S

Antenna integration

Antenna integration guidance

Application note

Abstract

This application note describes the requirements and methods to implement multiple antennas in a short range product with coexisting systems such as Wi-Fi, Bluetooth, and LTE in order to reduce system interference. It also describes the requirements and methods for antenna integration in multipath propagation systems such as MIMO and Diversity products.

UBX-18070466 - R02
C1-Public

Document information

Title	**Antenna integration**	
Subtitle	Antenna integration guidance	
Document type	Application note	
Document number	UBX-18070466	
Revision and date	R02	9-Feb-2021
Disclosure Restriction	C1-Public	

This document applies to the following products:

Product
u-blox short range radio products

Contents

1 Overview

While considering a short range product with coexisting radio systems – such as any combination of Wi-Fi, Bluetooth, and LTE – mitigations to reduce interference and to achieve full system performance must be implemented. Since the antenna relates to the mechanical and industrial design and cannot easily be changed at a later stage, it is recommended to consider antenna integration in an early design phase of the product development.

In general, the impact of coexistence interference is decided by the power of transmit signal leaking to the receiving system. A measure to reduce the leakage power is to isolate the systems from each other. This is achieved either by spatially separating the antennas or by other means such as using low gain antennas, directional antennas, orthogonal polarized antennas, or reducing the transmit power. To find the optimum product implementation and trade-off, each application and installation must be evaluated.

The requirements and estimations in this application note are indicative and the integrator must evaluate their specific integration to find the applicable requirements.

2 System performance

Antenna mutual isolation and thus systems isolation is a critical parameter for coexistence performance in a multiradio product. The system interference will inevitably cause bit errors and packet errors on the receiving system thus increasing the number of retransmissions, and reducing the data throughput.

Spatial antenna separation is the most common mitigation. However, in small sized applications, it is not possible to reach the required distance between the antennas. Other methods to implement include directional antennas, orthogonally polarized antennas, or lower gain antennas. Also consider reducing the transmitted output power.

Antenna spacing is also of importance to achieve sufficient isolation between the different propagation paths in systems using multipath propagation, such as MIMO or diversity. For diversity, it is important to avoid that the antennas simultaneously are placed in signal cancellations nodes, “nulls”, of the propagation path. For MIMO systems, the propagation paths shall be un-correlated to achieve sufficient isolation between the spatially separated data streams. This is achieved by separating the antennas from each other.

2.1 Wi-Fi 2.4 GHz to Bluetooth coexistence

Bluetooth operates in frequency hopping mode. On occasions when the Bluetooth channel coincides within the Wi-Fi channel and one of the systems is receiving and the other is transmitting, the signal to noise ratio of the received signal is degraded causing reduced sensitivity. Further, on occasions when the Bluetooth channel is adjacent to the Wi-Fi channel, adjacent channel interference will occur on the receiving system. Blocking is another issue that will cause degraded reception. In this case, the high power of the transmitting system must not block the receiving system. This puts limits on the maximum allowed power leaking into the receiving system.

To improve these issues, either implement sufficient antenna isolation or, if the link budgets allow, reduce the transmitted output power. These two measures can also be combined.

Software algorithms to enhance coexistence performance are available in some systems. These algorithms prioritize and schedule the system communication and data transmission to reach the highest possible data throughput.

2.2 Wi-Fi 2.4 GHz and Bluetooth to LTE coexistence

If the LTE band is adjacent to the ISM band, such as for the LTE bands 7, 40, 41 or 38, a dedicated coexistence filter is needed in the Wi-Fi and Bluetooth receive path. Even with the dedicated LTE filter, antenna isolation is the key to coexistence performance and must be addressed with the suggested mitigations.

In addition to these measures, an arbiter that schedules the Wi-Fi connection is available in some implementations. This requires a communication interface between the LTE and Wi-Fi systems consisting of both hardware and a software algorithm.

☞ The Wi-Fi and Bluetooth to LTE coexistence is similar to the Wi-Fi to Bluetooth coexistence.

☞ The LTE coexistence filter reduces Wi-Fi and BT modulation noise power leakage to the LTE receiver.

