

APU003 APPLICATION NOTE

AN INTRODUCTION TO DW1000 IN AGRICULTURAL APPLICATIONS

**Agricultural applications'
schemes and their
implementation with
DecaWave's DW1000 Wireless
Transceiver**

Version 1.00

**This document is subject to change without
notice**

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1 INTRODUCTION

This is one in a series of notes on application areas for DecaWave's DW1000 technology.

This note considers the use of DW1000 to implement Real Time Location Systems for animal management. It assumes the reader is familiar with the concepts and principles behind Real Time Location Systems – for more information on the principles of RTLS see the DecaWave website www.decawave.com.

2 THE CHALLENGE FACING FARMERS TODAY

As with every other form of production, farming is under continuous pressure to deliver quality product at the lowest possible price. Consumers, in the form of large multiples, are demanding lower prices for beef and dairy products and as a result the farmer's margins are under constant pressure.

To ensure the farmer achieves the maximum possible margin the efficiency of the farming process needs to be maximized. In the context of dairy cattle this means achieving the maximum output per animal in the most efficient way over the course of its life. In terms of beef cattle this means achieving the best animal weight and meat quality in the shortest time and for the lowest cost possible.

The problems of managing large animal herds are well documented; as the herd grows it becomes more and more difficult for the farmer to individually monitor each animal's behaviour and health. Without the use of monitoring technology and software a problem with a particular animal may not be noticed until it has reached an advanced stage and requires more dramatic intervention than would have been the case if it had been detected earlier.

The use of monitoring technology can prevent contagious disease transmission within the herd by allowing infected animals to be separated earlier than would otherwise be possible.

2.1 Key Areas in Herd Management

2.1.1 Maintenance of general animal health

The monitoring of the health of each animal in the herd is crucial. Each animal represents a considerable investment for the farmer and therefore knowing the state of each animal is important. However as the herd grows it becomes increasingly difficult to effectively monitor the health of each animal.

2.1.1.1 Ruminantion

Ruminantion is a part of normal digestion, in which the animal brings up swallowed food (usually grass or hay), chews it, and swallows it. This aids the animal by allowing it to eat quickly and chew later while it is resting. Ruminantion behaviour in cattle has been well documented and researched from the 1950's to the present day. The majority of the activity occurs at night although there is a distinct period of ruminantion during the day also.

By monitoring the animal's ruminantion behaviour it is possible to detect departures from the norm and thereby take corrective action before a serious problem develops.

2.1.1.2 Detection of ill health / disease

There are a number of common diseases that can be detected earlier by noting changes in animal behaviour.

- Ketosis

Detecting Ketosis early in its onset is crucial to farmers. If left untreated, a cow with ketosis will stop lactating within approximately 14 days. Prior to developing the disease cows spend less time eating and may show other behavioural symptoms

including changes in gait. Monitoring becomes very difficult in large herds without technological assistance. Prior to the availability of monitoring technology farmers detected the onset of the disease by noticing changes in the animals stool and eating patterns visually.

- Mastitis

Mastitis is an inflammatory reaction of udder tissue to bacterial, chemical, thermal or mechanical injury and is the most common disease in dairy herds. It's been estimated that without an effective mastitis control program up to 40% of cattle in the herd can be infected in 6 months. Detection involves the analysis of Somatic Cell Counts in the milk – there is no hard and fast threshold below which a cow is declared to be free from mastitis however a level of 50,000 cell/ml of milk is usually used as a starting point for closer observation.

2.1.2 Milking

It is important that lactating cows are milked at regular intervals. Failure to do so leads to a reduction in lactation rate and a loss of revenue to the farmer. As herd sizes increase it become more and more difficult to manually check that a particular cow has presented for milking at the required times.

2.1.3 Oestrous Detection

Cows and pigs are known as polyoestrous animals and can go into heat several times a year. The detection of when an animal is in heat is very important to the farmer so that he can make appropriate breeding choices for his herd, determine when to breed calves for the first time and determine when cows that have previously calved should be bred again to maintain milk production.

