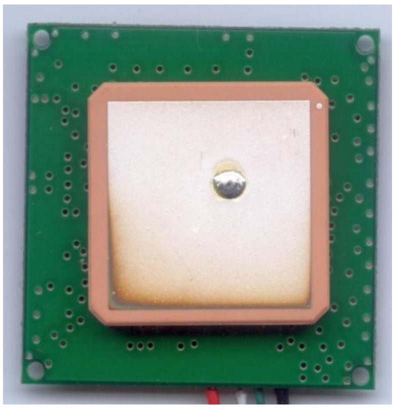
GPS

C04-6H

Smart Antenna with 25 x2 5 mm patch for LEA-6H Modules

Reference Design



Abstract

This document describes a u-blox 6 smart antenna Reference Design using the LEA-6H GPS module. It is intended as a template to make application specific smart antennas. This design is made available to u-blox customers as a blue print including schematic, layout, mechanical drawing and Gerber data.

Document Information	
Title	C04-6H
Subtitle	Smart Antenna with 25 x2 5 mm patch for LEA-6H Modules
Document type	Application Note
Document number	GPS.G6-HW-10105
Document status	Preliminary

Document status information	
Objective Specification	This document contains target values. Revised and supplementary data will be published later.
Advance Information	This document contains data based on early testing. Revised and supplementary data will be published later.
Preliminary	This document contains data from product verification. Revised and supplementary data may be published later.
Released	This document contains the final product specification.

Contents

1 Description

1.1 Product description

The C04-6H Smart Antenna reference design integrates a LEA-6H GPS receiver with a 25 x 25 x 4 mm ceramic patch antenna, UART serial interface, and USB. The C04-6H features the high performance u-blox 6 positioning engine, which enables navigation even in weak signal environments. u-blox reference designs are intended as a means to help system integrators to develop their own GPS-enabled end-products.

