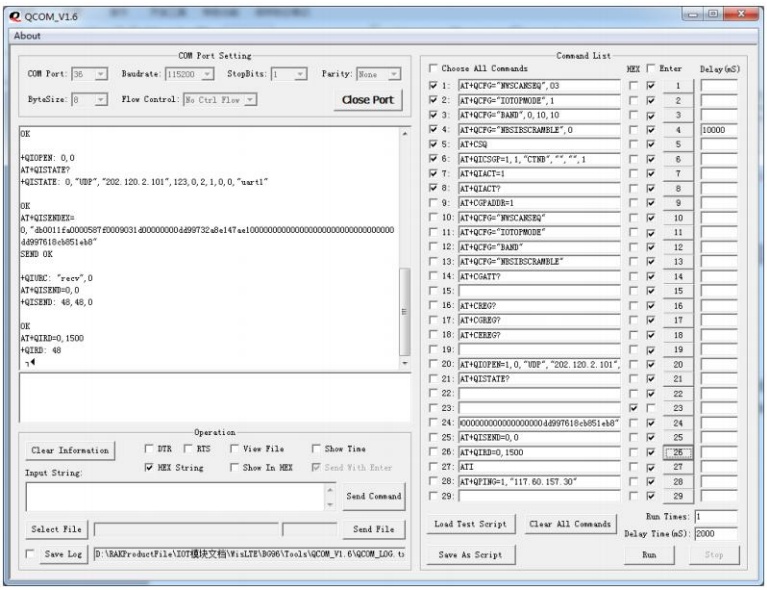
8. After activating the APN, you can establish a UDP connection; (In China Telecom's NB-IoT network, you must first inform the operator your server IP address. The operator will make binding before the connection is successful. Other networks might be different).

```
AT+QIOPEN=1,0,"UDP","202.120.2.101",123,0,0  // Establish a UDP connection
AT+QISTATE?          // Query connection is successful
```



9. If sending data to the server, there will be a prompt to receive data "recv", if there is no prompt, you can send the following commands to check whether there is data reception.

```
AT+QISENDEX=0,"db0011fa0000587f0009031d00000000dd99732a8e147ae100000000
00000000000000000000000000dd997618cb851eb8" // send data
AT+QISEND=0,0  // Query data is sent successfully
AT+QIRD=0,1500 // Check if there is data received, if there is, print it out directly
```



4.1.4 GPS Function Test

1. Plug in the module GPS antenna.
2. Select Quectel USB AT Port corresponding to the COM port.
3. Open the serial port tools.
4. Send the commands listed below to control the module's GPS capabilities. (For detailed GPS command description, please refer to: Quectel BG96 GNSS AT Commands Manual)

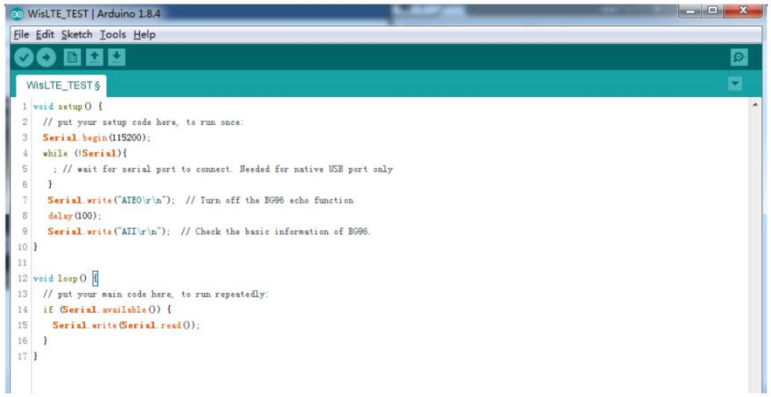
```
AT+QGPS=1           // Turn on GNSS
AT+QGPSLOC?         // Acquire Positioning Information
AT+QGPSEND          // Turn off GNSS
```

4.2 User Arduino Header Interface

BG96 LPWA IoT Cellular Arduino Shield also supports Arduino headers as defined by Arduino UNO R3. Please refer to the BG96 LPWA IoT Cellular Arduino Shield Arduino Header pin definition in the previous section.

Here is a test communication program to verify communication between an Arduino MCU base board and BG96 LPWA IoT Cellular Arduino Shield. Arduino library for BG96 LPWA IoT Cellular Arduino Shield will be provided later.

```
void setup()
{
      // put your setup code here, to run once:
      Serial.begin(115200);
      while (!Serial)
      {
            ; // wait for serial port to connect. Needed for native USB port only
      }
      void loop()
      {
            // put your main code here, to run repeatedly:
            if (Serial.available())
      {
            Serial.write(Serial.read());
      }
}
```



Revision History

Revision	Description	Date
1.0	Initial version	July 23, 2018

About RAKwireless:

Shenzhen RAKwireless Technology is a pioneer in providing innovated Lego-like IoT module solutions for the three critical elements of IoT edge devices – edge computing, cloud connectivity, and node sensing. It's patented,modularized, simplified design of combining one, two, or all the three elements to significantly help address diverse IoT applications and accelerate time-to-market.