Antenna Design Note

Rev. Antenna_Design_Note_V2.0

Date: 2018-01-02

Status: Released

Our aim is to provide customers with timely and comprehensive service. For any assistance, please contact our company headquarters:

Quectel Wireless Solutions Co., Ltd.
7th Floor, Hongye Building, No.1801 Hongmei Road, Xuhui District, Shanghai 200233, China
Tel: +86 21 5108 6236
Email: info@quectel.com

Or our local office. For more information, please visit:
http://quectel.com/support/sales.htm

For technical support, or to report documentation errors, please visit:
http://quectel.com/support/technical.htm
Or email to: support@quectel.com

GENERAL NOTES

QUECTEL OFFERS THE INFORMATION AS A SERVICE TO ITS CUSTOMERS. THE INFORMATION PROVIDED IS BASED UPON CUSTOMERS' REQUIREMENTS. QUECTEL MAKES EVERY EFFORT TO ENSURE THE QUALITY OF THE INFORMATION IT MAKES AVAILABLE. QUECTEL DOES NOT MAKE ANY WARRANTY AS TO THE INFORMATION CONTAINED HEREIN, AND DOES NOT ACCEPT ANY LIABILITY FOR ANY INJURY, LOSS OR DAMAGE OF ANY KIND INCURRED BY USE OF OR RELIANCE UPON THE INFORMATION. ALL INFORMATION SUPPLIED HEREIN IS SUBJECT TO CHANGE WITHOUT PRIOR NOTICE.

COPYRIGHT

About the Document

History

Revision	Date	Author	Description
1.0	2012-06-09	David WEI	Initial
1.1	2012-06-15	David WEI	Modified Figure 1
1.2	2012-08-01	David WEI	Added contact information for antenna manufacturers: Antenova and Pulse Electronics
1.3	2012-11-21	David WEI	Added contact information for GLONASS antenna manufacturer INPAQ
1.4	2013-07-10	David WEI	1. Added ceramic chip antennas 2. Updated contact information
1.5	2014-11-21	Jackie WANG	Added the antenna performance and LDS antenna
1.6	2015-04-11	Jackie WANG	Added applicable modules
1.7	2016-01-06	Mark ZHANG	1. Added external PCB antennas 2. Added contact information for antenna manufacturer SAINTENNA and JINGHONG
1.8	2016-06-01	Mark ZHANG	1. Updated the contact information of antenna manufacturer JESONCOM 2. Updated the address and contact information of antenna manufacturer Antenova
1.9	2017-07-14	Vick YANG	1. Added description of metal frame antennas in Chapter 3.8 2. Added description of internal Wi-Fi laminated antennas in Chapter 7 3. Updated antenna suppliers information in Chapter 8: ● Updated contact information of antenna manufacturers SAINTENNA and INPAQ ● Deleted information of antenna manufacturer JINGHONG ● Added information of antenna manufacturer SHEN XUN

2.0	2018-01-02	Vick YANG/ Beny ZHU	1. Optimized the description of EIRP (Effective Isotropic Radiated Power) in Chapter 2.1. 2. Updated the design note (item 3) for internal Wi-Fi laminated antenna. 3. Added Chapter 8: GNSS Antenna Isolation Design Requirements. 4. Updated the address and contact information (tel. number, email address and fax number) of antenna supplier Pulse. 5. Added Sunnyway and VLG as new antenna suppliers.

Contents

About the Document **2**
Contents **4**
Table Index **5**
Figure Index **6**

1 Recommended Component Placement of Main PCB **7**

2 Basic Parameters and Requirements of Antennas **8**
2.1. Basic Parameters of Antennas 8
2.2. Basic Requirements of Antennas 10

3 Internal 2G/3G/4G Antennas **11**
3.1. PIFA Antennas with FPC Form 11
3.2. PIFA Antennas with Plastic Bracket 12
3.3. Monopole Antennas 13
3.4. FPC Dipole Antennas 14
3.5. PCB Antennas 14
3.6. Chip Antennas 15
3.7. Laser Direct Structure Antennas 16
3.8. Metal Frame Antennas 17

4 External 2G/3G/4G Antennas **18**
4.1. Dipole Antennas 18
4.2. Monopole Antennas 19
4.3. PCB Antennas 20

5 Internal GNSS Antennas **21**
5.1. Internal GNSS Active Antennas with an RF Connector 21
5.2. GNSS Passive Antennas (Passive Antennas) with a Welding Needle 22

6 External GNSS Antennas **23**
6.1. External GNSS Antennas 23

7 Internal Wi-Fi Laminated Antenna **24**
7.1. Internal Wi-Fi Laminated Antenna 24

8 GNSS Antenna Isolation Design Requirements **25**
8.1. Antenna Isolation 25
8.2. Isolation between 3G/4G Antenna and GNSS Antenna 25
8.3. Isolation between Wi-Fi Antenna and GNSS Antenna 25