1.2 Photo

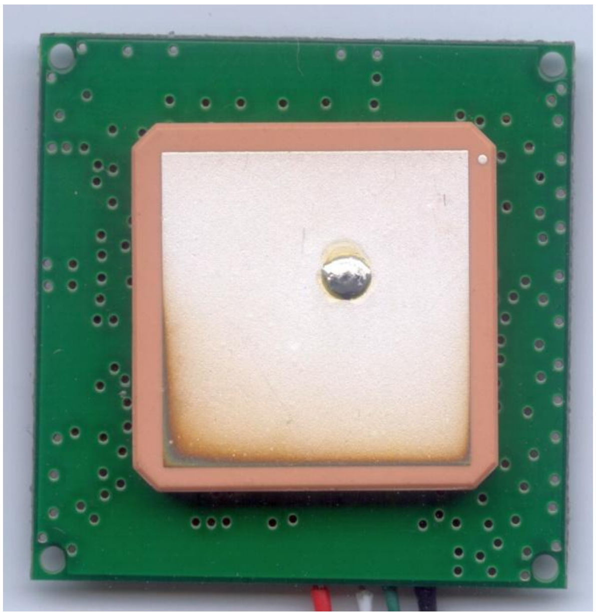


Figure 1: Top View C04-6H reference design

Figure 2: Bottom View C04-6H reference design

1.3 Block diagram

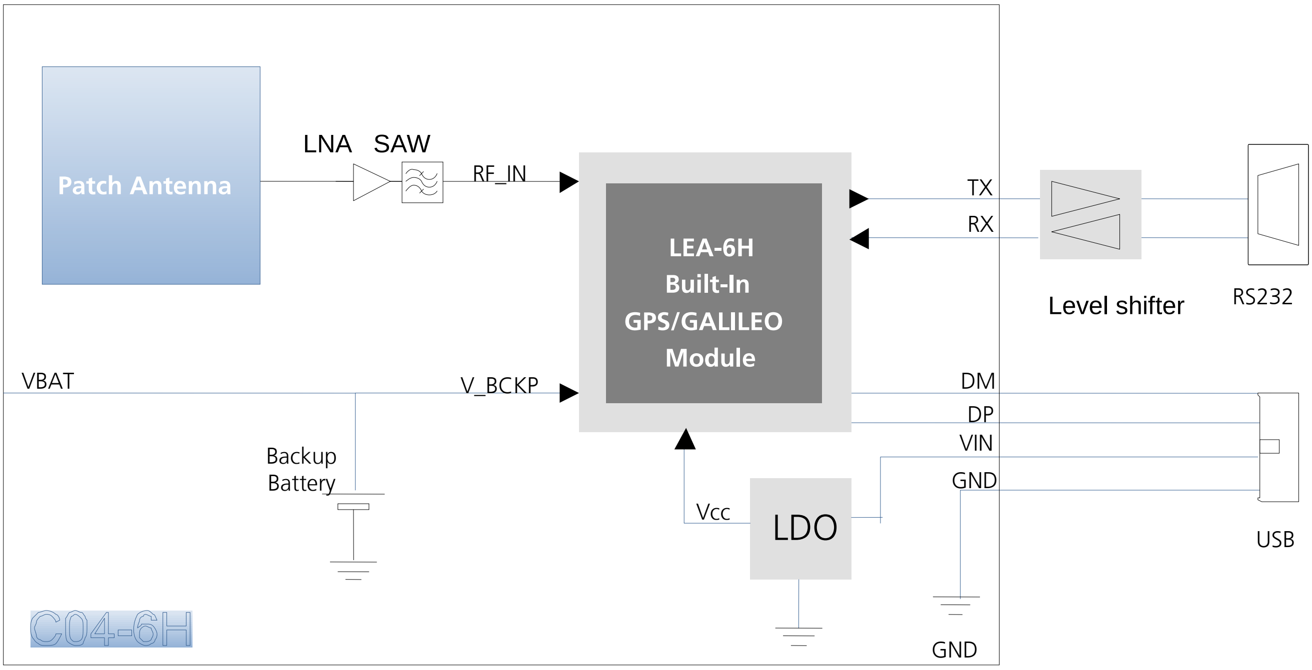


Figure 3: Block diagram C04-6H reference design

1.4 Electrical data

Power supply: Via USB (5 V)

External power supply (VIN): 3.6 to 5.5 V

1.5 Environmental data

Operating temperature: –20° C to 60° C

1.6 Mechanical dimension

Dimensions: 37 x 37 x 8.0 mm

Mounting: 4 tooling holes, 1.6 mm

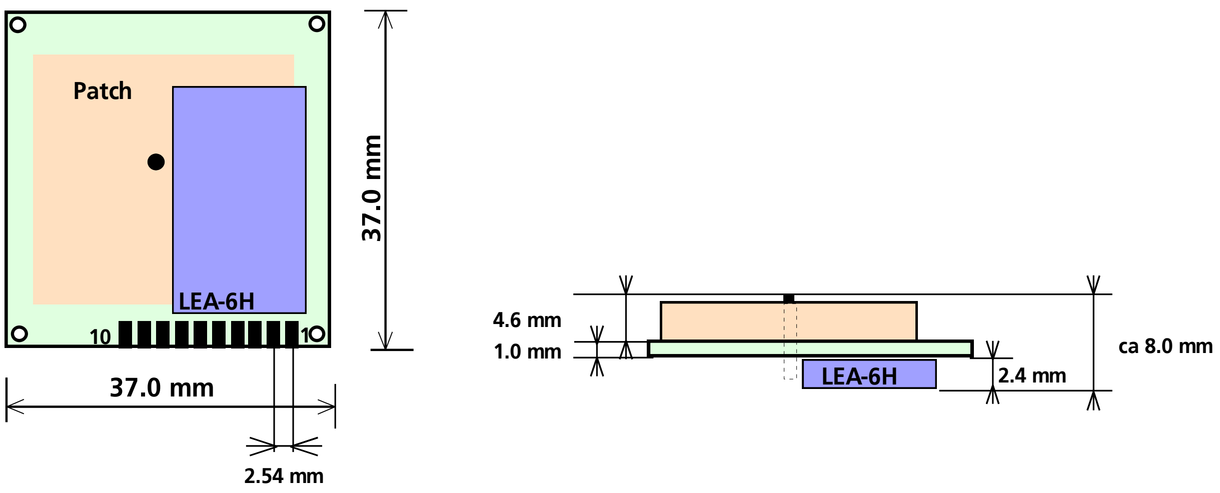


Figure 4: Top assembly drawing

1.7 USB

The C04-6H reference design features a USB V2.0 compatible serial port for power supply and data transfer.

If the USB isn't used:

- resistors R9, R10 and the protection IC U3 don't have to be fitted.
- R4A has to be replaced by R4B.

USB default configuration

Parameter	Description	Remark
USB, Input	UBX and NMEA protocol	
USB, Output	UBX and NMEA protocol	Only NMEA messages are activated by default

1.8 UART

The C04-6H reference design can be connected via UART. **RxD1/TxD1** supports data rates from 4.8 to 230.4 kBit/s. The signal output and input levels is 0 V to VCC (3.3V). An interface based on RS232 standard levels (+/-12 V) can be realized by using level shifters such as Maxim MAX3232.

If the UART isn't required, the Ferrite Bead FB1 and FB2 don't have to be fitted.

Serial port default configuration

Parameter	Description	Remark
Port 1, Input	UBX and NMEA protocol at 9'600 Baud	
Port 1, Output	UBX and NMEA protocol at 9'600 Baud	Only NMEA messages are activated by default

1.9 Connector

C04-6H reference design J1 Connector: SMD-pads for 10 pin header, Pitch: 2.54mm

J1 Pin#	Description	Remark
1	TxD1	Serial Port
2	RxD1	Serial Port
3	V_in	Power Supply (3.3 ... 5.5 V); internally connected with Pin 7
4	GND	Ground
5	GND	Ground
6	V_BAT	Backup Battery Voltage (2.0 ... 3.6V).
7	V_in	Power Supply (3.6 ... 5.5 V) internally connected with Pin 3
8	USB_DM	USB communication; Data -
9	USB_DP	USB communication; Data +
10	GND	Ground

Table 1: C04-6H reference design J1 Connector

☞ See Figure 5: C04-6H reference design Assembly Top for pin location

1.10 Antenna

The C04-6H reference design has a 25 x 25 x 4 mm ceramic patch antenna.The LNA and SAW have been added for better ESD & EOS immunity and better performance (i.e. lower Noise Figure).

