final report

Project Code: B.NBP.0230

Prepared by: Mr Ben White ,Mr Les Zeller & Mr Josh Giumelli

Kondinin Group Incorporated & Queensland Department of Primary Industries &Fisheries

Date published: December 2006

ISBN: 9781740362771

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Northern beef industry remote management technologies: practices, research and potential

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

The remote management technologies project has thoroughly investigated the range of remote management technologies currently being used and researched, both in the beef industry and in other industries. The project has focussed on the components of technology required to capture data, quantify parameters, transmit and receive information. Investigation of the capacity available was also evaluated with a listing of individuals, groups and organisations capable of providing these products and services.

Significant interest from producers, researchers and manufacturers was expressed during the course of the project with a consistent message that this technology is seen as one of the more promising paths to reducing overheads and a potential source of research interest and product development over the coming decade.

Most interest is currently focussed on water monitoring technologies as this is thought to be one of the most simple methods of reducing costs, however of blue-sky opportunities were also investigated.

A number of *biggest bang for your buck* recommendations have been made with a listing of opportunities for investment identified. These opportunities focus on not only investment in equipment and technologies but also in the development of capacity including training and training materials to design, customise and install systems.

Executive summary

With ongoing increases in costs and difficulty in obtaining skilled staff, Northern Beef producers are looking for opportunities to improve operational efficiency and reduce equipment overheads and on-costs. Remote management technologies promise to deliver cost savings and improve personnel and equipment efficiencies by reducing the time and inputs required to undertake tasks in beef operations.

A common example of this type of technology is the remote monitoring and management of stock water delivery systems. Of all remote management technology applications, equipment to undertake this task is currently the most available. Remote monitoring of water points reduces the required frequency of first-hand visits to water points to ensure their operation and integrity. Cost savings are delivered through reduced vehicle and fuel costs, improved labour efficiency and opportunity to utilise labour for other applications.

All of these technologies depend on three key components, the sensor; which detects, measures and quantifies, the data transmission; which relays the data between the point of measurement and the place where they are more conveniently assessed and the terminal; which interprets the data and displays it for management decisions, or enacts on the data collected.

There is great potential for the development and application of remote management technologies in northern beef operations, applications which producers have shown interest in include stock water point monitoring and management, walk-over-weighing, remote mustering, virtual fencing, unmanned aerial reconnaissance vehicles.

Benefits coming from the technology are primarily economic and will vary widely depending on the location, expanse, stocking rate, number of head, cost structure and geography of the operation. But other benefits delivered by the technology include increased efficiency of labour, improved working environment, improved timeliness and flexibility of operations.

The primary challenges along the pathway to implementing this technology include a lack of capacity and skill in the remote locations required to undertake system design and installation of the technology. Further development of some technologies is still required with a requirement for improved on-animal power generation and attachment methods to be addressed. Data transfer, capable of higher bandwidths than currently available, is required maintaining ability to transmit over the large distances required in northern beef operations. This may or may not utilise existing communications infrastructure.

The most prominent challenge however, is the requirement to win the confidence of the northern beef producer. Provision of the tools required to justify the purchase and implementation of this technology are needed to achieve this confidence. In addition to demonstration the application through economics and convenience, producers will undoubtedly need to have the technology demonstrate capability and reliability prior to acceptance.

Contents

Page

1 Background

The northern beef industry has the opportunity to improve efficiency and minimise labour input costs through the use of remote management technologies.

Given escalating labour costs, a need for operational efficiency and the increasing difficulty of obtaining and retaining staff, the industry is looking to technology to limit the requirement of physically inspecting, switching, weighing, locating, measuring and adjusting cattle or equipment on cattle operations.

Sensor, computer and telecommunications developments combine to deliver an opportunity for northern beef producers to increase remote operations and improve the efficiency of their business.

While the use of this technology for the northern beef industry is currently being trialled, researched and conceptualised, a stock take of the performance, promise and potential for applicable technologies is required. This will include investigating application and research applying this technology to other industries.