9 Antenna Suppliers Information **27**

Table Index

TABLE 1: VSWR AND RETURN LOSS 9
TABLE 2: BASIC REQUIREMENTS OF ANTENNAS 10

Figure Index

FIGURE 1: RECOMMENDED COMPONENT PLACEMENT 7
FIGURE 2: EXAMPLE OF AN FPC PIFA ANTENNA USING SOLDERING PADS AS FEED POINTS 11
FIGURE 3: EXAMPLE OF AN FPC PIFA ANTENNA USING SPRING PROBES AS FEED POINTS 11
FIGURE 4: EXAMPLE OF AN FPC PIFA ANTENNA USING METAL SHRAPNEL AS FEED POINTS 11
FIGURE 5: EXAMPLE OF A PIFA ANTENNA WITH PLASTIC BRACKET 12
FIGURE 6: EXAMPLE OF AN FPC MONOPOLE ANTENNA 13
FIGURE 7: EXAMPLE OF AN FPC MONOPOLE ANTENNA PASTED INSIDE THE CASING 13
FIGURE 8: EXAMPLE OF A MONOPOLE ANTENNA WITH PLASTIC BRACKET 13
FIGURE 9: EXAMPLE OF A DIPOLE ANTENNA WITH FPC FORM 14
FIGURE 10: EXAMPLE OF PCB ANTENNAS 14
FIGURE 11: PRACTICAL APPLICATION OF PCB ANTENNAS 15
FIGURE 12: EXAMPLE OF A CERAMIC CHIP ANTENNA 15
FIGURE 13: EXAMPLE OF A LASER DIRECT STRUCTURE ANTENNA 16
FIGURE 14: EXAMPLE OF A METAL FRAME ANTENNA 17
FIGURE 15: EXAMPLE OF A DIPOLE ANTENNA 18
FIGURE 16: EXAMPLE OF MONOPOLE ANTENNAS 19
FIGURE 17: EXAMPLE OF PCB ANTENNAS 20
FIGURE 18: EXAMPLE OF INTERNAL GNSS ACTIVE ANTENNAS WITH AN RF CONNECTOR 21
FIGURE 19: EXAMPLE OF A GNSS PASSIVE ANTENNA (PATCH ANTENNA) WITH A WELDING NEEDLE 22
FIGURE 20: PRACTICAL APPLICATION OF GNSS PASSIVE ANTENNAS WITH WELDING NEEDLE 22
FIGURE 21: EXAMPLE OF AN EXTERNAL GNSS ANTENNA 23
FIGURE 22: EXAMPLE OF AN EMBEDDED WI-FI LAMINATED ANTENNA 24

1 Recommended Component Placement of Main PCB

This document is applicable to all Quectel modules.

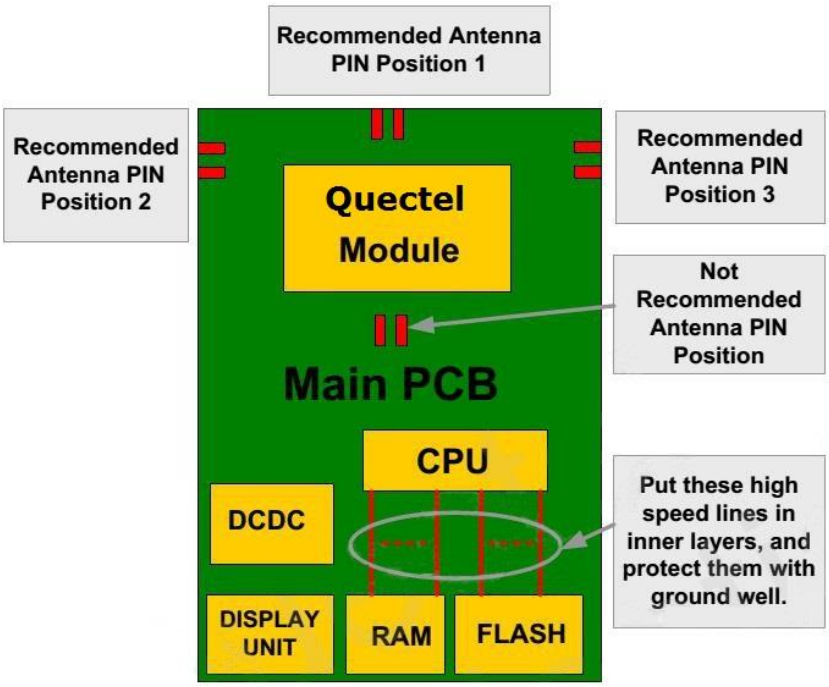


Figure 1: Recommended Component Placement

Notes:
1. It is suggested to keep the RF ports on the outer side of PCB when placing the module.
2. Put antenna feed points at the edge of the main PCB, rather than in the center.
3. Keep the antenna as far away from CPU/SDRAM/Flash/DCDC/Display FPC components as possible. It is NOT recommended to place the antenna and these components on the same layer and same edge of the main PCB.
4. Keep the high speed lines between CPU and SDRAM/Flash/Display FPC as short as possible, and put these lines in inner layers with ground shielding on not only upper and lower layers but also right and left sides. Add an EMI filter on high speed lines between CPU and display FPC if necessary.
5. Put ZIFs of CPU/SDRAM/Flash/DCDC/Display FPC into the shielding case, and copper-nickel-zinc alloy shielding case is preferred.

2 Basic Parameters and Requirements of Antennas

2.1. Basic Parameters of Antennas

Gain (dBi): The ratio of “power of antenna” and “power of isotropic radiation from an ideal current source” in maximum transmitting direction with the same input power. “dBi” is widely used as the unit of antenna gain.

Gain (dBd): The ratio of “power of antenna” and “power of half wave dipole antenna” in maximum transmitting direction with the same input power. When it represents the same gain, one formula indicating relationship between dBi and dBd is given as below: dBi=dBd+2.15.

Directivity: The ratio of “power of antenna” and “power of isotropic radiation from an ideal current source” in maximum transmitting direction with the same radiated power.

Efficiency: The ratio of the antenna radiation power and antenna input power.

Gain=Directivity × Efficiency
Efficiency=Output Power/Input Power

APIP (Antenna Port Input Power): The input power of antenna.

EIRP (Effective Isotropic Radiated Power): EIRP (Effective Isotropic Radiated Power) is the amount of power that a theoretical isotropic antenna (which evenly distributes power in all directions) would emit to produce the peak power density observed in the direction of maximum antenna gain. It is also called Equivalent Isotropic Radiated Power. EIRP can take into account the losses in transmission line and connectors and includes the gain of the antenna. The EIRP is often stated in terms of decibels over a reference power emitted by an isotropic radiator with an equivalent signal strength. The EIRP allows comparisons between different emitters regardless of type, size or form. From the EIRP, and with knowledge of a real antenna's gain, it is possible to calculate real power and field strength values.