1.11 Backup battery

A 3V rechargeable Li Battery is equipped on the C04-6H reference design. In case of a power failure, real-time clock (RTC) and backup RAM are supplied through Backup battery. This enables the U-BLOX 6 GPS Receiver to recover from power failure with either a Hot start or a Warm start (depending on the duration of VCC outage)

There are 2 different ways to connect a backup battery to the GPS receiver on the smart antenna reference design.

- Use the onboard battery B1.
- If a backup voltage is available on the main board, connect it to pin J1/6 and insert R4. In this case, the battery B1, diode D1 and the resistor R3 doesn't have to be fitted. External backup power: 1.4 V to 3.6 V, 22 uA

1.12 Configuration

The C04-6H reference design are fully configurable with UBX protocol configuration messages (see the u-blox 6 Receiver Description Including Protocol Specification [3]). The Current Configuration can be changed during normal operation by sending any UBX-CFG-XXX message to the receiver over an I/O port. The Current Configuration can be made permanent (stored in a non-volatile memory). This is done by sending a UBX-CFG-CFG message.

1.13 Assembly

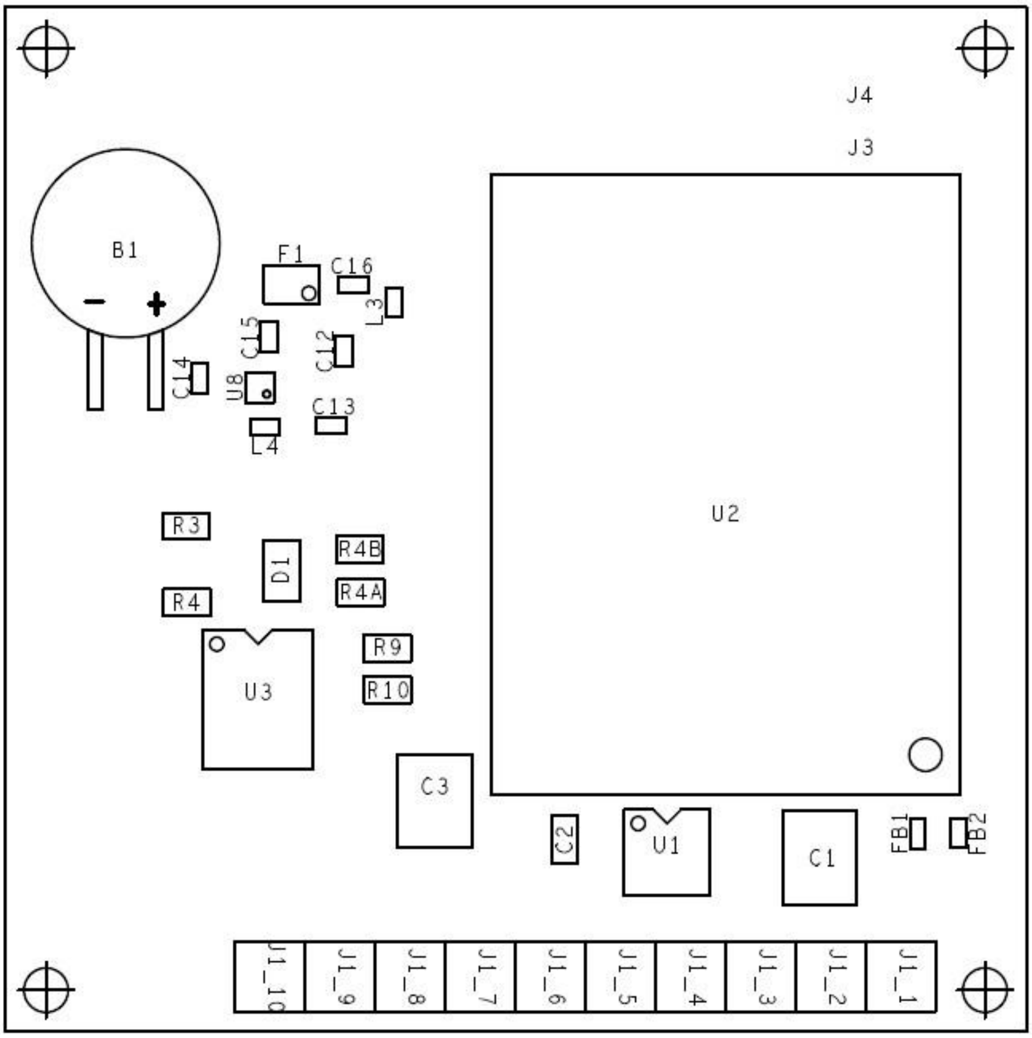


Figure 5: C04-6H reference design Assembly Top

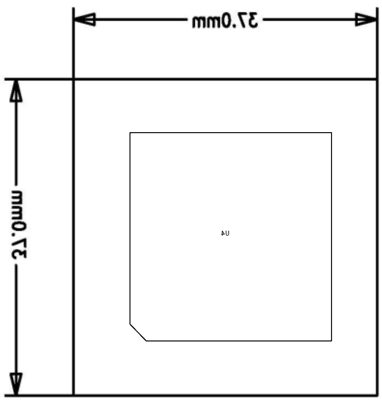


Figure 6: C04-6H reference design Assembly Bottom