2.3 MIMO

A Wi-Fi Multiple-Input-Multiple-Output (MIMO) system utilizes spatially separated radio propagation paths with low correlation each carrying unique data streams. To implement a MIMO system, the multiple antennas must be spatially separated by at least half a wavelength but preferably with several wavelengths to accomplish low antenna correlation. The antenna correlation is measured by Envelop Correlation Coefficient (ECC), where 1 represents completely correlated and 0 uncorrelated. An ECC of 0.2 is sufficient in many solutions though it can go up to 0.5.

The minimum distance for 2.4 GHz > $\frac{\lambda}{2}$~6 cm, where λ is the wavelength in air of the applied frequency, in this case 2.4 GHz.

2.4 Diversity

In Diversity, dual or multiple antennas are used to improve throughput and sensitivity in a multipath propagation fading environment and to mitigate signal cancellation due to phase shifts, time delay, and attenuation. For optimum performance, the antennas shall be separated by at least half a wavelength. This will improve the probability to avoid simultaneous cancellations or “null” for the diversity antennas.

Diversity is supported in V2X. In this case, the antennas shall be separated by a minimum distance of $\lambda/2$. In general, further distance improves the performance.

2.5 Requirements

In order to achieve good coexistence performance, fulfill the requirements listed in Table 1 . These requirements are dependent on the implementation of each system and the used frequency bands. The integrator must evaluate their specific integration and derive the requirements for the specific application based on the components’ data sheet and link budget.

Requirement	Antenna mutual isolation	Spatial separation
Wi-Fi 2.4 GHz to LTE Coexistence Band 7, 38, (40), 41. BAW coexistence filter	30 dB	60 cm (3 dBi antenna gain)
Wi-Fi 2.4 GHz to Bluetooth Coexistence	30 dB	60 cm (3 dBi antenna gain)
Wi-Fi 2.4 GHz to Bluetooth Coexistence w scheduler	20 dB	20 cm (3 dBi antenna gain)
Wi-Fi Diversity	N/A	> $\frac{\lambda}{2}$~3 cm (2.5 GHz)
Wi-Fi MIMO	N/A	> $\frac{\lambda}{2}$~6 cm (2.5 GHz)

Table 1. Requirements for system isolation and antenna spacing

2.6 Verification

In early product design phase, it is recommended to test system isolation on an electromechanical mockup consisting of at least a bare main PCB with embedded antennas. The isolation is then measured by either a network analyzer or with a signal generator and spectrum analyzer.

3 Antenna integration

The mitigations listed below reduce the system interference in a multiradio coexistence product. Based on the product's performance requirements, one or several of these can be implemented to reach the required system isolation.

- **Spatial antenna separation:** The system isolation follows the free space path loss.
- **Directional antennas:** One or both the antennas can be a directional type placed with non-overlapping radiation patterns.
- **Orthogonal polarized antennas:** The antennas' mutual coupling is decreased by implementing orthogonally polarized antennas.
- **Low gain antennas:** This reduces the power transmitted and received and could be implemented in either or both the systems.
- **Reduction of transmitted power:** This reduces the field strength and thus the power at the receiving system's antenna.

3.1 Antenna spacing

It is recommended to place the antennas in the far field region. The range can be one to two wavelengths from the transmitted antenna and beyond.

More specifically, the far field region starts at a distance from $2 * D^2/\lambda$ where D is the maximum dimension of the antenna. The reactive Near Field ends at about 0.159 * λ.

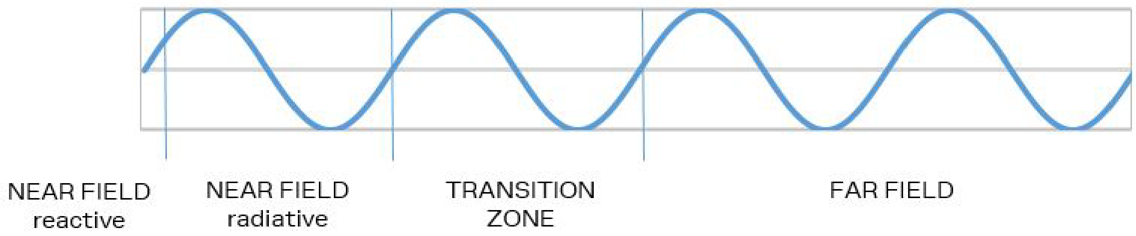

Figure 1. Near and far field radiation profile

In the far field region, the power declines by 6 dB for every double distance and the **Free Space Path Loss** is calculated using the formula mentioned below:

$$FSPL = 10log\left(\left(\frac{4\pi df}{c}\right)^2\right)$$

The **Free Space Path Loss** vs. distance is shown in Table 2.