EIRP=Pt × Gt
Pt: the transmitting power of the transmitter (unit: dBm)
Gt: the antenna gain of the transmitting antenna (unit: dBi)

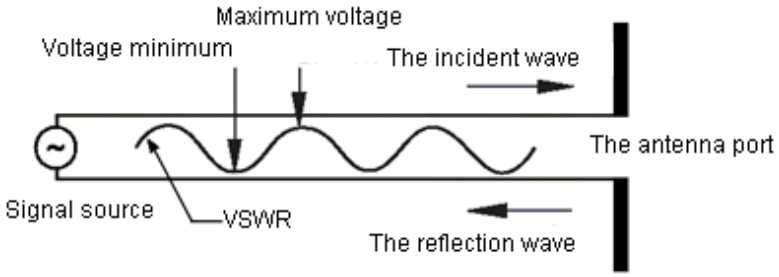
Logarithmic (dB) formula:
EIRP = P - Loss + G
P: output power of transmitter (unit: dBm)
Loss: feeder loss between transmitter output terminal and antenna feed source (unit: dB)
G: antenna transmission gain (unit: dBi)

PEIRP (Peak Effective Isotropic Radiated Power): The peak value of EIRP.

ERP (Effective Radiated Power): Comparing to half wave dipole antenna, it is the power obtained in maximum transmitting direction.

VSWR (Voltage Standing Wave Ratio):

$$VSWR = \frac{Vmax}{Vmin} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$



VSWR is commonly represented in Return Loss (RL) (indicated as S11) in engineering:

$$RL = -20\lg\frac{V+1}{V-1} \text{ (dB)}$$

The corresponding relationship between RL and VSWR is shown in the table below:

Table 1: VSWR and Return Loss

VSWR	1.20	1.25	1.30	1.35	1.40	1.50	2.00
Return Loss (dB)	-21.00	-19.00	-17.60	-16.60	-15.60	-14.00	-9.50

2.2. Basic Requirements of Antennas

Table 2: Basic Requirements of Antennas

Items	Requirements
Frequency Band	Determined by the supported operating bands of devices
VSWR	≤ 3
Gain (dBi)	≥1
Max Input Power (W)	50
Input Impedance (Ω)	50
Polarization Type	Vertical linear polarization Horizontal linear polarization Left/right hand circular polarization

3 Internal 2G/3G/4G Antennas

3.1. PIFA Antennas with FPC Form

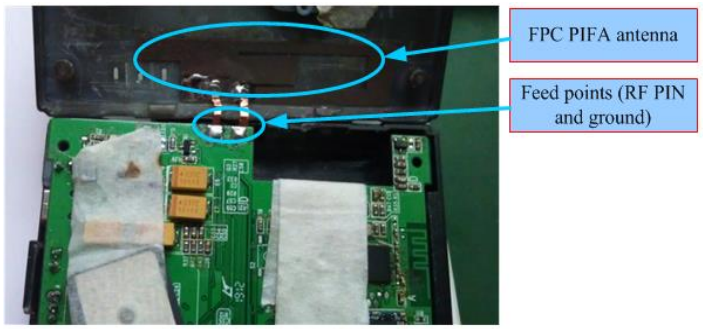


Figure 2: Example of an FPC PIFA Antenna Using Soldering Pads as Feed Points

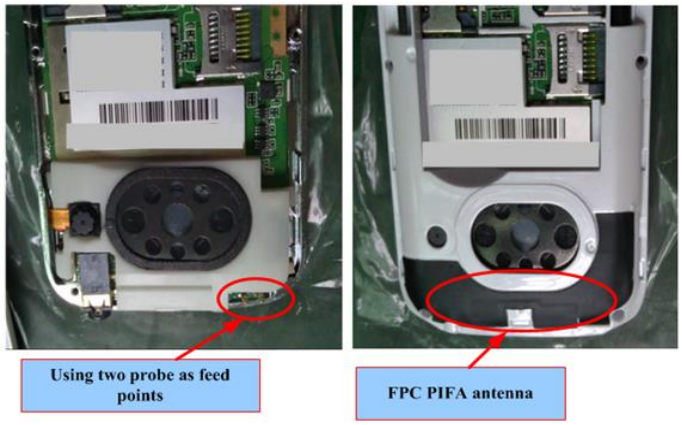


Figure 3: Example of an FPC PIFA Antenna Using Spring Probes as Feed Points

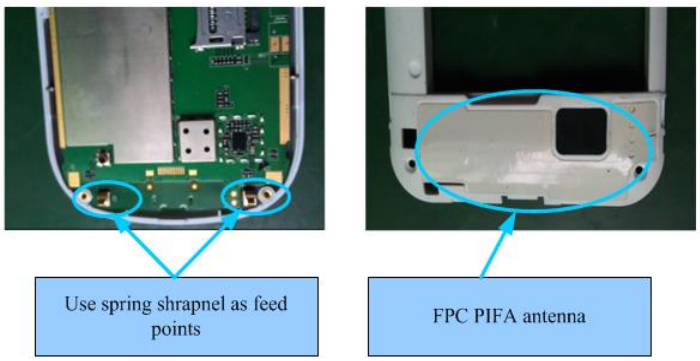


Figure 4: Example of an FPC PIFA Antenna Using Metal Shrapnel as Feed Points

Notes:
1. The FPC PIFA antenna can be pasted in the casing, which saves space especially for PDA and automotive devices. Three feed points will be used on the antenna, the middle one is signal feed point, the other two are ground feed points. When bandwidth of a high-frequency band is not enough during tuning the antenna, one ground feed point will be used to increase the bandwidth.
2. Keep the distance between antenna and the main PCB at least 5mm.
3. Ground copper is required under antenna area on the main PCB.
4. Feed points can be designed as soldering pads, probes or shrapnel. For a higher reliability, some hot melt columns can be designed inside the device casing.