1.14 Schematic

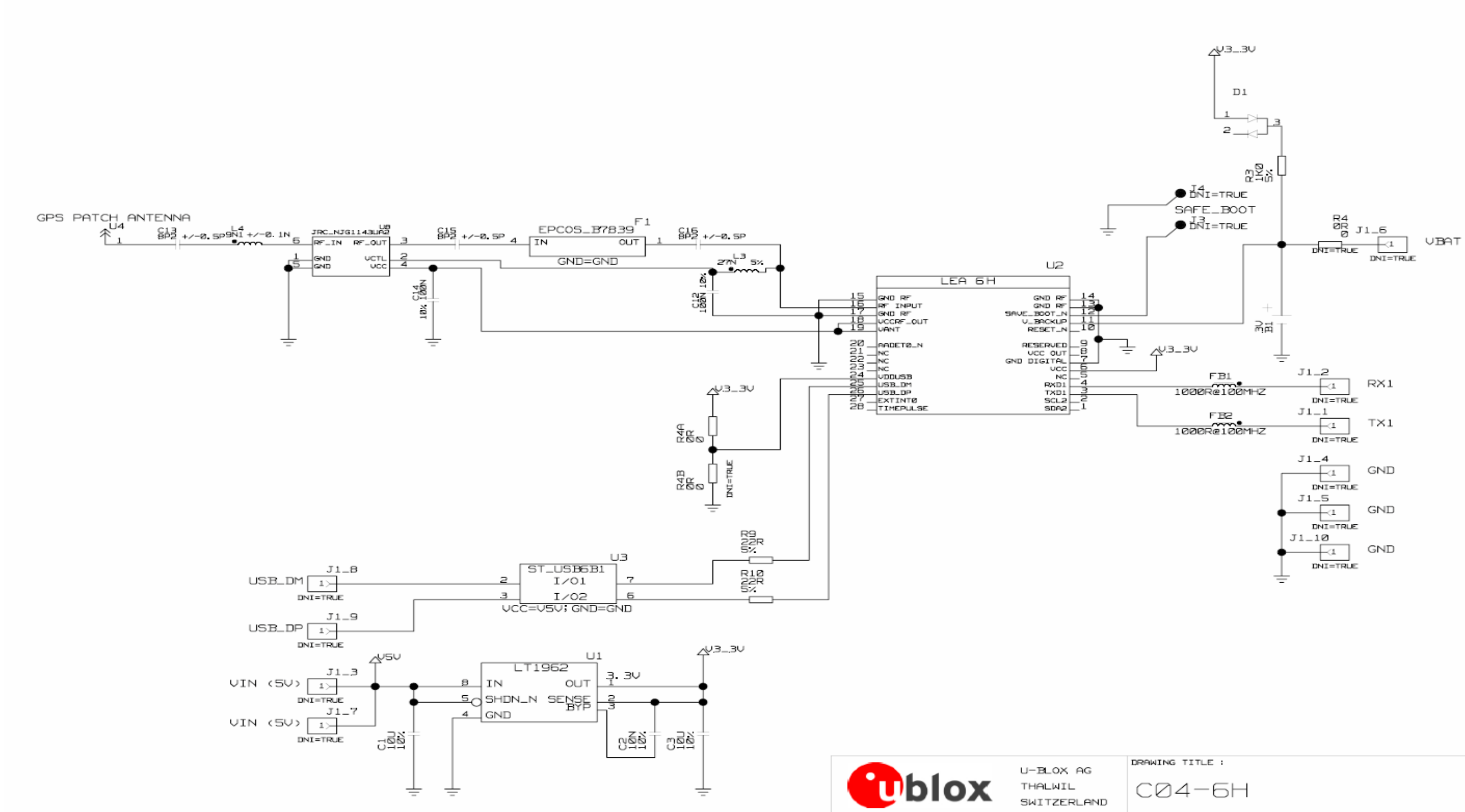


Figure 7: Schematic C04-6H

1.15 Bill of Material

	Part description	*Remarks*
B1	BATTERY PANASONIC ML621S 3V Rechargeable Li Battery	
C1	CAP CER X5R 1210 10uF 10% 10V	
C12	CAP CER X5R 0402 100nF 10% 10V	
C13	CAP CER COG 0402 8.2pF +/-0.5pF 25V	
C14	CAP CER X5R 0402 100nF 10% 10V	
C15	CAP CER COG 0402 8.2pF +/-0.5pF 25V	
C16	CAP CER COG 0402 8.2pF +/-0.5pF 25V	
C2	CAP CER X7R 0603 10nF 10% 25V	
C3	CAP CER X5R 1210 10uF 10% 10V	
D1	DIODE SCHOTTKY INFINEON BAS70-04W 70V 0.07A	
F1	SAW FILTER FOR GPS EPCOS B7839	
FB1	FERRITE BEAD MURATA BLM15HD 0402 1000R@100MHZ	
FB2	FERRITE BEAD MURATA BLM15HD 0402 1000R@100MHZ	
L3	IND MURATA LQG15H 0402 27nH 5% 0.3A	
L4	IND MURATA LQP15M 0402 9.1nH +/-0.1nH 0.1A	
R10	RES THICK FILM CHIP 0603 22 Ohm 5% 0.1W	
R3	RES THICK FILM CHIP 0603 1 kOhm 5% 0.1W	
R4	DO NOT INSTALL (RES THICK FILM CHIP 0603 0 Ohm 0.1W)	only needed for external VBAT
R4A	RES THICK FILM CHIP 0603 0 Ohm 0.1W	USB Supply
R4B	DO NOT INSTALL (RES THICK FILM CHIP 0603 0 Ohm 0.1W)	See 1.7
R9	RES THICK FILM CHIP 0603 22 Ohm 5% 0.1W	
U1	LOW DROPOUT REGULATOR LINEAR LT1962 MS8 3.3V 0.3A	
U2	GPS RECEIVER U-BLOX LEA-6H-0 3.6V	
U3	USB DATA LINE PROTECTION ST USB6B1 SO8	Recommended for USB
U4	ANTENNA PATCH THT 25mm x 25mm INPAQ 1589MHZ	e.g. PA1575MZ50I4G-13-13/1589 - Inpaq (see also section 0)
