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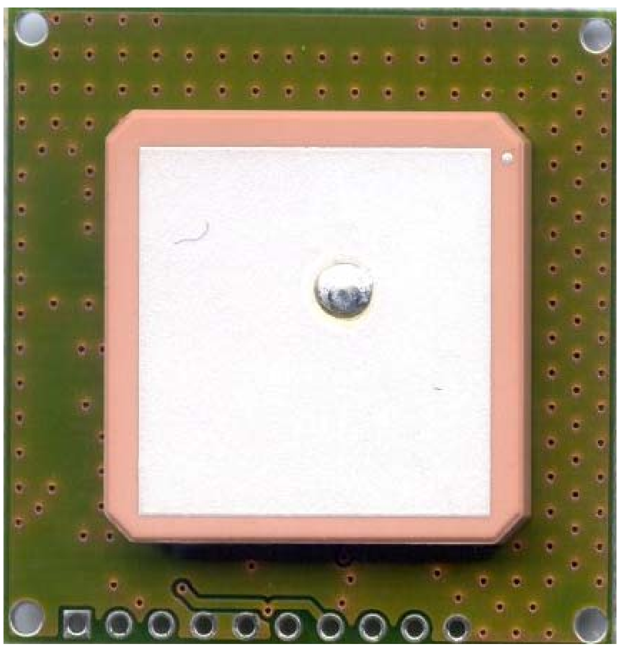
Smart Antenna for LEA Modules

Demo Design



Abstract

This document describes a smart antenna Demo Design based on ANTARIS® 4 GPS modules (LEA-4A, LEA-4P, LEA-4H and LEA-4S). It is intended for being used as a template to make application specific smart antennas. It will be made available to u-blox' customers as blue print including schematic, layout, mechanical drawing and Gerber data.

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Demo Design

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Title	Smart Antenna for LEA Modules		
Subtitle			
Doc Type	Demo Design		
Doc Id	GPS.G4-CS-05004-A		
Revision Index	**Date**	**Name**	**Status / Comments**
Initial version	18/10/2005	JF / TC	
1	25/11/2005	SV / TN	Added hints for adaptation to customer requirements
2	30/11/2005	TN	Added copper cladding for PCB
A	30/05/2006	TN	Simplified design for LEA-4x and larger GND plane for improved sensitivity

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1 Disclaimer

This document describes a smart antenna Demo Design based on ANTARIS® 4 GPS modules (LEA-4A, LEA-4P, LEA-4H and LEA-4S). Receiver specific features like the GPSMODE setting for ROM only receivers have been taken into consideration. Please refer to the ANTARIS 4 System Integration Manual [1] for more information about the differences between the various receivers.

The Demo Design is intended for being used as a template to make application specific smart antennas. The Customer is aware that in order to use the Demo Design it is necessary to make an adaptation of the Demo Design to the specific needs of the respective customer. u-blox assumes no design services for this purpose. The Customer is further aware of that an application dependent configuration must be defined, which may influence operation, accuracy and availability of the determining data. The default values provided by u-blox are only examples. u-blox assumes no warranty for the accuracy of the items, speeds, and time determined and calculated by any design and products based on this Demo Design. u-blox makes no warranties, either expressed or implied with respect to the information and specifications contained in these documents. Performance characteristics listed in these documents are estimates only and do not constitute a warranty or guarantee of product performance.