3.2. PIFA Antennas with Plastic Bracket

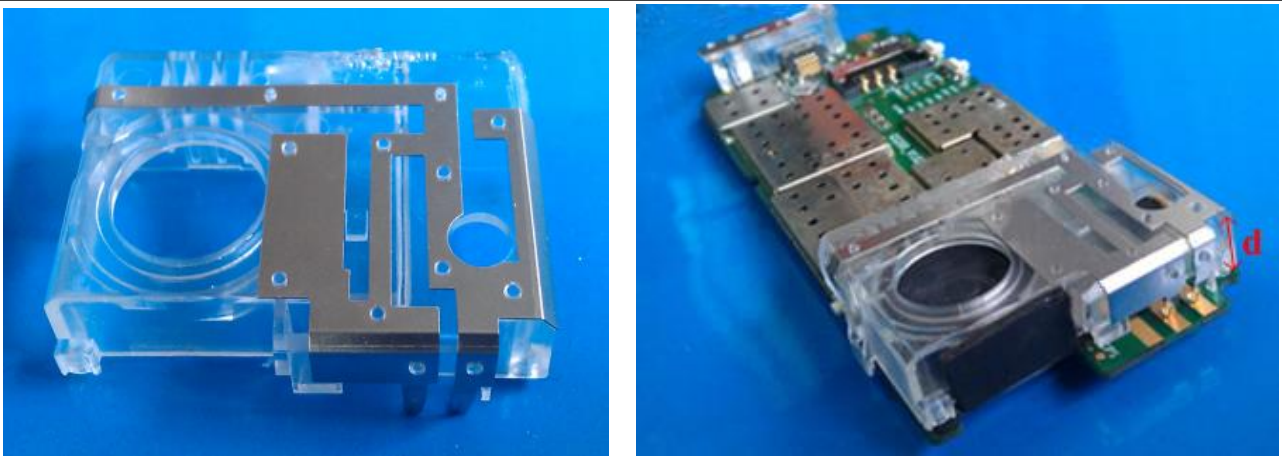


Figure 5: Example of a PIFA Antenna with Plastic Bracket

Notes:
1. The antenna needs 3 feed points, the middle one is signal feed point, the other two are ground feed points. When bandwidth of a high-frequency band is not enough during tuning the antenna, one ground feed point will be used to increase the bandwidth.
2. Ground copper is required under antenna area on the main PCB.
3. For GSM quad-band antennas, the height of bracket (marked as "d") should be about 8mm.
4. For old model of PIFA antennas, clearance area should be no less than 30mm×20mm and the height of bracket ("d") is no less than 8mm.

3.3. Monopole Antennas

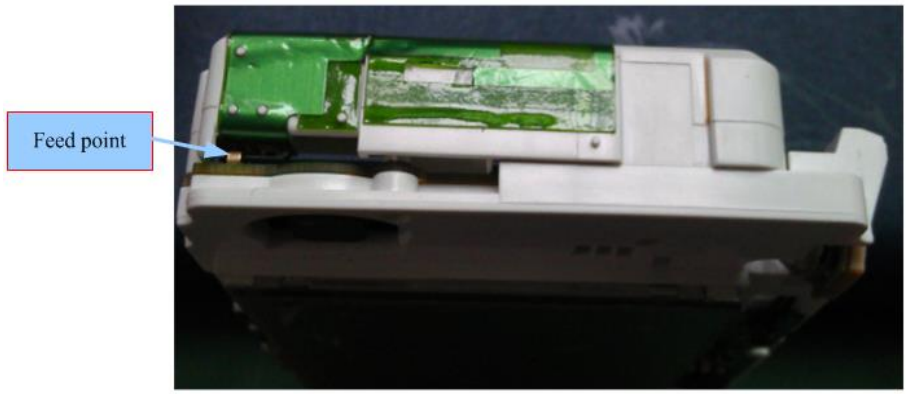


Figure 6: Example of an FPC Monopole Antenna

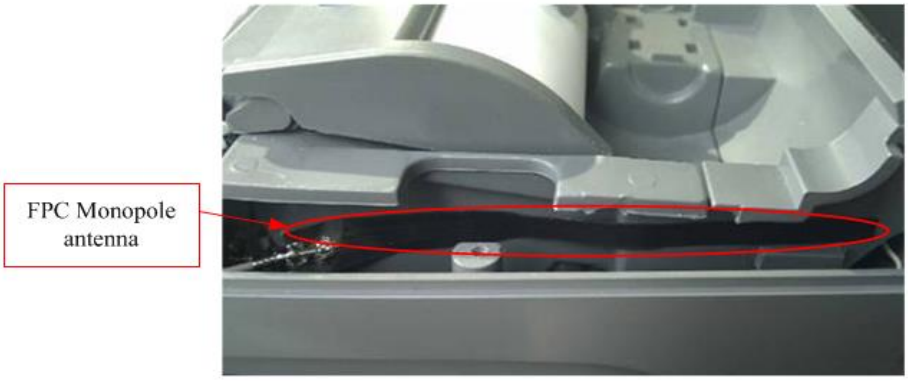


Figure 7: Example of an FPC Monopole Antenna Pasted inside the Casing

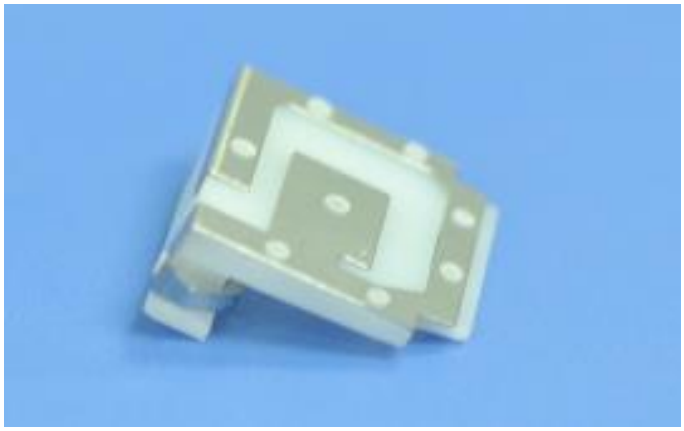


Figure 8: Example of a Monopole Antenna with Plastic Bracket

Notes:

1. Generally, the antenna only has one signal feed point. When bandwidth of a high-frequency band is not enough during tuning the antenna, a ground feed point should be used to increase the bandwidth.
2. A certain clearance area in all layers under antenna of main PCB is required.

3. For GSM dual-band antennas, the height of the bracket should be more than 6mm and the projected area should be more than 360mm^2. For GSM quad-band antennas, the height of the bracket should be more than 8mm and the projected area should be more than 400mm^2. Meanwhile, the clearance area should be no less than 30mm×20mm, and the height is recommended to be 7mm.

3.4. FPC Dipole Antennas

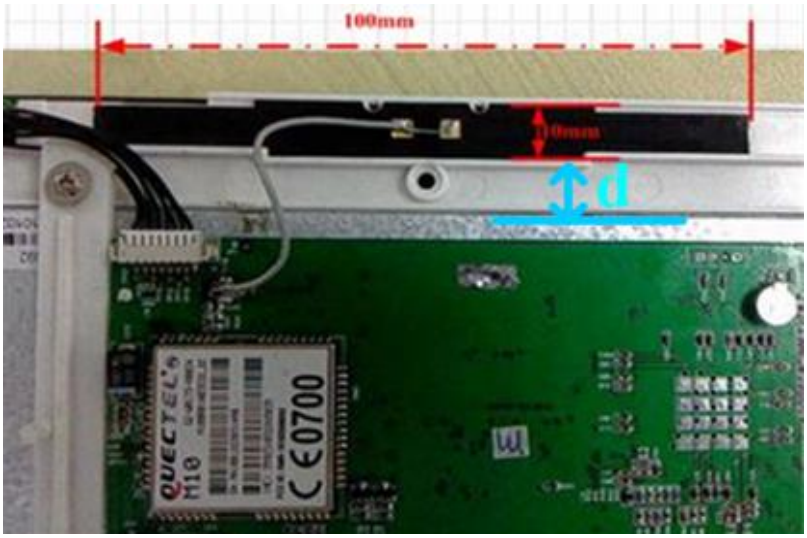


Figure 9: Example of a Dipole Antenna with FPC Form

Note:

The distance between inner edge of antenna and the ground of main PCB (marked as “d”) should be more than 8mm.

3.5. PCB Antennas

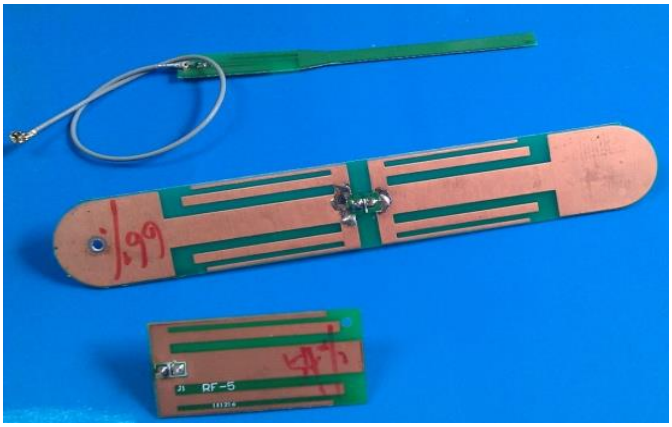


Figure 10: Example of PCB Antennas

Figure 11: Practical Application of PCB Antennas

Notes:
1. The antenna can be fixed to plastic box and does not occupy any space on the main PCB. It will be better if the antenna is mounted in a suitable notch.
2. There should be no metal material around antenna, and keep the antenna at least 8mm away from the main PCB.
3. Antenna can be connected by RF connector or soldered onto the RF output port on the main PCB.

3.6. Chip Antennas

Figure 12: Example of a Ceramic Chip Antenna

Notes:
1. RF performance of the chip antenna mainly depends on the radiation ground on both sides of the antenna, so the antenna should be placed in the middle of the PCB edge, and keep at least 30mm away from the edge of the radiation ground (marked as "d").
2. A certain clearance area in all layers under antenna of main PCB is required.
3. The antenna can be packaged in SMT type.

3.7. Laser Direct Structure Antennas

Figure 13: Example of a Laser Direct Structure Antenna

Notes:
1. The antenna features high compatibility and precision, stable performance as well as simple and environment-friendly manufacturing process.
2. The signals of the antenna are radiated onto a device shell to prevent the interference of the components inside the device and ensure the signal quality of device. Meanwhile, its space-saving design makes the device smaller and thinner.
3. The cost of an LDS antenna is higher than a common one.