U8	LOW NOISE AMPLIFIER GAAS MMIC 1.575 GHZ 1.5V-3.6V JRC EPFFP6-A2 3.6V	

Table 2: C04-6H reference design Bill of Material

Depending on the required interface (USB or UART), several parts don't have to be fit. The same applies to the backup battery if an external backup supply is available.

1.16 Layout

2 layer PCB, 1mm FR4

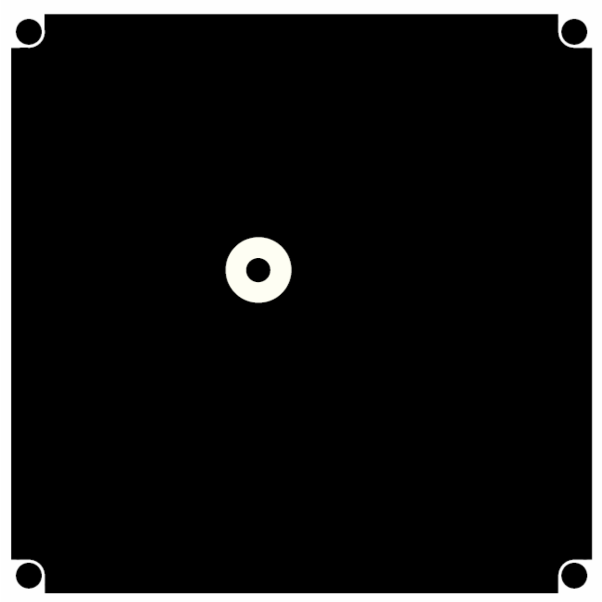


Figure 8: C04-6H reference design Top

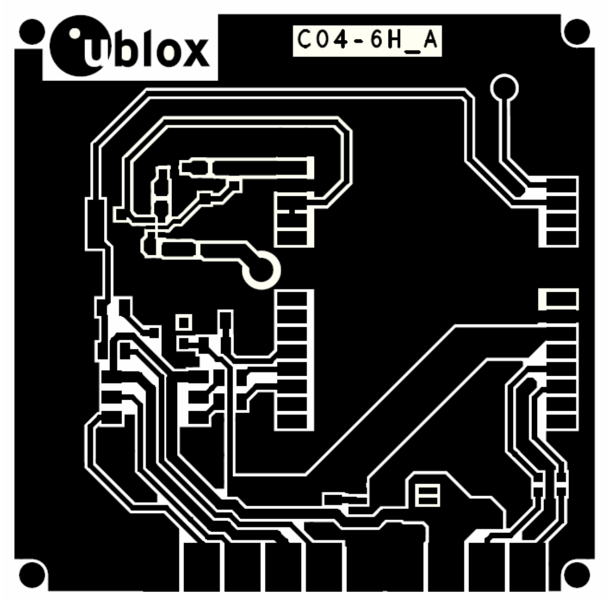


Figure 9: C04-6H reference design Bottom

☞ It is strongly recommended to use the proposed layout as it is. Should this not be possible, strictly follow the recommendations in the LEA-6 / NEO-6 Hardware Integration Manual [1] and contact u-blox' support for assistance.

1.17 How to bringing it to work (USB)

Connect (solder) J1 on the C04-6H with a USB cable with open end with the USB port of your PC.

J1 Pin#	*Description*	*Remarks*	*USB*
7	V_in	USB Power Supply (typical 5 V)	red wire
8	USB_DM	USB communication; Data -	white wire
9	USB_DP	USB communication; Data +	green wire
10	GND	Ground	black wire

Table 3: C04-6H reference design J1 Connector

1.18 How to bringing it to work (UART)

Feed the C04-6H reference design with 5 V (3.3V to 5.5V) Connect Rx and Tx directly to the Rx and Tx of the host processor of the application.

or

Connect Rx and Tx over a level shifter with an RS232 port.