2 Project objectives

Objective 1: Identify and detail the range of remote management technologies currently being used or researched in the Australian grazing industry, including their applications, costs and their realised and potential benefits.

Objective 2: Identify and detail the range of remote management technologies currently being used or researched in other industries that may be of value to the northern beef industry, including their potential applications, costs and benefits.

Objective 3: Produce a list and detail the expertise of those research groups and manufacturers active in the field of remote management technologies.

Objective 4: Recommend those technologies most likely to benefit the northern beef industry based on their potential cost, potential benefit and likelihood of reaching commercial production.

3 Methodology

3.1 Producer requirements, current use and understanding

To ensure remote management technology requirements for producers were well understood, visits and phone calls to producers on a range of scale and location were undertaken. The primary purpose of these visits was to understand the complexities of the economics, logistics and scale of operations, which ultimately affect the requirements, challenges and potential benefits producers have seen, or can expect from the deployment of remote management technologies in their operation.

These visits were used to understand and investigate specific costs, benefits and potential for the use of a range of identified remote management technologies which could be employed or may have potential in the operation. Producers were also questioned about the application of more left-field technologies in their operation including technologies capable of delivering remote aerial mustering and walk-over animal weighing.

Visits and phone calls to producers aimed to understand; operations performed, the operation scale and perceived importance of these operations and the associated incurred costs of performing these operations. With this understanding, researchers were able to evaluate the impact of efficiencies gained and the potential for a reduced labour requirement in various facets of the operation.

3.2 Manufacturer capacity and technology snapshot

A technology audit was used to identify and investigate technologies currently used, available, potentially applicable and under development by manufacturers. This involved looking across a range of industries, both within and outside Australia to find technologies which may be applicable to the Northern beef industry.

Having identified technologies applicable to the Northern beef industry, researchers investigated the potential, challenges and limitations of these technologies when used within operations in the Northern beef industry. This involved understanding the specifications and limitations of the technologies and how they may be applied.

In addition to identifying these technologies, visits to manufacturers were undertaken to observe production facilities, production capacity, currently available equipment, future prototypes and proposed product developments.

3.3 Research conducted, proposed and research capacity

To understand the range of research into remote management technologies applicable or potentially applicable to the northern beef industry, researchers evaluated the applicability of recent research conducted both in Australia and overseas.

Research investigated and evaluated was both within the range of beef industry sectors and externally in other industries including information communications technologies.

In addition to reviewing and evaluating the range of applicable research, visits were made to key researchers to evaluate the current state of research, applicable research capacity, areas of expertise and proposed future research programmes.

3.4 Other industries

The use of remote management technologies in other industries was also investigated. The Northern Beef Industry is not the only industry facing challenges requiring the use of remote management technologies. Horticulture, transport and industry including mining industries have employed the use of remote management technology to monitor and control operations remotely for at least two decades.

Key contacts within these industries were consulted to investigate the use and potential use of remote management technologies in these industries which may be applicable and available for use in the Northern Beef Industry.

Researchers aimed to focus on the technologies employed in these industries that may be applicable to the Northern Beef Industry. This was done with the knowledge of the specific challenges facing operators in the area including the harshness of the environment, large distances involved and the reliance on sourced power supplies.

3.5 Recommendations and opportunities

Utilising a tabular style assessment, remote management component technologies were evaluated according to their suitability and application to the northern beef industry. This assessment included an evaluation of capital and operating costs relative to current overheads wherever the application of technology was deemed potentially applicable.

This tabular assessment was used to focus on the strengths and the weaknesses of each of the components within the system, including capacity, specifications, price and potential savings. This assessment was used to isolate areas of opportunity which could be considered for development or application within the Northern Beef Industry.

In addition to identifying potential technology applicable, researchers also endeavoured to identify potential paths to ensuring a successful roll-out of this technology in the northern beef industry.

4 Results and discussion

4.1 Producer requirements, current use and understanding

After consultation with producers, cost reduction appears to be the primary driver for the adoption of remote management technologies in operations in the northern beef industry. This is particularly evident in larger and corporate operations where cost reduction or profit increase is the primary driver for the implementation of new technology.