3.8. Metal Frame Antennas

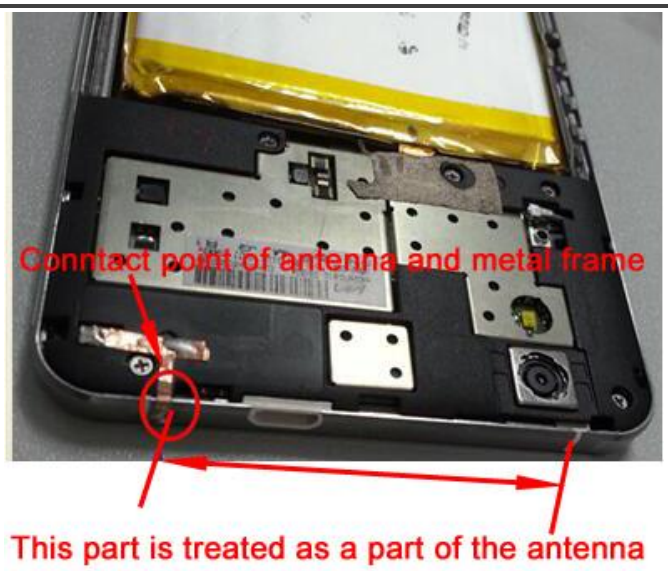


Figure 14: Example of a Metal Frame Antenna

Notes:

1. It is the mainstream 4G antenna, and the metal frame of the device is a part of the antenna. Generally, frequency bands can be switched. There are three feed points on the small main board, the middle one is the signal feed point, the other two are ground feed points in metal shrapnel format. The shrapnel connects the antenna with the metal frame, and the optimal contact point during antenna tuning is the location where the shrapnel is designed.
2. The clearance area in all layers under antenna of the main PCB should be 45mm×10mm, and the height of the bracket should be 7mm.
3. Breaks should be symmetrically designed to isolate the antenna and the metal frame.

4 External 2G/3G/4G Antennas

4.1. Dipole Antennas

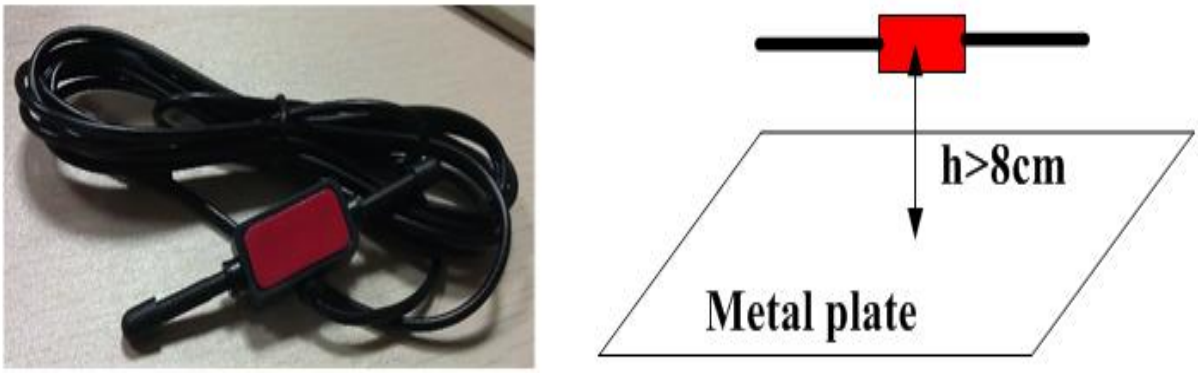


Figure 15: Example of a Dipole Antenna

Notes:
1. The height between antenna and metal plate "h" should be more than 8cm.
2. The length of cable should be as short as possible. The copper wire mesh should be as dense as possible, that is, the quantity for surround copper lines used to shield signal should be no less than 32.

4.2. Monopole Antennas

Figure 16: Example of Monopole Antennas

Notes:
1. There should be no other metal poles within 200mm of the antenna.
2. VSWR for stubby antenna should be less than 4, and VSWR for vehicle with long cable should be less than 2.
3. The length of cable should be as short as possible, and the quantity for surround copper lines used to shield signal should be no less than 32.