J1 Pin#	*Description*	*Remarks*
1	TxD1	Serial Port
2	RxD1	Serial Port
3	V_in	Power Supply (3.3 ... 5.5 V)
4	GND	Ground

Table 4: C04-6H reference design J1 Connector

2 Performance Considerations

Modifications to the reference designs will be required to adapt it for different applications. Before making such modification, carefully read this chapter. It lists a number of important factors influencing the performance of the reference design.

2.1 Ground plane and antenna size

The reference design is built around a standard 25x25x4 mm patch antenna connected to a LEA-6H GPS module. As a result of using LNA, the sensitivity can only be improved by increasing the ground plane underneath the patch. The larger the ground plane, the better the GPS signal gain (see Figure 10).

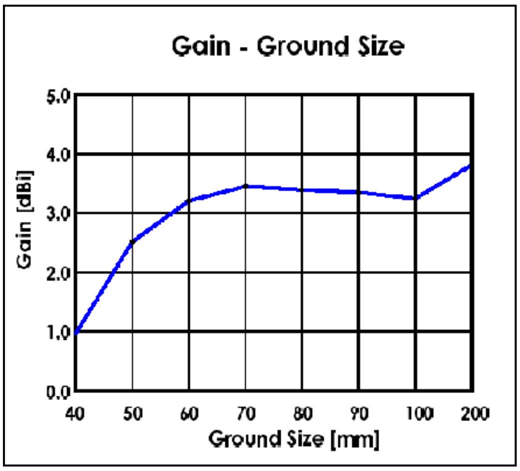


Figure 10: Patch antenna gain function of the GND plane

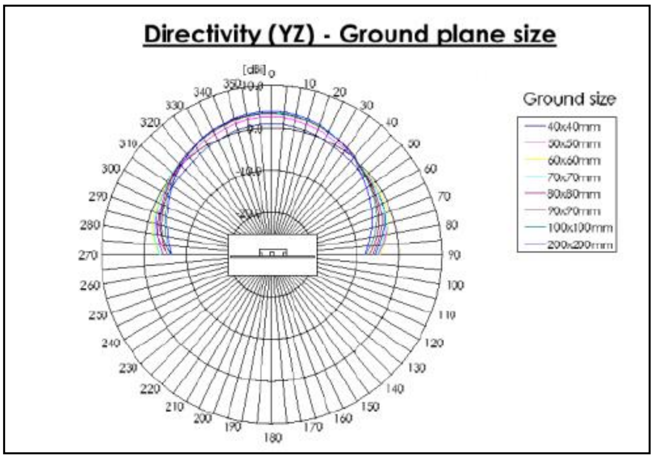


Figure 11: Back lobe function of the GND plane size.

Patch antennas with small ground planes will also have a certain back-lobe in their radiation pattern, making them susceptible to radiation coming from the backside of the antenna. The larger the size of the ground plane, the less severe this effect becomes (Figure 11).

One could either enlarge the board (and GND size) of the reference design or mount it onto a metalized fixture (see Figure 13). If a larger board is feasible, u-blox suggests increasing the size in such a way that the patch antenna will have a fairly equal distance to all board side (see Figure 12). Theoretically, it's also possible to reduce the board size. Since this will lead to a reduced overall sensitivity and introduce an unwanted directivity, u-blox does not recommend reducing the board (GND plane).

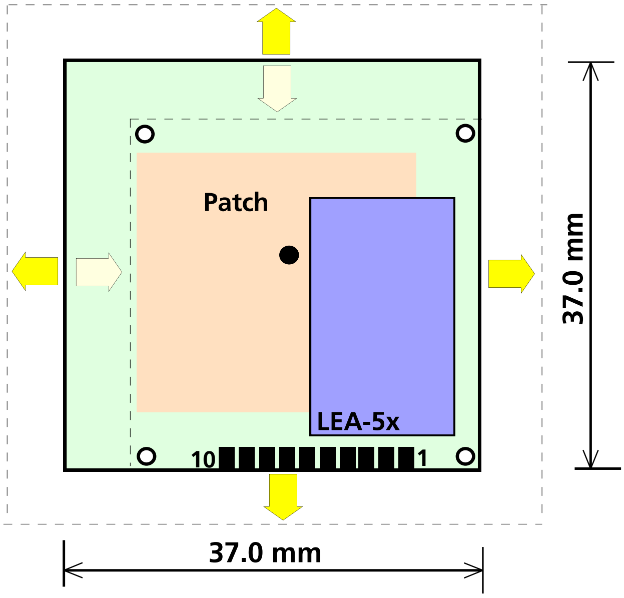


Figure 12: Enlarging the reference design for better sensitivity

☞ For an improved performance of the reference design, u-blox recommends increasing the board size.

2.2 Housing

Although the most important factors influencing the sensitivity of an antenna are patch volume and ground plane size, one also has to consider the frequency shift caused by objects in the near field i.e. the radome (see Figure 13).