Equally important is the identification of those cows who have not displayed oestrous signs over an extended period indicating the need for attention before a more serious problem develops.

2.1.4 Regulatory Issues

Concerned with the problem of food safety and traceability, International Standards Organizations, National Governments and supra-national organizations such as the EU have implemented a variety of regulations detailing the required level of traceability for food, particularly meat products, giving rise to the phrase “farm to fork”. This is currently a legal requirement in many jurisdictions worldwide.

3 THE TECHNICAL SOLUTION

From the above we can see that up to date information about each animal in the herd is the key to early detection of problems and maximizing output. What is required is a scheme to automatically collect this information, analyse it and present the results of that analysis to the farmer in a form that allows the farmer to make sensible herd management decisions.

3.1 Early solutions

The first technology to be applied to herd management, driven by regulatory requirements, was that of RFID – by implanting an RFID tag into each animal the movements of that animal through the normal daily processes of eating, drinking, entering and leaving various places on the farm can be logged.

The International Standards Organisation (ISO) has been involved in defining standards related to the use of RFID for animal applications including ISO11784, 11785 and 14223-1.

However, RFID has significant drawbacks: -

- It can tell us that an animal has passed a particular location at a particular time but it cannot tell us where the animal is now
- It gives us no information about the current state of the animal – its temperature, whether it is lying down / standing up / leaping etc.

So it is a useful first step but is not the complete picture.

3.2 Wireless Sensor Monitoring

A more recent innovation in animal management is the use of active wireless sensors to relay various parameters about the state of the animal, particularly temperature, orientation and activity to a centralized system. This allows a profile of each animal to be built up over time and, more importantly, allows deviations from those patterns to be spotted early – before symptoms that might be noticed by the farmer had presented themselves.

RFID and wireless sensor monitoring together give a system that can tell the farmer whether the animal has passed various readers and can also give information about the state of the animal to allow patterns to be built up and deviations from those patterns to be spotted.

3.3 Integrated Real Time Location System

The next step in the evolution of animal management systems is to have continuous real-time information about the location and state of the animal. This necessitates a real time location system. General information on RTLS using DW1000 is available in other notes in this series on www.decawave.com.

RTLS implemented for animal management requires high accuracy location and high precision, which can be provided by the DW1000 device.

Consider for example that the animal profiling software has determined that one of the tagged pigs in the barn has an elevated temperature and has not presented itself for feeding today. The animal needs to be located, isolated from the remaining animal to avoid possible spread of disease and then treated. To find the animal in a large herd presents a major logistical problem. With accurate RTLS information the location of the animal is known

exactly and finding it is not necessary.

Similarly with accurate RTLS it is possible to determine whether the animal is standing or lying – this information can be used as part of the profiling process and to detect anomalous behaviour.

4 THE BUSINESS CASE FOR RTLS IN AGRICULTURE

4.1 Introduction

The two main business drivers for the introduction of RTLS in Agriculture are to: -

- Reduce Cost
- Increase Revenue

4.2 Reducing Cost

Cost reductions come about in two main areas: -

4.2.1 Minimizing sickness in the herd

By quickly identifying potentially sick animals, locating them rapidly and isolating them from the rest of the herd the farmer can ensure that none of the other animals is affected - which could lead to further loss of revenue.

Locating and isolating the sick animal as early as possible ensures the animal receives the necessary treatment. Treatment in the early stages of a disease is likely to be less severe than in latter stages, which means the treatment generally costs less, takes effect more quickly and the animal can be returned to useful production sooner than would otherwise be the case.

