![Decawave logo]

APH007 APPLICATION NOTE

Antenna Selection / Design Guide for DW1000

Version 1.2

This document is subject to change without notice

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1 INTRODUCTION

Compared with narrowband wireless systems, UWB applications require additional features from antennas. For some DW1000-based products, an off-the-shelf UWB antenna will be sufficient while others may require a customised antenna to meet size, performance or cost criteria.

This application note is intended to be used as a brief general guide to assist in the selection or design of the most appropriate antenna for your DW1000-based product.

2 ANTENNA AND SYSTEM PERFORMANCE

As with narrowband systems, the link behaviour in UWB systems is governed by Friis's Transmission Equation [3]:

$$P_{RX} = \frac{P_{TX}\ G_{TX} G_{RX}\ \lambda^2}{(4\pi r)^2}$$

Where P_{RX} is the received power, P_{TX} is the transmitted power, G_{TX} is transmit antenna gain, G_{RX} is the receive antenna gain, λ is the wavelength and r is the distance between the receiver and transmitter. (All units are linear)

From the above formula we can deduce that the higher the antenna gain in either or both transmitter and receiver, the greater the amount of power received and hence the greater the operational distance of the product. Transmit power for regulatory purposes, is however, normally defined in terms of Effective Isotropic Radiated Power (EIRP) which is given as:

$$EIRP(f) = P_{TX}(f)\ G_{TX}(f)$$

So the product of the transmitter power and the **peak** transmitter antenna gain must be lower than the regulatory limit with the antenna in any orientation.

3 DW1000 OPERATIONAL CHANNELS AND BANDWIDTHS

DW1000 can be programmed to operate on the following channels defined by the IEEE 802.15.4a-2011 standard [2]:

Table 1: UWB PHY channel frequencies for DW1000

Channel Number	Centre Frequency (MHz)	DW1000 operational BW (MHz)
1	3493.4	500
2	3993.6	500
3	4492.8	500
4	3993.6	900
5	6489.6	500
7	6489.6	900

For DW1000-based product designs that are intended to operate only on a single channel, the user can either use an antenna that can function over all these channels or use an antenna designed to operate over a reduced number of channels or just the specific channel

of interest. Antennas that operate over a reduced bandwidth are generally physically smaller and make the product less prone to out of band interference since they have less gain outside their designed band of operation.

4 ANTENNA SPECIFICATIONS

The RF connection to the outside world from the DW1000 IC is via a pair of 100 Ω differential pins, RF_P and RF_N. In theory one could simply connect these pins to a balanced antenna with a 100 Ω input impedance over the frequency band of interest. To date, DecaWave has not found this method satisfactory in terms of link performance (see section 2), as typically the gain of balanced UWB antennas is less than the combined 'gain' of a single-ended UWB antenna and UWB balun.

The following specifications can be used as a starting point for antenna designs and purchases.

4.1 Antenna Gain

The DW1000 transmitter is optimised to meet regulatory transmit limits (nominally -41.3 dBm/MHz), with margin for temperature and voltage variation when used with a 1 dB loss balun and 0 dBi gain antenna.

In an RTLS anchor a higher gain antenna could be used as more space is generally available to accommodate a larger antenna structure.

4.2 Return Loss

As with narrowband antennas, the higher the return loss the better. A good target would be to have a return loss of 10dB of greater in the band of operation.

4.3 Antenna Efficiency

Efficiency or radiated efficiency in antennas is usually defined as a measure of the efficiency with which a radio antenna converts the radio-frequency power accepted at its terminals into radiated power. For UWB antennas an acceptable figure would be at least 60% with the aim of achieving 90% efficiency.

4.4 Absolute Bandwidth

The bandwidth of the antenna will depend on the operational channel or channels of the product and whether a 'full-band' or 'channelised' antenna is required. The bandwidth should be chosen such that UWB signal from the transmitter (or to the receiver) is undistorted by the antenna and such that regulatory limits are met.

4.5 Directivity

The directivity of the antenna is related to the gain and is usually defined as the relative gain of the main beam of an antenna pattern to a reference antenna, usually an isotropic antenna. The directivity of the antenna will depend on where and how the product or part of the product is to be used. In a wearable asset tag where the orientation is not known, an omni-directional antenna is probably the most desirable whereas in a fixed anchor it may be more efficient to use a 180º radiation pattern if the anchor is fixed to a wall.
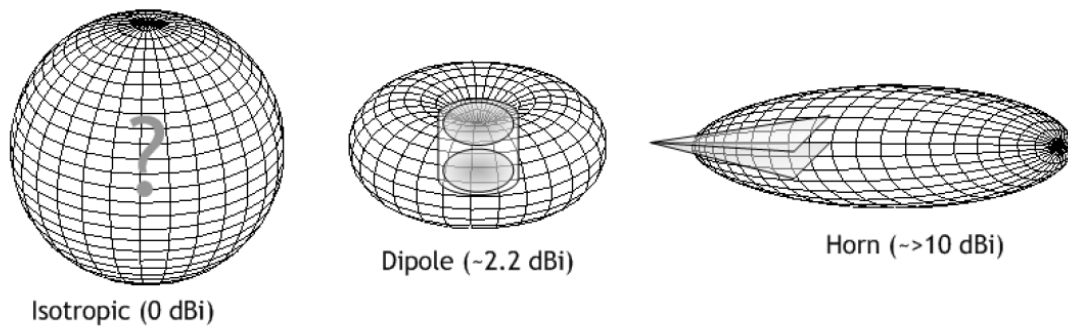
Figure 1: Typical Radiation Patterns

4.6 Fidelity Factor

Fidelity Factor is normally only associated with UWB antennas. It is a measure of how the integrity of the UWB pulse is preserved when it passes through the antenna. For UWB antennas for use with DW1000 a Fidelity Factor of ≥ 99% is recommended.