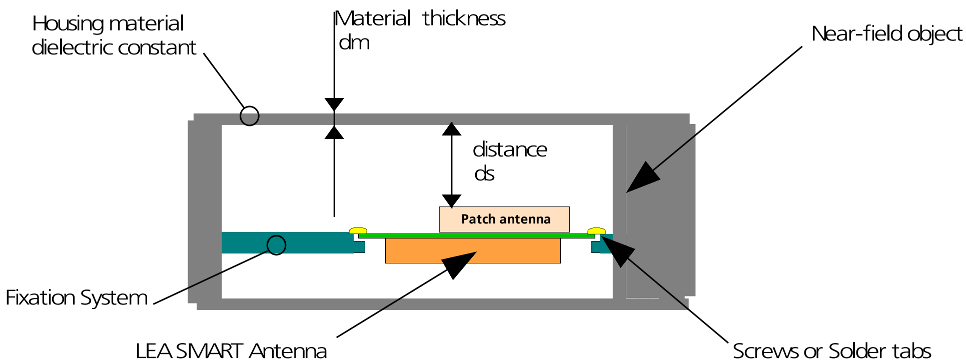


Figure 13: Factors influencing the housing performance factors

The frequency shift depends on radome material and thickness, distance between patch and radome and shape of the housing surrounding the patch antenna. Since it's too complicated to calculate the frequency shift in advance, patch manufacturers offer a selection of pre-tuned patches in the same form-factor. Choosing the optimally tuned patch is usually done by experiment. Using a network analyzer is an alternative. Shifting the center frequency with a matching filter is also possible but requires extensive RF experience is therefore not recommended.

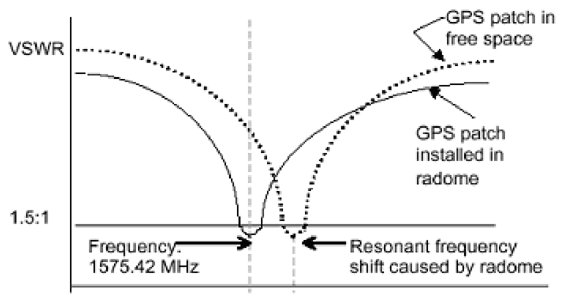


Figure 14: Patch antenna gain function of the GND plane

2.2.1 Housing material and dielectric constant ε_r

The housing into which the reference design is integrated **must be electrically non-conductive** to allow proper GPS signal reception (at least the side above the antenna). Non-conductive materials or insulators are mostly plastics (for instance PE or ABS materials). Nevertheless nearly every type of polymer (such as Polycarbonate, PEEK conductive thermoplastics) can be compounded with electrical conductive fillers and shall then be used carefully.

The dielectric constant ε_r of plastics for the 1.5 GHz frequency range is not commonly available and therefore cannot provide an estimation of the GPS signal attenuation. To verify this dielectric constant and the corresponding performance degradation, measurements as described in chapter 3 can easily be performed.

2.2.2 Material Thickness dm

The thickness d_m of any material above the patch antenna should be as thin as possible. Standard thicknesses of 0.5 to 2mm are commonly used and should work fine.

2.2.3 Distance ds between enclosure and antenna

More than 5mm between the patch antenna and the inner surface of the housing will not influence the performance noticeably. There is a small chance to slightly decrease the performance when the antenna is place closer than 5mm or even touching the housing. In this case performance has to be verified with the measurements described in section 3.

2.2.4 Near-field objects

Any near-field object, be it a part a (human) body, an equipment or the housing can reduce the sky visibility and miss-tune the antenna and therefore reduce performance of the reference design. As the influence of surrounding objects can't be quantified, the only way to estimate the impact of such objects is do measurements as proposed in section 3.

2.3 Shielding of other components

When integrating the reference design be aware that its patch antenna is sensitive to high frequency signals such as those radiated from devices such as display driver, microcontroller, DC/DC converters, etc. If other means like moving the reference design away from emitting parts on the motherboard, slowing down the rise time of clocks, etc. are not sufficient, it is recommended to shield such parts to reduce RF emissions into the antenna. But avoid placing large shields very close to the antenna as this could influence on the other hand the GPS antenna performance (see also 3).

3 Design Verification

For a successful integration of the reference design, it first recommended to perform outdoor static measurements (measurement performed in a defined location with good sky visibility). Following the step-by-step procedure below is recommended:

1. Measure the standalone (i.e. not integrated into the application) performance of the reference design in a 12 or 24h static outdoor test.
2. Repeat the test with the reference design integrated into the application and compare the results. Ideally, this is done with the u-center Sky View (see also section 4).
3. If the performance of the second test is worse, switch off all electronics but the reference design (provide power from an external source) but leave the reference design in the housing and redo the test. Should the performance now be good, focus the search on emissions from the motherboard. Try to reduce the signal rise and fall time of your electronics and make sure, the power supply to the reference design is clean (the ripple on Vcc should be below $50mV_{pp}$.
4. Should the performance still not match the one of test 1, check whether the recommendations in section 2 have been observed (i.e. tuning frequency of the patch).

After achieving the best static performance, dynamic measurements (i.e. road tests) could be performed to verify the overall performance of your application in various environments.

4 Performance Quantification using u-center

u-center is the ideal tool for the design verification. Particularly the Sky View and the Statistic View are helpful.