4.2.2 Opportunity cost of looking for animals displaying abnormal behaviour

Once an animal has been identified as displaying abnormal behaviour which could be the result of disease or, for example, oestrous, the farmer needs to locate that animal. The larger the herd the more difficult this is and the longer it takes. The longer a farmer has to spend looking for animals the less time he / she has for other activities

4.3 Increasing Revenue

4.3.1 Maximising Milk output in dairy cattle

Lactating cows need to be milked according to a regular schedule in order to maximise their milk output. If they are not their milk production will fall and in some cases cease altogether. In a large herd it is difficult for the farmer to ensure all cows present themselves for milking as they should. The ability to rapidly identify and locate lactating cows that have not presented for milking allows the farmer to ensure those cows are milked or to deal with whatever other problem may be the cause. By doing this the farmer can extend the lactation period from each cow and thereby maximise his revenue per animal.

4.3.2 Maximising weight gain in beef cattle

By ensuring cattle present themselves for feeding at required intervals, consume the optimum amount of feed and spend the necessary time ruminating the farmer can ensure his cattle gain as much weight as possible in the shortest time giving him / her a shorter time to revenue and an increased revenue amount per animal.

4.3.3 Choosing the most appropriate time for breeding

By accurately detecting oestrous signs in cows and then being able to quickly locate the animal the farmer can make the most appropriate breeding decisions for the herd thereby maximising calf and milk production.

4.4 System Costs

4.4.1 Initial costs

There are three initial cost elements in an Agriculture RTLS system: -

Table 1: Initial cost elements in an agriculture RTL & Information System

Item	Description
The Animal Tags themselves	The individual animal tags and associated animal collars or other methods of securing the tag to the animal The number of tags required is the same as the number of animals in the herd
The RTLS Infrastructure	The RTLS "Anchor" hubs that are required to receive transmission from the animal tags, time stamp them and send that information back to the location engine server
The location engine server and its associated software	The relevant computer hardware, software and links to other farming systems

4.4.2 Ongoing costs

Table 2: Ongoing cost elements in an agriculture RTL & Information System

Item	Description
Hardware maintenance	Maintenance, including replacement of batteries, repair and replacement of hardware components as necessary
Software maintenance	Ongoing Software upgrades