4.7 Proximity Effects

At the frequencies and bandwidths in which DW1000 operates, the performance of UWB antennas can be degraded when not operated in a free space environment. Proximity to walls, metal, human body and even some plastic enclosures can reduce the antenna performance.

For anchors (or tags) that will be mounted against a wall for instance, an antenna with an integrated ground plane is recommended. This has the effect of shielding the antenna from the wall and so prevents any loss in antenna performance (although directivity in the wall direction is not possible).

For tags that are attached to human or animal bodies it is recommended to either use antennas that negate body proximity effects or to design the system such that degradation due to body proximity is accounted for in the system design e.g. possibly use more anchors to avoid RF blind spots.

4.8 Group Delay versus antenna orientation

DW1000 uses a Time-of-Flight (ToF) calculation to determine range or position. In the calculation the speed of light is used calculate distance. At the speed of light, one nanosecond equates to approximately 30 cm travelled. Because of this, any changes in antenna group delay due to a change in antenna orientation will cause some reduction in the ToF calculation accuracy. A group delay variation of ≤100 ps over the useful orientation range of the antenna is recommended to reduce inaccuracies.

5 ANTENNA VENDORS

The following is a list of UWB off-the-shelf antennas that DecaWave has either tested or has received feedback on from our customers.

Table 2: Vendor List

Part number	Vendor	Antenna type	Comments
AH 086M555003	Taiyo Yuden	SMD chip	Full-band, recommended by DecaWave
ANT1085-4R1-01A	TDK	SMD chip	Only operates up to 5.2 GHz
FR05-S1-P-0-107	Fractus	SMD chip	Only operates up to 5.0 GHz. DecaWave has had poor results with this antenna.
ACS5200HFAUWB	Partron	SMD chip	Full-band

6 LAYOUT AND ANTENNA PLACEMENT CONSIDERATIONS

For the layout and placement of DW1000, the guidelines in [1] should be followed as much as is practical. Typically antenna vendors give guidelines for the placement of their antennas and these should be followed as much as possible.

In addition to these guidelines the following points should be considered: -

1. Antenna performance may be degraded if insufficient ground-plane is used. Ground fill should be used as much as possible on the PCB design except in the "keep-out" areas specified by the antenna vendors / designers.
2. Enclosures should be as 'RF transparent' as possible. This usually means using some form of plastic. Note that some plastics are more 'RF transparent' than others. The lower the dielectric constant and especially the lower the loss factor the better. Table 3 below gives some typical values of some commonly used enclosure materials.
3. For antennas that are designed to operate free standing such as planar monopole antennas, proximity to non 'RF transparent' materials (walls, metal, human body) will cause nulls in the radiation pattern. These nulls can be significant enough to cause communication to be lost. To avoid these nulls, antennas should be sourced / designed with regard to the final product use environment.
4. Tests have shown that antenna performance, especially for monopole antennas, can be degraded if a smooth transition between the feeding line and the antenna is not provided.

Table 3: Electrical Properties of Plastics

Polymer	Dielectric constant @ 1 MHz	Loss factor @ 1MHz x 10^{-4}
PP	2.20	4.4
ABS	2.40	170
SPS	2.50	31
PC	3.00	290
PBT	3.10	620
PEEK	3.25	98
PES	3.54	200

7 REVISION HISTORY

Table 4: Document History

Revision	Date	Description
1.0		Initial release
1.1	31st July 2018	Scheduled update
1.2	14th May 2024	

8 MAJOR CHANGES

Revision 1.0

Page	Change Description
All	Initial release

Revision 1.1

Page	Change Description
All	Update of version number to 1.1
All	Update of company logo

Revision 1.2

Page	Change Description
All	Modification to footer

9 REFERENCES

9.1 Listing

Reference is made to the following documents in the course of this Application Note: -

Table 5: Table of References

Ref	Author	Date	Version	Title
[1]	DecaWave		2.00	DW1000 Data Sheet
[2]	IEEE	2011		IEEE802.15.4-2011
[3]	H.T Friis	1946		H.T.Friis, *Proc. IRE*, vol. 34, p.254. 1946

10 GLOSSARY

Table 6: Glossary

Abbreviation	Full Title	Explanation
EIRP	Equivalent Isotropically Radiated Power	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 gain of the antenna being used
IEEE	Institute of Electrical and Electronic Engineers	Is the world's largest technical professional society. It is designed to serve professionals involved in all aspects of the electrical, electronic and computing fields and related areas of science and technology
RTLS	Real Time Location System	System intended to provide information on the location of various items in real-time.
TDOA	Time Difference of Arrival	Method of deriving information on the location of a transmitter. The time of arrival of a transmission at two physically different locations whose clocks are synchronized is noted and the difference in the arrival times provides information on the location of the transmitter. A number of such TDOA measurements at different locations can be used to uniquely determine the position of the transmitter. Refer to DecaWave's website for further information.
UWB	Ultra Wideband	A radio scheme employing channel bandwidths of, or in excess of, 500 MHz

11 FURTHER INFORMATION

Decawave develops semiconductors solutions, software, modules, reference designs - that enable real-time, ultra-accurate, ultra-reliable local area micro-location services. Decawave's technology enables an entirely new class of easy to implement, highly secure, intelligent location functionality and services for IoT and smart consumer products and applications.

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