However convenience and ease of use delivered by the use of remote management technology is also a consideration employed by smaller producers. According to these producers, the primary drivers include considerations other than cost including personal time saving, reassurance of animal welfare and quality assurance.

According to larger producers, water monitoring is the most obvious starting point to implement remote management technology. Apart from being simple and more easily understood by producers, the technology has been demonstrated in projects including the Pigeon Hole project which, according to producers, has been successful in deploying the technology, is well publicised and relatively well understood.

Of the producers met, all were able to identify potential steps they would take if they were to undertake an implementation strategy for the deployment of remote management technology on their property. In the majority of cases, these steps would involve initially implementing water monitoring and management technology on the farthest, and potentially the most difficult and expensive, water point. This is also the point at which the risk of failure is at its highest. Failure of the system in the early stages has the potential to decrease the rate of adoption due to reduced confidence in the equipment and poor reputation via word-of-mouth.

A number of producers have already adopted or are considering adopting water monitoring RMT. Interest was also shown in other technologies including walk-over weighing and remote aerial observation and mustering.

4.2 Producer case studies

4.2.1 Case study: Pigeon Hole (Heytesbury) – Northern Territory

Pigeon Hole Station, located around 500km south of Darwin, has pioneered the use of 'Observant' telemetry equipment on a trial area of around 400km2 of their 1800km2 operation.

Currently the equipment is used on 17 remote sites monitoring water pumping status, turkey nest depth, water medication status and on one site, visual monitoring of the watering point. At this stage, all available remote management tools are used at the borehole and water delivery points.

Immediate benefits delivered included reduced labour input requirement for the boreman freeing a multi-skilled boreman up to perform other work required on the station. In this development phase, the converse has applied, with the drive to develop a commercially suitable remote management package demanding an additional time requirement for the boreman. This additional time requirement is expected to recede as development continues delivering ongoing product improvement and reliability. As a significant installation, the Observant product has been adapted and developed during the implementation with modifications ultimately improving the reliability and useability of the package.

Labour savings appear to be the major potential benefit on Pigeon Hole. This delivers a reduction in the monitoring cost – allowing the boreman to be available for other roles on the property, for example, grader driving. There is also a reduction in the cost of vehicle depreciation, fuel use and tyre wear.

Other opportunities for remote management technology application on Pigeon Hole include remote monitoring of fence lines and flood-gates (for damage during the wet-season) which may be undertaken with remote reconnaissance aircraft and remote mustering assistance, both of which would reduce the reliance on helicopter services which currently cost around $400 per hour. Total annual investment in these helicopter services exceeds $15,000 for fence and floodgate checks and $136,000 for mustering.

Another potential for remote management technology application on Pigeon Hole is weaning. Calves are weaned at around 150kg into a fresh paddock. Typically this is done gradually as the calves come up to weight with 100-200 weaned at a time. The use of walk-over weighing in combination with automated drafting could see this process automated. Currently, mustering a paddock of up to 1500 head requires 1 helicopter and 9 musterers.

4.2.2 Case Study: Paul Jonas (S. Kidman & Co) – Quinyambie

With the farthest bore from the Quinyambie homestead being around 250km away, the cost of maintaining and switching pumps has been reduced significantly, saving 1 boreman ($40,000 p.a.) and 1 vehicle (nominal costing $35,000) plus 20,000 litres of fuel.

These savings have come about with an investment of $40,000 in GME remote monitoring and switching equipment monitoring 13 water points. The system was installed by Tim Stockman of Stockman Electronics, Burra, SA.

Additional saving have also been forthcoming with the switching facility reducing the fuel wastage on mono pumping systems. Once a pump has been switched on remotely, tank levels are monitored so that the pump is switched off when the tank is full.

According to Quinyambie station manager, Paul Jonas, the system has proven to be reliable requiring minimal maintenance since installation.

The GME System installed utilises the already-established UHF repeater network on Quinyambie. This enables the signal to be transmitted over the large distances required without having to install dedicated UHF data repeaters.