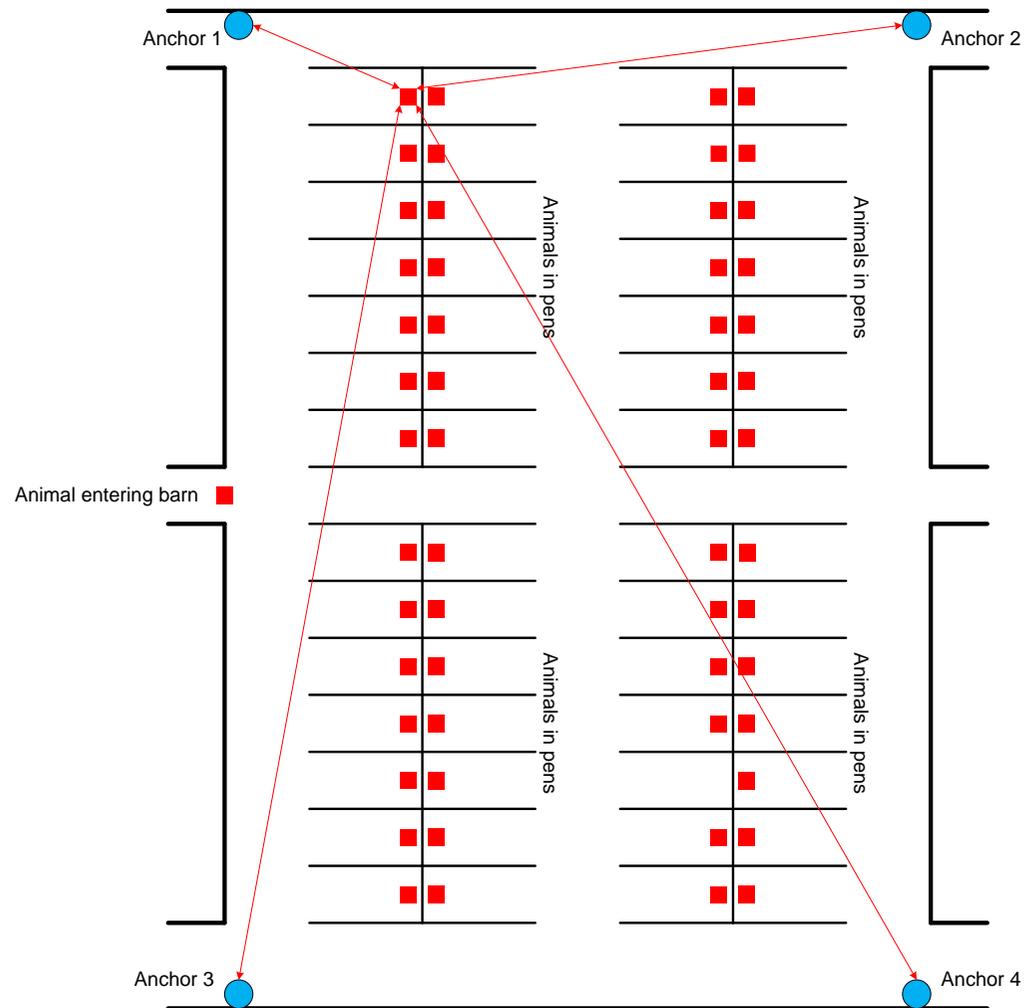


Figure 1: A typical animal monitoring RTLS application

5 IMPLEMENTATION OF RTLS IN AGRICULTURE

The following are some general comments and notes on the implementation of RTLS schemes in agriculture; in particular, wireless schemes based on DecaWave's Ultra Wideband technology.

DecaWave's DW1000 wireless technology provides the dual capability of accurately determining location (to +/- 10cm) as well as transferring sensor data at high speed so is ideally suited to the implementation of a combined RTLS and wireless sensor network such as is required here.

DecaWave will be pleased to explore the use of our technology for location and monitoring systems in agriculture with customers.

5.1 Requirements for an Agriculture RTLS system

There are a number of fundamental requirements for an Agriculture RTLS system that can be summarized as follows: -

Table 3: Requirements for an Agriculture RTLS system

Parameter	Requirement
Communications – Multipath immunity	The radio scheme should handle farm environments well – in particular it should be capable of operating reliably in the severe multi-path conditions that are found in metal barns and sheds
Communications - Range	A long communications range, particularly in Non-Line-of-Sight conditions, is desirable to reduce the number of anchors required and reduce system cost
Long Battery Life	Batteries need to last a significant length of time – typically 3 years.
Location Update Rates	These should be variable to match animal activity. If the animal is moving then location updates should be more frequent than if the animal is stationary
Location Accuracy	Increasing accuracy allows better information to be gathered about the animal, build a more complete profile of the animals behaviour and detect smaller anomalies from the profiled behaviour
Physical Security	Tags should not fall off animals or be capable of being removed by animal activity

5.2 Implementation of RTLS in general

See the application note on www.decawave.com for more information on the overall implementation of RTLS schemes in general.

5.3 Implementation of the Animal Tag

At a high level, an animal tag consists of: -

- A **sensor** system to gather data about the animal. The type and number of sensors included depends on the system requirements but a temperature sensor should be included and possibly an accelerometer.
- A **Micro-Controller Subsystem** to take the sensor data and interface to the wireless subsystem – the choice of Microcontroller as well as the type and amount of memory depends on the required level of functionality vs. the need to minimize power consumption
- A **Wireless Subsystem** to interface to the anchors / communications hubs on the farm – DecaWave’s DW1000 provides a simple interface to a microcontroller allowing a number of different communications schemes to be implemented
- A **Power Supply Subsystem** the complexity of which depends on the type of and voltage range of the batteries being used vs. the power supply requirements of individual components
- The packaging / enclosure