4.3. PCB Antennas

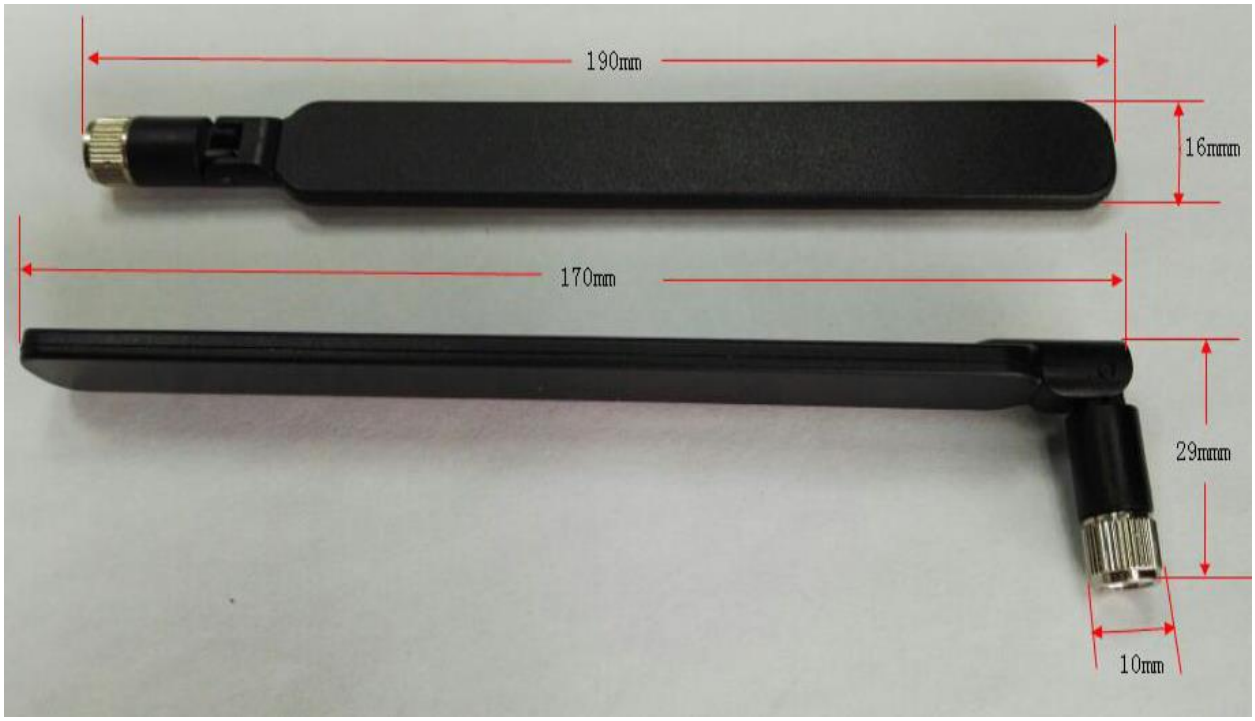


Figure 17: Example of PCB Antennas

Notes：

1. The external PCB antennas feature stable and superior performance.
2. Keep the antennas perpendicular to the ground and avoid being surrounded by metal objects.
3. As two branches of LTE antennas, the main antennas are responsible for sending and receiving signals and the diversity antennas are only responsible for receiving signals. Diversity antennas mainly resist multipath fading and fast fading. Considering the receive gain of diversity antennas is much worse than main antennas, the gain of diversity antennas should be controlled under 3dBi.
4. Attention should be paid to the relative position between main antennas and diversity antennas, the overall performance would be better when distance is larger than 10dB between antennas in view of distance and polarization isolation. And main antennas and diversity antennas should NOT be placed at the same edge of the host.
5. The multi-antenna technology (MIMO) has the ability to transmit high-speed data and resist interference.

5 Internal GNSS Antennas

5.1. Internal GNSS Active Antennas with an RF Connector

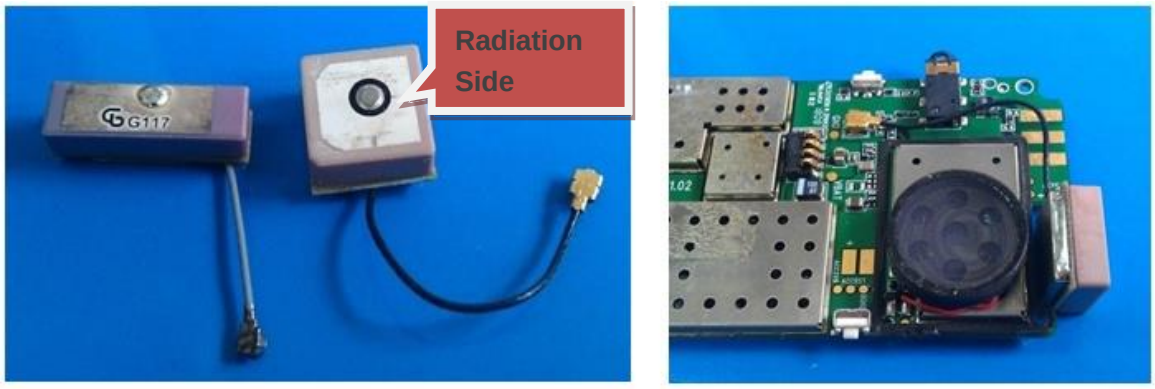


Figure 18: Example of Internal GNSS Active Antennas with an RF Connector

Notes:
1. The active antenna has an LNA to improve signal strength, please keep antenna radiation side towards open sky during practical applications.
2. Make sure the height of metal component nearby is lower than the antenna.
3. Square-shaped antenna is right hand circular polarized, rectangle-shaped antenna is linear polarized, and the former is preferred.
4. Keep RF cable as short as possible, and low loss cable is recommended.

5.2. GNSS Passive Antennas (Patch Antennas) with a Welding Needle

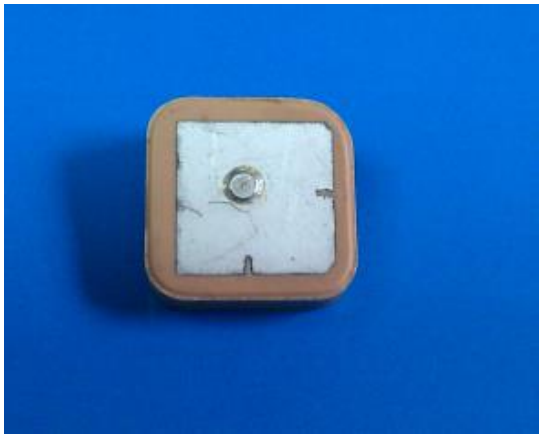


Figure 19: Example of a GNSS Passive Antenna (Patch Antenna) with a Welding Needle

Figure 20: Practical Application of GNSS Passive Antennas with Welding Needle

Notes:
1. An LNA should be mounted on the motherboard to improve signal strength of the passive antenna. Please keep antenna radiation side towards open sky during practical application.
2. Make sure the height of metal component nearby is lower than the antenna.
3. Square-shaped antenna is right hand circular polarized, rectangle-shape antenna is linear polarized, and the former is preferred.

6 External GNSS Antennas

6.1. External GNSS Antennas

Figure 21: Example of an External GNSS Antenna

Notes:
1. Keep antenna radiation side towards open sky during practical application.
2. The antenna should be placed away from metal components.
3. Square-shape antenna is right hand circular polarized, rectangle-shaped is linear polarized, and the former is preferred.
4. Keep RF cable as short as possible, and the quantity for surround copper lines used to shield signal should be no less than 32.

7 Internal Wi-Fi Laminated Antenna

7.1. Internal Wi-Fi Laminated Antenna

Figure 22: Example of an Embedded Wi-Fi Laminated Antenna

Notes:
1. The antenna adopts 2.4GHz and 5GHz bands, and can realize the best performance to a certain direction. The distance between the antenna and main board is preferred to be 20mm.
2. The antenna should be placed away from metal components.
3. The top patch antenna in green color works at 5GHz, and the ceramic antenna in white color works at 2.4GHz. The polarization design for the two antennas should be the same as that for the transmitting antenna.
4. Keep RF cable as short as possible and low loss cable is recommended.