A mobile monitoring head unit is utilised in one of the station utilities and is referred to for monitoring of tank, trough and pump switch status. This removes the requirement to be at the homestead and in-front of a computer to monitor these.

Paul believes that the resolution of the system (maximum 4 levels) is sufficient and that images would not provide any additional benefits in the Quinyambie operation.

With mustering operations occurring twice per year, investment in aviation is around $40,000 annually and is used primarily for stock location rather than mustering. Paul believes that the development of an NLIS ear tag with a combined tracking ability would be particularly beneficial and estimates the savings in mustering costs would exceed $30,000 annually.

4.2.3 Andrew Richardson & Peter Fox, Ten Mile Cattle Co

Andrew Richardson & Peter Fox, Goondiwindi QLD, are looking for a system that will deliver real-time images between a remotely located block and the homestead located 35km apart through trees and undulating country.

Peter believes live images of water troughs would provide assurance that troughs in his rotational grazing system were adequately filled, in good operating condition and that cattle are using them.

According to Peter, level indicators are a good start and potentially very useful, but numbers or indicators will not tell you if a beast has become stuck in the trough, the trough is overflowing, damaged or the water is unpalatable for livestock.

Initially, it was thought that a Semfios style WiFi link would be adequate, but given the topography and vegetation over the 35km line-of-sight distance, transmission without a repeater is not likely to be possible. Given that the country in between these two blocks is not part of Ten Mile, installation of a repeater is not an option.

Cost savings for a system capable of meeting requirements are estimated to be around 3 person-hours per day with a reduction in site visits from four per week to one. This equates to a total of 9 hours saved every week, approximately 420km travel saved (approx $252 per week in vehicle and fuel costs). Applying a nominal figure of $25 for labour, annual savings are estimated at over $24,500.

But cost savings are not the only factor driving the search for this technology at Ten Mile. Convenience and flexibility, combined with an ability to make informed decision would permit staff to make appropriate decisions about the timeliness required for visits between properties. While there is no objective measure for these factors, Peter Fox believes this is one of the primary drivers for implementing the technology.

Other remote management applications which could be applied to the Ten Mile operation include walk over weighing for agistment monitoring and with automated drafting at turn-off weight.

4.2.4 Peter Knights – “Carrington” QLD

Peter Knights has 12 water points he would like to monitor on his 11km long holding south of Roma QLD. Peter has adequate UHF voice communications over the property and the 11km extents are well within the 20km range of a WiFi network.

Currently Peter is able to monitor all 12 water points in around half an hour in his vehicle as all of the water points are roughly in a line and most are along a central property road making water checks more convenient.

While the time requirement and resulting cost is not significant (approximately $10 in vehicle and fuel costs and 0.5 hours of Peters time) the convenience of knowing water points are operating correctly and stock are using them is difficult to put a value on.

Peter expects that as the technology becomes more affordable, he will install remote monitoring equipment on his troughs but feels a comfortable investment level would be around $15,000.

4.3 Manufacturer technology and installer capacity snapshot

There has been considerable investment into the development of packages incorporating all of the required components to perform basic remote management. While the majority of efforts have been focussed on water point management, the components required to undertake this task also form the backbone for most other remote operations.

Some of these components have been well developed and require little or no development while others are specific to the task of remote management and require adaptation specifically for the required task.

A tabular assessment of technology components and their status can be seen in appendix 1.

More generally, the status of technology for each of the components required to construct a system were individually evaluated as follows:

4.3.1 Sensors

The type of sensor depends on the parameter being measured and can vary in price and complexity depending on the resolution, accuracy, and signal conditioning eg; amplification, linearization etc.

Sensors are generally categorized by the parameter that they measure but are not limited to that use. For example to measure the volume of water in a tank we can use:

1. A pressure sensor which will give a signal proportional to the head of water above the sensor. And knowing the physical dimensions of the tank and the position of the sensor a volume can be calculated. Alternatively the sensor can be external to the tank with a pipe or tube fed back to the bottom of the tank.

2. An ultrasound sensor to measure the distance from a point above water down to the surface of the water, again allowing the volume to be calculated.