☞ With omnidirectional antennas having +3 dBi gain, double spacing is required as compared with isotropic 0 dBi antennas. 30 dB is needed for several use cases according to Table 1; this corresponds to a minimum antenna spacing of 60 cm if the antennas have 3 dBi gain. For 0 dBi gain antennas, the distance is reduced to 30 cm.

Distance	Free space path loss	Dual 3 dBi antenna gain
10 cm	20.4 dB	14.4 dB
20 cm	26.4 dB	20.4 dB
30 cm	29.9 dB	23.9 dB
60 cm	36.0 dB	30.0 dB
100 cm	40.4 dB	34.4 dB
110 cm	41.2 dB	35.2 dB
200 cm	46.4 dB	40.4 dB

Table 2. Free space path loss and system isolation vs antenna spacing

3.2 Directional antennas

In most applications, omnidirectional antennas are preferred. However, in reality, most antenna implementations do not have isotropic radiation pattern as a perfect dipole. If the antennas are placed with non-overlapping radiation patterns, the leakage power will be reduced.

Even though omnidirectional antennas are preferred in most applications, multipath propagation might allow use of semi-directional antennas.

3.3 Polarized antennas

Another method to achieve antenna isolation is to use orthogonally polarized antennas. This would mean having one horizontally polarized and one vertically polarized antenna. This could also be involve using antennas with slant polarization (internally orthogonally polarized).

A typical example to achieve orthogonal polarization is to use dipole antennas arranged perpendicularly.

☞ In a multipath propagation environment, the radio path changes polarization in each reflection and even if the antennas are polarized there will most likely be a matching polarized path.

Figure 2: Example of orthogonally polarized dipole antennas

3.4 Antenna gain

The gain of both the transmitting and the receiving antenna affects the interfering signal power in the receiving system. Considering the roll off of the free space path loss, 6 dB per octave gives that if 0 dBi antennas are used instead of 3 dBi antennas, half the distance between the antennas will provide equal isolation.

3.5 Transmit power

Another method to reduce the leakage power at the receiver input is to back off the transmit power. Correlating power to antenna distance 1 dB transmit power equals roughly 10% antenna spacing.

4 Antenna types

The integrators shall select the antenna type best suited for their application. In Table 3, the most common antenna types are listed with their typical properties. These could in some cases both be implemented printed on the application PCB or as discrete antenna components either on a ceramic substrate or as a punched metal sheet.

Antenna Type	Radiation Pattern	Polarization
Planar Inverted-F antenna	Omnidirectional	Mixed
Patch Antenna	Directional	Mixed / Circular
Dipole	Omnidirectional	Linear

Table 3. Different antenna types with characteristic properties

4.1 Antenna radiation pattern

Figure 3 shows the radiation diagram for a Planar Inverted-F Antenna having mixed polarization. From Figure 4, it can be observed that for a product implementing two of these antennas, minimum system coupling is achieved if the antennas are directed perpendicularly.