8 GNSS Antenna Isolation Design Requirements

8.1. Antenna Isolation

Antenna isolation is an important index in electromagnetic compatibility (EMC), and it is typically defined as the ratio between absorbed power of receiver (P_a) and the available power of transmitter (P_L). It is a measure of how tightly coupled antennas are. Typically, antenna isolation is measured for antennas on the same product - that is, the isolation between a GNSS antenna and a Wi-Fi/3G/4G antenna, for instance. Therefore, the isolation should be as large as possible.

Antenna to antenna isolation can be increased by:

- Increasing the physical separation between the antennas
- Using different polarizations for the antennas in question
- If the antennas have different frequencies, using filters to reduce efficiency at the opposite antenna's frequency
- Reducing the correlation coefficient between the antenna's radiation patterns - that is, have the antenna's peak radiation in different or opposite directions

8.2. Isolation between 3G/4G Antenna and GNSS Antenna

- The isolation between a 3G/4G antenna and a GNSS active antenna should be at least 10dB.
- The isolation between a 3G/4G antenna and a GNSS passive antenna should be at least 15dB.

8.3. Isolation between Wi-Fi Antenna and GNSS Antenna

- The isolation between a 2.4GHz Wi-Fi antenna and a GNSS antenna (either active or passive antenna) should be at least 15dB.
- The isolation between a 5GHz Wi-Fi antenna and a GNSS antenna (either active or passive antenna) should be at least 20dB.

In order to achieve the above design requirements, it is usually recommended to add a filter near the GNSS antenna so as to suppression the interference from other antennas.

9 Antenna Suppliers Information

Antenna Manufacturer	Address	Contact Information			Main Products
SAINTENNA	2nd Floor, Building 8, No.611, Baoqi Road, Baoshan District, Shanghai, China	Wu Xiaofang	Fax:	+86-21-36307757	Offers all kinds of internal/external antennas and LTE/NB-IoT/ WCDMA/GNSS/ Wi-Fi/GSM antennas.
			Email:	wuxiaofang@sainte nna.com	
			Tel:	+86-21-36307754 +86-152-2100-5199	
JESONCOM	No.358, Liuyuan Road., Baoshan District, Shanghai, China	Zhang Yuegang/ Yu Donglin	Tel:	+86-181-0181-6628 +86-186-2185-0533	Offers all kinds of internal/external antennas and LTE/ NB-IoT/ WCDMA/GNSS/ EVDO/GSM antennas.
			Fax:	+86-21-66276923	
			Email:	Alex.zhang@shjeso ncom.com	
			Website:	www.shjesoncom.c om	
SHEN XUN	2nd Floor, Building 3, No. 2710 Fengxiang Road, Jiading District, Shanghai, China	Li Xuanwen	Tel:	+86-135-6499-3005	Offers all kinds of internal/external antennas and LTE/ NB-IoT/ WCDMA/GNSS/ EVDO/GSM antennas.
			Fax:	+86-21-69986369	
			Email	lxw@sh-shenxun.co m	
			Website:	www.sh-shenxun.co m	
Antenova	2nd floor, Titan Court, 3 Bishop Square, Hatfield, Herts, AL10 9NA, United Kingdom		Fax:	+44 (0) 1223 810650	Antenova's broad range of antennas and RF solutions are ideally suited for GSM and CDMA, 3G, 4G, LTE, GNSS, Wi-Fi®, Bluetooth®, WiMAX™, WiBro, ZigBee®, FM, mobile TV and M2M applications.
			Tel:	+44 (0) 1223 810600	
			Email:	sales@antenova-m 2m.com	
			Website:	www.antenova-m2 m.com	

Pulse Electronics	No.99, Huoju Road, Suzhou New District, Suzhou City, Jiangsu Province, P.R. China	Shi jinchun	Fax:	+86-512-6809-8023	Pulse Electronics is a leading global supplier of LTE, WLAN, 3G/4G, navigation, and M2M fixed and mobile solutions.
			Tel:	+86-187-1789-6755	
			Email:	gavinshi@pulseelectronics.com	
			Website:	www.pulseelectronics.com	
INPAQ	4th Floor, Zhao Feng Universe Building Block D, No. 1800, Zhongshan West Road, Xuhui District, Shanghai, China	Chen Tiantian	Tel:	+86-134-7249-1553 +86-21-64400398-26816	INPAQ offers all kinds of GNSS antennas such as patch antennas, active antennas, chip antennas as well as customized antennas.
			Email:	tt.chen@inpaqgp.com	
			Website:	www.inpaq.com.tw	
Sunnyway	Room 302, Building 65, No. 421, Hongcao Road, Xuhui District, Shanghai, China	Yao Qingqing	Tel:	+86-139-1774-5111 +86-21-64842326	Offers all kinds of internal/external antennas and LTE/ NB-IoT/ WCDMA/GNSS/ EVDO/GSM antennas.
			Email:	yaoqingqing@sunnyway.com	
			Website:	www.sunny-way.com	
VLG	Room 1B-102, Building 3, No. 401, Caobao Road, Xuhui District, Shanghai, China	Zhang Qiao	Tel:	+86-21-54452321 +86-159-8667-1903	Offers all kinds of internal/external antennas and LTE/ NB-IoT/ WCDMA/GNSS/ EVDO/GSM antennas.
			Email:	Pm4@vlg.com.cn	
			Website:	www.vlg.com.cn	
Note: If the salesmen listed above cannot be contacted for some reason, please visit their web site and get the products and contact information.					