3. An optical sensor to measure the distance from a point above water down to the surface of the water, again allowing the volume to be calculated.

4. A load cell can be used to weigh the tank and therefore from knowledge of the density of water a volume can be determined.
   These sensors have analogue voltage or current outputs and therefore provide a continuous signal between the minimum and maximum levels. The accuracy of the sensor is determined by the measurement technique and is reported in the sensor specifications whereas the resolution or smallest measurement increment is dependent on the instrumentation connected to the sensor. These sensors require power to work and therefore current draw is a consideration when selecting batteries and solar panels.

5. A lower cost alternative is to use a float switch to indicate the level is above or below a set point or multiple set points. This is a common low cost solution using a float incorporating a magnet, reed switches and a series of resistors. The number and separation distance between the reed switches determines the range and resolution.

   The use of reed switches within the sensor eliminate the need to power the sensor but it should be noted that the reed switch has a defined life being a mechanical switch and will eventually require replacement.

Water level and flow measurement are common place in industry and the technologies available are proven and reliable.

The question is “what information is important to the farmer?” At present with visual inspections the farmer can tell that the bore is working by the fact that water flows into the tank when the bore is running. In an automated system the bore operates when the level of the tank drops to a predetermined level (lower set point) and continues to operate until the tank level rises to the upper set point. Therefore the farmer knows that the system is working properly as long as the level of water in the tank is equal to or between the lower and upper set points. A knowledge of the actual level is not necessary if the only management information required is to know if the system is working.

However knowing the rate of flow into or out of the tank can be an indicator:
- that the pump needs servicing if the flow rate is reduced
- there is a leak in the system if the flow rate has increased

Alternatively the flow rate out of the tank represents the animal’s water consumption which may relate to the number of animals drinking from the trough. Access to historical data can provide information for management decisions.

This flow rate information can be gained by monitoring and recording actual water levels periodically or by timing the intervals between:
- the upper set point and lower set point for water usage which will relate to the consumption rate
- or the lower set point and upper set point to monitor pump condition.

There are a large number and range of sensors available that can be utilised by the Australian beef industry. These are becoming more prominent as technology finds its way into the bush.

4.3.2 Other sensors

Sensors are currently available to measure the following parameters:

Acceleration and Vibration Sensing - Sensors for measuring vibratory or oscillatory motion.

Acoustic - Sensors and instruments for measuring sound levels and frequency.

Analytical Sensors - A wide classification of sensors that are used to analyse material samples, or their components, and record data specific to the application.

Density and Specific Gravity Sensing - Any method used to determine density and specific gravity including hydrometers, digital instruments, pycnometers, etc.
Displacement Sensing - Devices used to detect (optical, Hall effect, inductive, etc.) or measure changes in displacement.

Electrical and Electromagnetic Sensing - Devices used to detect and measure electrical and electromagnetic signals.

Encoders and Resolvers - Motion feedback devices providing position and velocity information to closed-loop control systems.

Environmental Sensors - Sensors designed to measure and test for changes in environmental conditions, including radiation (both wavelength and as a hazardous emission), temperature, moisture and dew point, smoke, dust and opacity, light, weather, and water quality.

Flow Sensing - Flow measurement instruments are used to determine flow rate by monitoring the amount of media passing during a specific time. Devices within this category can monitor liquids, gases or solids, and measure in units of mass, velocity or volume.
Force Sensing - Sensors and equipment for measuring static or dynamic force or torque.

Gas Sensing - Any method used to measure the amount of a specific gas or gases in a given environment including both sensors and instruments.

Humidity and Moisture Sensing - Sensors for measuring humidity, moisture content and weather conditions.

Level Sensing - Devices used to detect or measure level of liquids, gases or solids, within pipes or tanks, or to detect the interfaces between different materials.

Linear Position Sensing - Devices used to measure the linear displacement of an object.

Orientation Position Sensing - Sensors used to detect rotary position, angular position, tilt, or inclination relative to the horizon or a linear position.