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2 Design Description

2.1 Schematic

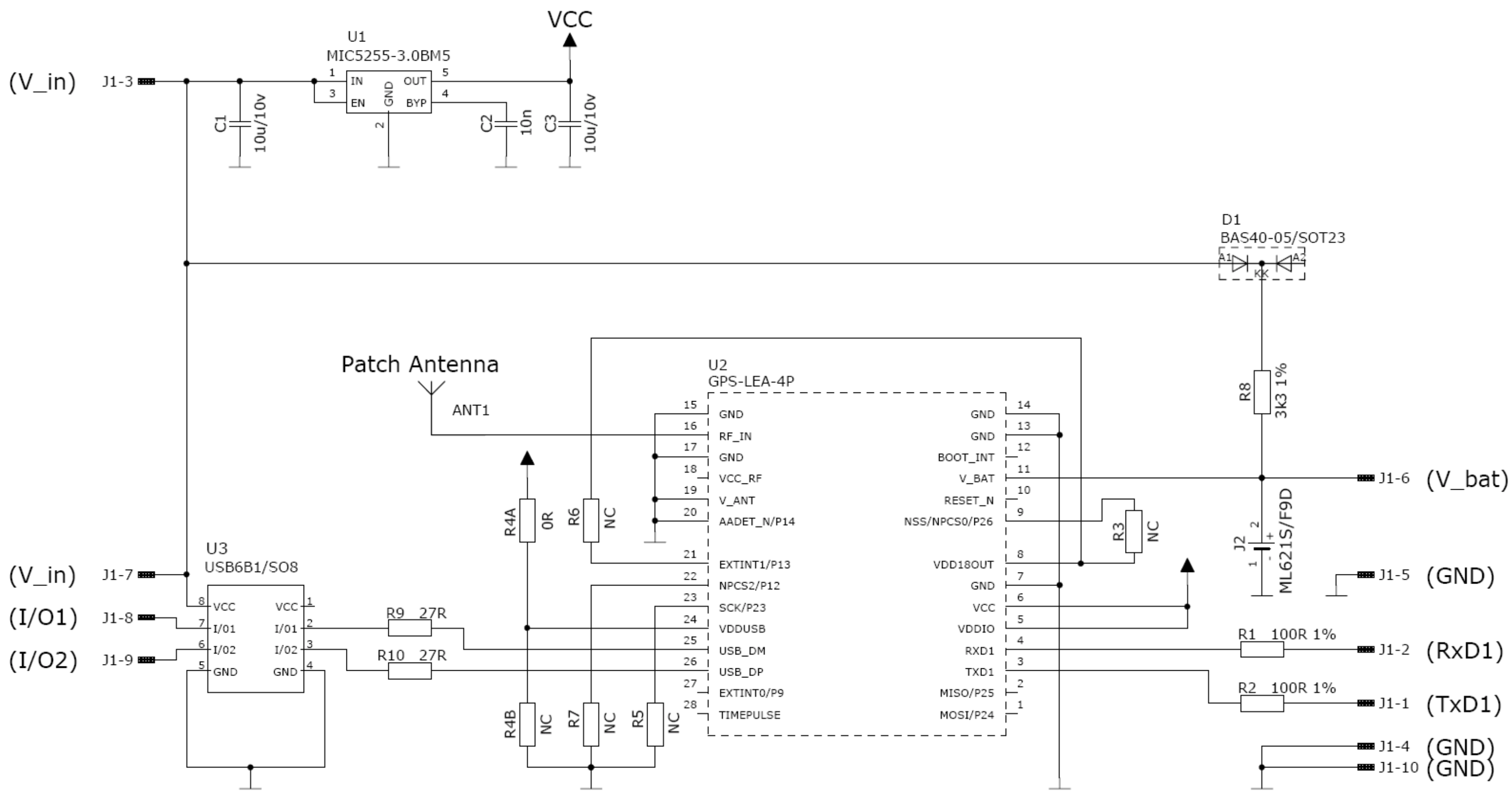


Figure 1: Schematic

2.2 Serial Interfaces

The demo design can be connected via USB and/or UART (TTL level, not RS232). If the USB isn't required, the resistors R5, R9, R10 and the protection IC U3 don't have to be fitted. Furthermore, R4A has to be replaced by R4B. This results in cost and power savings (up to 3mA).

Don't populate resistors R1 and R2 if the RxD/TxD lines aren't used.

2.3 Backup Battery

In case of a power failure, real-time clock (RTC) and backup RAM are supplied through pin V_bat. This enables the ANTARIS®4 GPS Receiver to recover from power failure with either a Hotstart or a Warmstart (depending on the duration of VCC outage) and to maintain the configuration settings. If no Backup Battery is connected, the receiver performs a Coldstart upon a power up.

There are 2 different ways of how to connect a backup battery to the GPS receiver on the smart antenna demo design. If a backup voltage is available on the main board, one only needs to connect it to pin J1/6. In this case, the battery J2, diode D1 and resistor R8 don't have to be fitted.

The demo design features a rechargeable backup battery for application where no external backup supply is available. However, the charging circuitry is rather basic and it's necessary to adapt the value of R8 to the supply voltage according to the formulas given in the battery datasheet.

The proposed battery charging circuit (see Figure 1) is ideal if the nominal supply voltage (V_in) is 3.3V. With a supply voltage of 5.0V, the maximum battery charging voltage is exceeded. This can be prevented with voltage divider depicted in Figure 2.