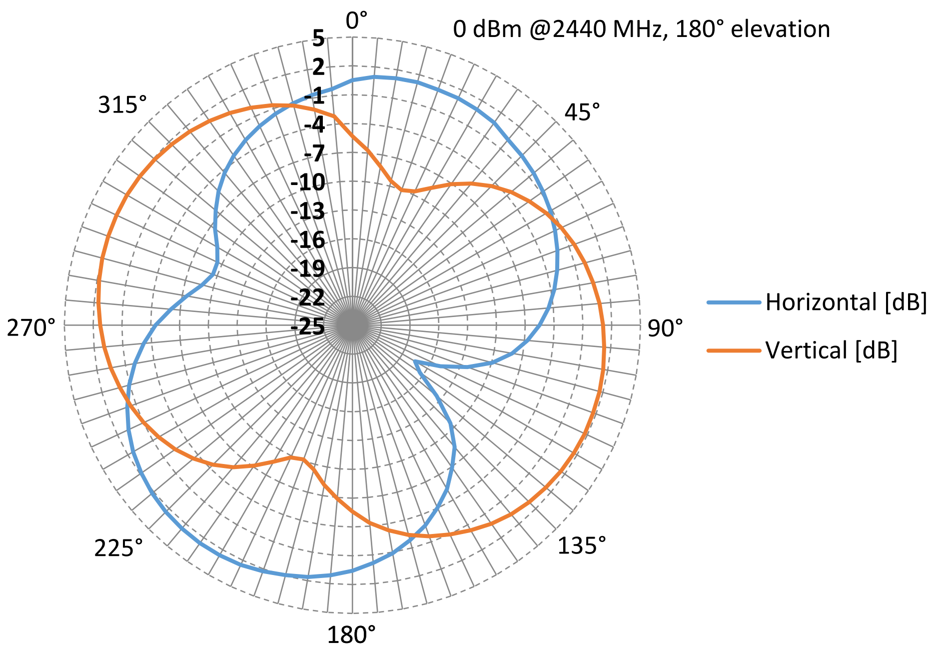

Figure 3: Radiation pattern

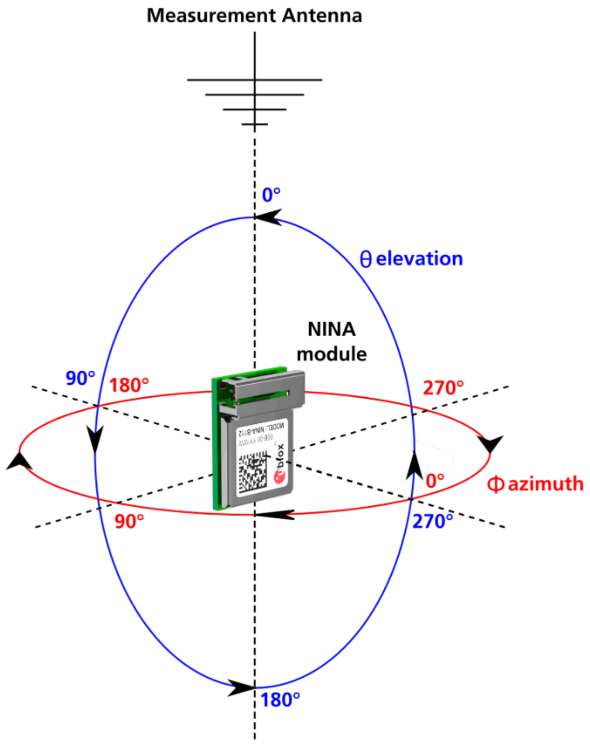

Figure 4: Radiation pattern test definition

Appendix

A Glossary

Abbreviation	Definition
ISM	Industrial, Scientific and Medical radio band
dBi	Antenna gain of isotropic antenna
LTE	Long term evolution mobile cellular system
MIMO	Multiple input Multiple output
PCB	Printed circuit board
V2X	Vehicle to Anything

Table 4: Explanation of the abbreviations and terms used

Related documents

☞ For product change notifications and regular updates of u-blox documentation, register on our website, www.u-blox.com.

Revision history

Revision	Date	Name	Comments
R01	28-Mar-2019	lber	Initial release.
R02	09-Feb-2021	lber	Updated section 2.3. Described spatial separation preference for low antenna correlation in MIMO system.

Contact

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

u-blox 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: +1 408 573 3640
E-mail: info_us@u-blox.com

Technical Support:

Phone: +1 703 483 3185
E-mail: support@u-blox.com

Headquarters
Europe, Middle East, Africa

u-blox AG

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

Phone: +61 3 9566 7255
E-mail: info_anz@u-blox.com
Support: support_ap@u-blox.com

Regional Office China (Beijing):

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

Regional Office China (Chongqing):

Phone: +86 23 6815 1588
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office China (Shanghai):

Phone: +86 21 6090 4832
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office China (Shenzhen):

Phone: +86 755 8627 1083
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office India:

Phone: +91 80 405 092 00
E-mail: info_in@u-blox.com
Support: support_in@u-blox.com

Regional Office Japan (Osaka):

Phone: +81 6 6941 3660
E-mail: info_jp@u-blox.com
Support: support_jp@u-blox.com

Regional Office Japan (Tokyo):

Phone: +81 3 5775 3850
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