4.1 Sky view

The "Sky View" tool of the u-center software is excellent for analyzing performance of antennas as well as the conditions of the satellite observation environment. The polar plot graphically displays the averaged satellite signal strength, the position of satellites in the sky, identifies satellites by number and indicates which satellites are being used.

When recording over a long time period, the "sky view" is ideal to display the antenna visibility and to do a comparison between two designs. Regarding the distribution of GPS satellites, perform at least a 24 hours measurement to have a 360-degree antenna visibility view of your reference design. Record a second 24 hours test with the reference design turned by 180 degree in the horizontal plane. Play and compare the recorded files for both designs for the north and the south hemisphere.

The following pictures show 24h outdoor measurements done with the reference design. While the picture on the left side shows mediocre performance (recommendations described in section 2.2 and 2.3 have not been followed), the one on the right side shows successful integration of the reference design.

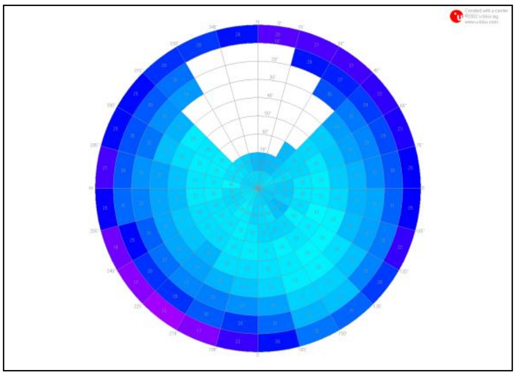


Figure 15: 24-Hour Sky view test with poor Antenna

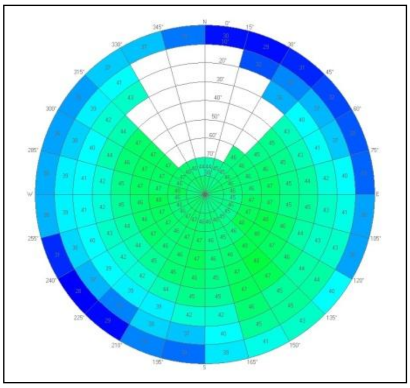


Figure 16: 24-Hour Sky view test with C04-6H

☞ These pictures show example of possible measurements. Bear in mind that the plots might be influenced by the environment (e.g. buildings or hills close by) as well as GPS characteristics (there are no satellites above the north and South Pole).

4.2 Statistic view

The "statistic view" values displayed in the table below can be easily copied from the u-center Software and pasted in an Excel sheet for comparison purposes.

Title	Current	Minimum	Maximum	Average	Deviation	Unit
SVs Used	6	5	11	8	1	
Used SVs	3,11,14,21,28,31					
SVs Tracked	7	7	12	9	1	
Tracked SVs	3,11,14,20,21,28,31					
SV C/N0	42.13	35.7	44.5	41.56	1.06	dBHz

Table 5: Example of statistic view

Average, minimum and maximum signal strength ratios, so called C/No (carrier to noise ratio), provide good estimations about the signal reception quality. Under good conditions (e.g non urban environment) we could expect during a 24h test to receive at least 8 satellites. Average CNo should be > 44 dBHz for satellites with elevation > 50°.

Related Documents

[1] LEA-6 / NEO-6 Hardware Integration Manual, Docu No GPS.G6-HW-09007

[2] u-center – User Guide, Docu No GPS.SW-08007

[3] u-blox 6 Receiver Description including Protocol Specification, Docu No GPS-SW-09017

All these documents are available on our homepage (http://www.u-blox.com).

☞ For regular updates to u-blox documentation and to receive product change notifications please register on our homepage.

Revision history

Revision	Date	Name	Status / Comments
-	November 12, 2010	jfur	Initial release

Contact

For complete contact information visit us at www.u-blox.com

Headquarters

u-blox AG
Zuercherstrasse 68
CH-8800 Thalwil
Switzerland

Phone: +41 44 722 74 44
Fax: +41 44 722 74 47
E-mail: info@u-blox.com

Offices

North, Central and South America

u-blox America, Inc.
Phone: +1 (703) 483 3180
E-mail: info_us@u-blox.com

Regional Office West Coast:
Phone: +1 (703) 483 3184
E-mail: info_us@u-blox.com

Technical Support:
Phone: +1 (703) 483 3185
E-mail: support_us@u-blox.com

Europe, Middle East, Africa

u-blox AG
Phone: +41 44 722 74 44
E-mail: info@u-blox.com

Technical Support:
Phone: +41 44 722 74 44
E-mail: info@u-blox.com

Asia, Australia, Pacific

u-blox Singapore Pte. Ltd.
Phone: +65 6734 3811
E-mail: info_ap@u-blox.com
Support: support_ap@u-blox.com

Regional Office China:
Phone: +86 10 68 133 545
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office Japan:
Phone: +81 3 4360 5343
E-mail: info_jp@u-blox.com
Support: support_jp@u-blox.com

Regional Office Korea:
Phone: +82 2 542 0861
E-mail: info_kr@u-blox.com
Support: support_kr@u-blox.com

Regional Office Taiwan:
Phone: +886 2 2657 1090
E-mail: info_tw@u-blox.com
Support: support_tw@u-blox.com