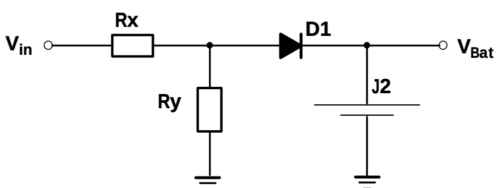


Figure 2: Improved battery charging circuit

2.4 Configuration Settings

The ANTARIS®4 GPS Receivers are fully configurable with UBX protocol configuration messages. The configuration of the receiver can be changed during normal operation mode. On receivers with onboard Flash memory (i.e. LEA-4P and LEA-4H), the configuration can permanently be stored whereas on receivers without Flash (i.e. LEA-4A and LEA-4S), the configuration changes can be saved to battery backup RAM. As an alternative, LEA-4A and LEA-4S feature the so-call GPSMODE pins. By changing the logical level at these pins, it's possible to modify some of the default settings. The Demo Design has been prepared to optionally populate pull-up and –down resistors (R3, R5, R6 and R7) on 4 GPSMODE pins.

2.5 Mounting

For optional mounting holes for M1.6 screws have been foreseen.

Demo Design has been designed to work without being mounted above an additional ground plane. However, connecting it to a ground plane will improve its performance (see also 3.1).

2.6 RF Shield

No RF shield has been foreseen since the LEA-xx modules hardly emit any noise and tests at u-blox did not show an improved performance with a shield. It is up to the customer to add a shield for mechanical purpose if necessary.

2.7 Bill of Material

	Part description	**Remarks**
ANT1	25 x 25mm Ceramic Patch Antenna	E.g. INPAQ PA1575MZ50I4G-13-13/1589 (see also section 3.1)
C1, C3	10µ, 20%, S0805	
C2	10n, 10%, S0603	
D1	Schottky diode, e.g. BAS40-05	Only required if optional battery J2 is used.
J1	10-pin connector, 2.54mm pitch	e.g. Molex 7395 right angle header
J2	Sanyo ML621-TZ1 Rechargeable Li Battery	Optional. If not used, connect pin J1-6 to battery on motherboard or to GND (see also 2.3).
R1, R2	100R Resistor, 10%, S0603, 0.063W	Do not fit if USART (RxD1/TxD1) is not used
R3	100k Resistor, 10%, S0603, 0.063W	Do not fit for LEA-4H and LEA-4P designs. Fitting R3 in a LEA-4A or LEA-4S design modifies the default configuration of the receiver (GPSMODE6, see *ANTARIS 4 System Integration Manual* for more information). Do not fit if default configuration is desired.
R4A, R4B	0R Resistor, S0603	Fit R4A if USB is used, otherwise fit R4B.
R5	0R Resistor, S0603	Fit R5 if USB is "Self Powered". Do not fit R5 if USB is "Bus Powered" or USB is not used.
R6	100k Resistor, 10%, S0603, 0.063W	Do not fit for LEA-4H and LEA-4P designs. Fitting R6 in a LEA-4A or LEA-4S design modifies the default configuration of the receiver (GPSMODE5, see *ANTARIS 4 System Integration Manual* for more information). Do not fit if default configuration is desired.
R7	100k Resistor, 10%, S0603, 0.063W	Do not fit for LEA-4H and LEA-4P designs. Fitting R7 in a LEA-4A or LEA-4S design modifies the default configuration of the receiver (GPSMODE2, see *ANTARIS 4 System Integration Manual* for more information). Do not fit if default configuration is desired.
R8	3k3 (680R) Resistor, 10%, S0603, 0.063W	Required if optional battery J2 is used. Do not fit otherwise. Use 3k3 For a supply voltage (V_in) of 5.0V or 680R for V_in = 3.3V. See also section 2.3.
R9, R10	27R Resistor, 10%, S0603, 0.063W	Do not fit if USB is not used
U1	Micrel LDO MIC5255-3.0BM5, SSOT23_5	
U2	LEA-4x module	
U3	USB6B1, SO8, ST Microelectronics	Do not fit if USB is not used

Table 1: Bill of Material

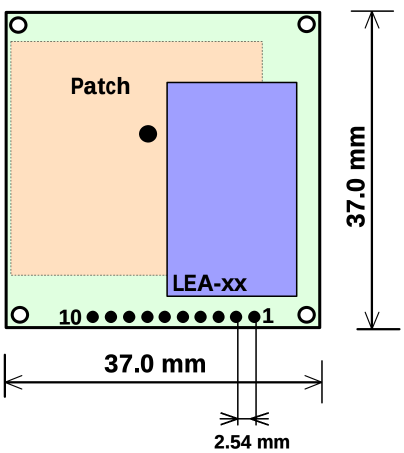
! **Note:** Depending on the required interface (USB or UART), several parts don't have to be fit. The same applies to the backup battery if an external backup supply is available. Refer to Table 1 for the feasible options.