This can be illustrated as follows: -

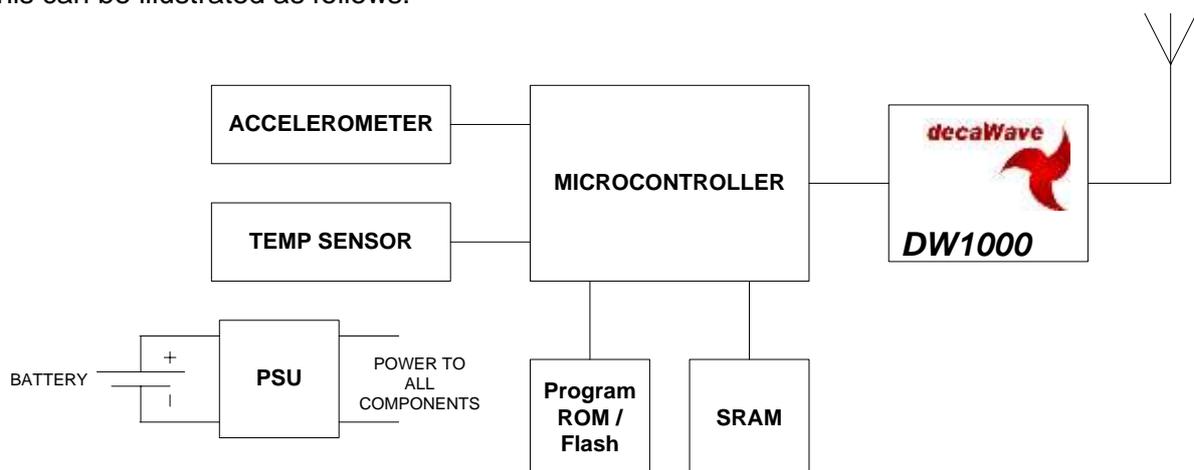


Figure 2: Overall block diagram of a tag for agricultural use

The accelerometer detects motion and can be used to control the tag update rate to the location engine. An animal at rest may not need its location updated as frequently as one that is moving. Keeping the update rate as low as possible while meeting all the other system requirements is a key approach to maximizing battery life and minimizing cost of system ownership.

Clearly there are many design decisions and tradeoffs that can be made here in both hardware and software in terms of functionality, complexity, power consumption and so on.

5.4 Implementation of the Infrastructure

There are two elements to the infrastructure required to implement a RTLS: -

- Anchors
- Location Engine

5.4.1 Anchors

Anchors are mounted around the area in which the farmer wishes to track the animals and receive messages broadcast by the tags. The number of anchors required is a complex trade-off between tag power consumption (higher data rates use less overall power) and the required range between tags and anchors (lower data rates give longer range). See www.decawave.com for more information on the actual specifications for range and power consumption at different data rates.

Depending on the RTLS scheme implemented the Anchors will either: -

- Conduct 2-way ranging exchanges with the animal tags to establish the distance between the tag and the anchor and pass this on to the location engine or;
- Time-stamp the received message from the tag and pass it on to the location engine

In the second case above all the anchors must be synchronized in time – see the RTLS application note on www.decawave.com for further discussion of this topic.

Notwithstanding the above, a typical anchor includes the following sub-systems: -

- A **Wireless Subsystem** to receive the transmitted messages from the animal tags. These messages are time-stamped on arrival at the anchor for location purposes but can also be used to transmit sensor data from the animal tag.
- A **Micro-Controller Subsystem** to take the time-stamped messages and associated sensor data and relay them to the Location Engine – the choice of Microcontroller as well as the type and amount of memory depends on the required level of functionality vs. the need to minimize power consumption
- A **Communications Interface** to the Location Engine. The time-stamped messages need to be communicated to the Location Engine via some kind of communications interface. There are many ways of doing this but essentially they fall into two categories: -
 - Wireless connection
 - Wired connection