2.8 Connectors

Pin#	Description	Remarks
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). Shall be left open if battery on Demo Design is used.
7	V_in	Power Supply (3.3 ... 5.5 V) internally connected with Pin 3
8	USB_DM	USB communication; Data -
9	USB_DP	USB communication; Data +
10	GND	Ground

Table 2:

2.9 Physical Dimension



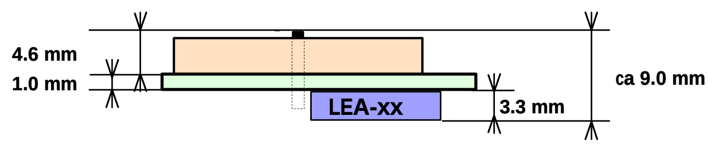


Figure 3: Top Assembly Drawing

2.10 Photo

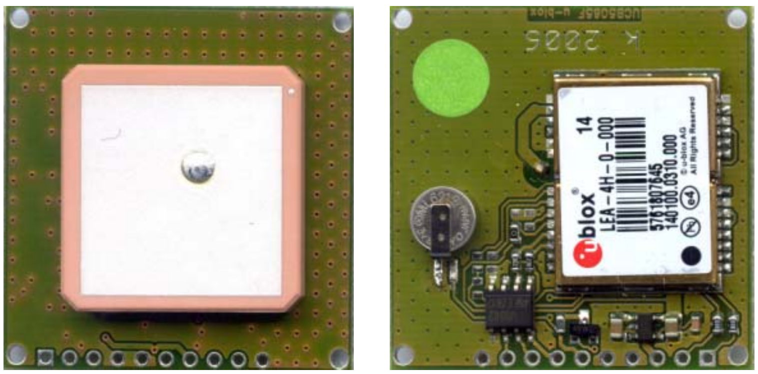


Figure 4: Top and Bottom View

2.11 Placement

The physical part dimensions for the resistors and capacitors are indicative.

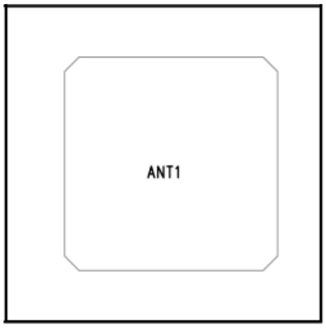


Figure 5 Component side

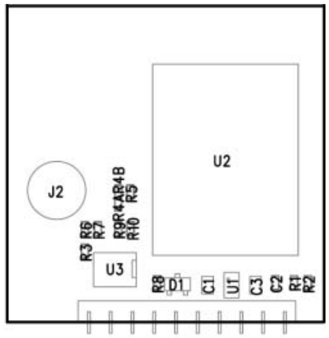


Figure 6 Solder side

The antenna shall be on one side, all other components on the other side.

2.12 Layout

The layout is designed for a **2-layer 1mm FR4 PCB board with 1 once (35µm) copper cladding**.

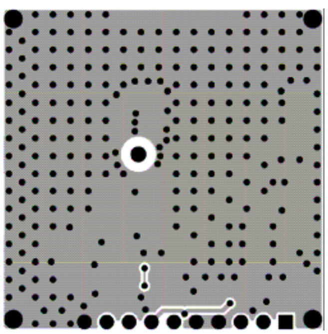


Figure 7: Top Layer

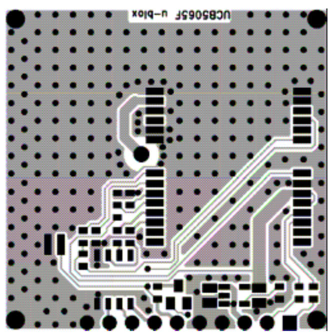


Figure 8: Bottom Layer

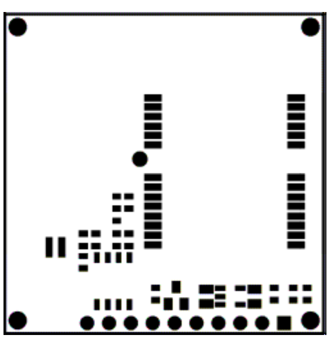


Figure 9: Top Solder Mask

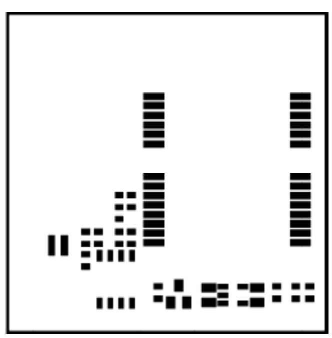


Figure 10: Bottom Solder Mask

! Note u-blox strongly recommends using the proposed layout as it is. Should this not be possible, strictly follow the recommendations in the ANTARIS 4 System Integration Manual [1] and contact u-blox' support for assistance.

3 Performance Considerations

The Demo Design has been made in order to demonstrate how to combine a GPS module and patch antenna in the smallest possible form-factor. Modifications to the Demo 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 Demo Design.

3.1 Ground plane and antenna size

The Demo Design is built around a standard 25x25mm patch antenna connected to a LEA GPS module. As long as the RF strip line is maintained matched to 50 Ohms, 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 11). For this reasons, it's ideal if the smart antenna can be mounted on a large GND plane.

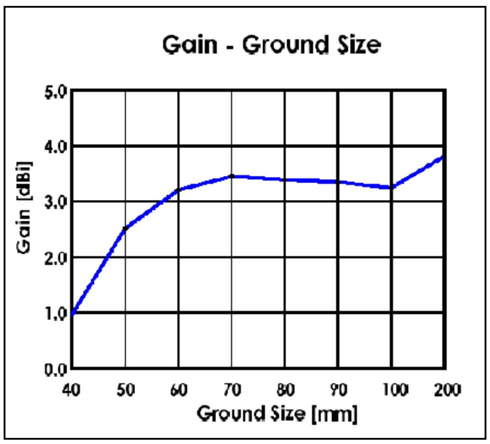


Figure 11: Patch antenna gain function of the GND plane

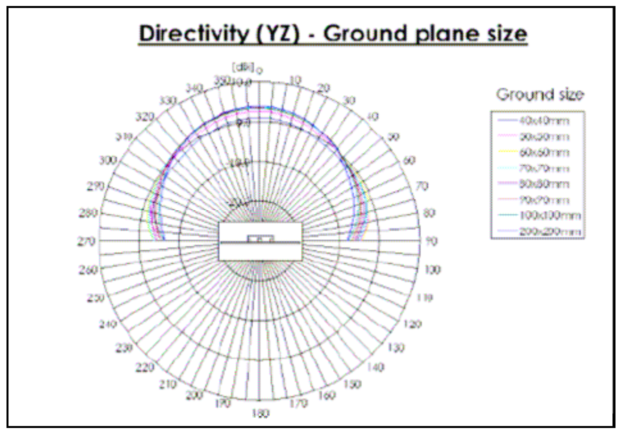


Figure 12: Back lobe function of the GND plane size.

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 12).

One could either enlarge the board (and GND size) of the Demo Design or mount it onto a metalized fixture (see Figure 14). 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 13). 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) size if the antenna isn't mounted on a large external GND plane (see Figure 14).

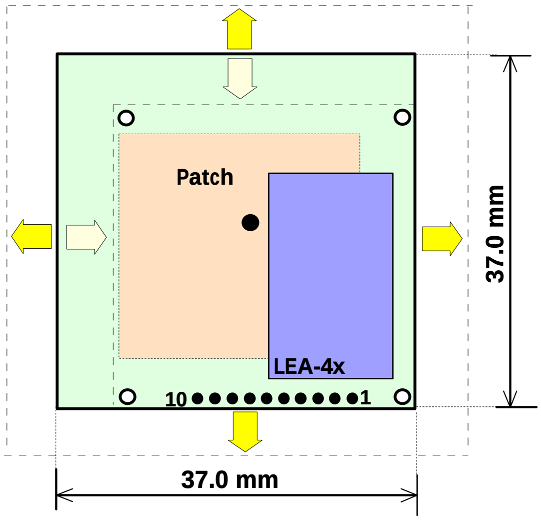


Figure 13: Enlarging the Demo Design for better sensitivity

! **Note:** For an improved performance of the Demo Design, u-blox recommends increasing the board size.