Wireless connections, since they do not need cables, are obviously cheaper to install than wired connections. Care needs to be taken in the choice of wireless scheme

- A **Power Supply Subsystem** the complexity of which depends on the supply available (batteries / mains power) vs. the power supply requirements of individual components
- The Packaging / Enclosure

This can be illustrated as follows (with a wireless connection to the Location Engine): -

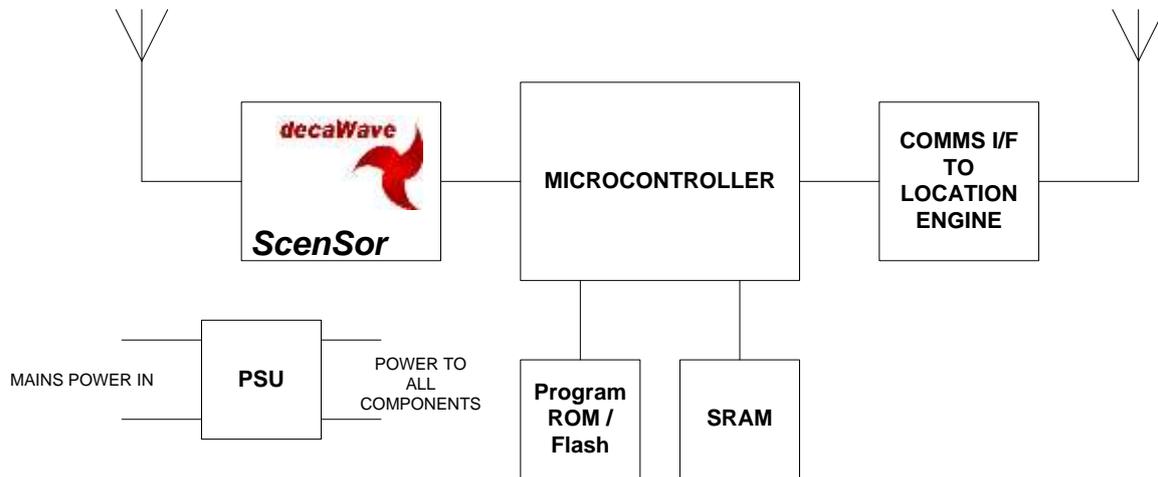


Figure 3: Block diagram of an Anchor

5.4.2 Location Engine

A location engine is a software application that runs on a PC or server. It receives time-stamped messages from the anchors and once it has sufficient time-stamped messages relating to one tag it processes them to give a location which is usually displayed on a floorplan of the barn or farm area where the animals are located.

In an animal monitoring scheme the Location Engine is only one component of a complex software suite that: -

- logs individual animal parameters such as temperature, activity levels, location and so on;
- builds profiles for each animal;
- monitors the animals parameters for departures from the profile
- provides database facilities for new animals to be entered / sold animals to be deleted

DecaWave has a demonstration version of a Location Engine that we will be pleased to share with customers building an RTLS based on our silicon.

6 REFERENCES

6.1 Listing

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

Table 4: Table of References

Ref	Author	Date	Version	Title
[1]	DecaWave		2.00	DW1000 Data Sheet
[2]	DecaWave		1.00	DW1000 User Manual

7 ABOUT DECAWAVE

DecaWave is a pioneering fabless semiconductor company whose flagship product, the DW1000, is a complete, single chip CMOS Ultra-Wideband IC based on the IEEE 802.15.4-2011 UWB standard. This device is the first in a family of parts that will operate at data rates of 110 kbps, 850 kbps and 6.8 Mbps.

The resulting silicon has a wide range of standards-based applications for both Real Time Location Systems (RTLS) and Ultra Low Power Wireless Transceivers in areas as diverse as manufacturing, healthcare, lighting, security, transport, inventory & supply chain management.

Further Information

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