3.2 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 14).

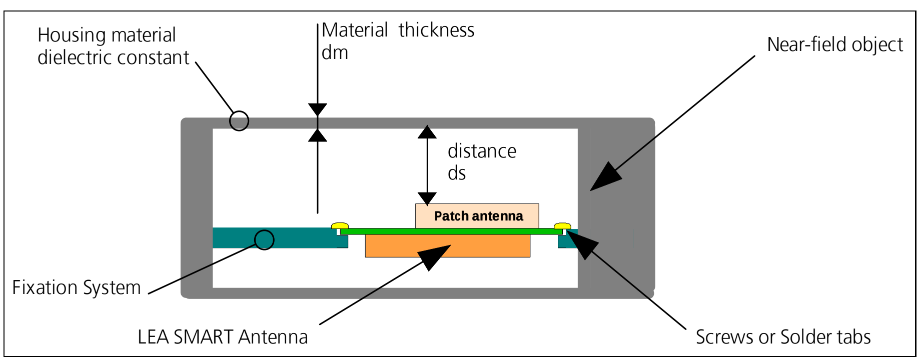


Figure 14: Factors influencing the housing performance factors

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.

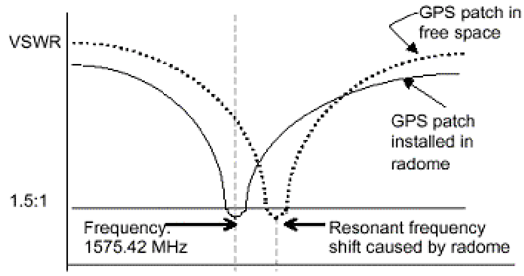


Figure 15: Patch antenna gain function of the GND plane

3.2.1 Housing material and dielectric constant ε_r

The housing into which the Demo Design is integrated **shall 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 4 can easily be performed.

3.2.2 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.

3.2.3 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 have to be verified with the measurements described in section 4.

3.2.4 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 mis-tune the antenna and therefore reduce performance of the Demo 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 4.

3.3 Shielding of other components

When integrating the Demo 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 Demo 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 2.6).

4 Design Verification

For a successful integration of the Demo 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 Demo Design in a 12 or 24h static outdoor test.
2. Repeat the test with the Demo Design integrated into the application and compare the results. Ideally, this is done with the u-center Sky View (see also section 5).
3. If the performance of the second test is worse, switch off all electronics but the Demo Design (provide power from an external source) but leave the Demo 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 Demo 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 3 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.

5 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.

5.1 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 12 hours measurement to have a 360-degree antenna visibility view of your Demo Design. Record a second 12 hours test with the Demo 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 Demo Design. While the picture on the left side shows mediocre performance (recommendations described in section 3.2 and 3.3 have not been followed), the one on the right side shows successful integration of the Demo Design.

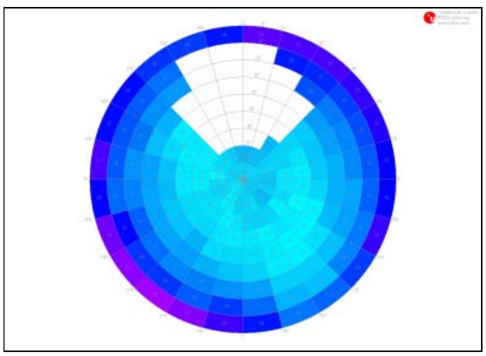


Figure 16: 24-Hour Sky view test with poor Antenna

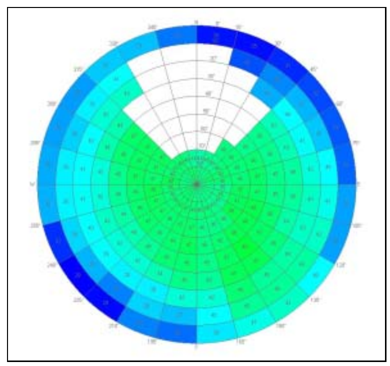


Figure 17: 24-Hour Sky view test with a standalone reference

! **Note** 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).

5.2 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 3: 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.

Related Documents

[1] ANTARIS 4 System Integration Manual, Doc No GPS.G4-MS4-05007

[2] u-center ANTARIS Edition – Users Guide, Doc No GPS.SW-02001

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

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