Pressure Sensing - Sensors for measuring the pressure applied to a surface from a liquid, bulk material or discrete component.

Proximity or Presence Sensing - Sensors for proximity sensing, including capacitive, photoelectric, inductive, Hall effect, ultrasonic, and other technologies.

Rotary Position Sensing - Devices for sensing and measurement of angular motion, speed, and position; includes encoders, resolvers, synchros and similar devices.

Safety Sensors and Switches - Safety sensors and switches are used in machines and other industrial applications to safeguard equipment and prevent personal injury.

Temperature Sensing - Devices that are designed to detect or measure changes in temperature such as temperature probes, sensors, etc. these include thermometers, RTDs and monolithic integrated circuits.

Tension Sensing - Sensors that measure tension in cable, fibre, belts, sheets and other webs.
Tilt Sensing - Sensors that detect inclination relative to the horizon, rotary position, angular rates or linear acceleration.

Torque Sensing - Sensors that measure torque in shafts, cables, fibres, rods and other components.

Vacuum Sensing - Sensors for measuring sub-atmospheric pressures, vacuum levels.

Velocity Sensing - Sensors that measure velocity or speed in shafts or other moving components.

Viscosity Sensing - Sensors for measuring the viscosity (resistance to flow) or viscoelastic properties of liquid or molten glass and plastic.

Vision Sensing - CCD, CMOS or other image capturing sensors that form the heart of a digital camera or imaging system.

Weather Sensing - Instruments or sensors designed to measure one or multiple components of weather; including wind speed and direction, rain/snow fall, solar radiation, temperature, pressure and humidity.

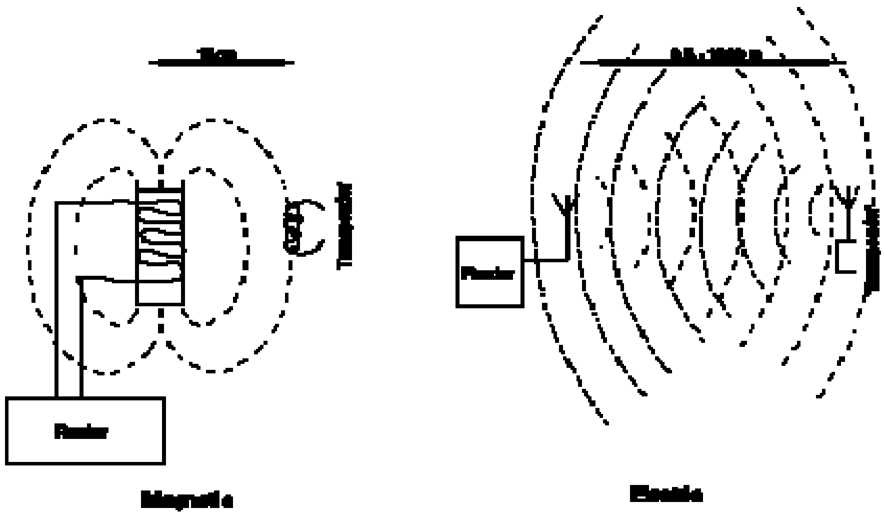
4.3.3 Radio Frequency Identification RFID

The use of RFID technology through the National Livestock Identification Scheme (NLIS) which is being adopted throughout Australia is an example of how modern technologies can be used in livestock production. This technology uses a burst of radio frequency energy to power a tag which in-turn transmits its unique identification code. RFID cards are also known as "proximity" or "proxy" cards and come in three general varieties: passive, semi-passive (also known as semi-active), or active.

Passive RFID tags have no internal power supply. The minute electrical current induced in the antenna by the incoming radio frequency signal provides just enough power for the CMOS integrated circuit in the tag to power up and transmit a response. The main advantage of this system is that the tags require no batteries and are robust.

Unlike passive RFID tags, active RFID tags have their own internal power source which is used to power any ICs that generate the outgoing signal. Active tags are typically much more reliable (e.g. fewer errors) than passive tags due to the ability for active tags to conduct a "session" with a reader. Active tags, due to their onboard power supply, also transmit at higher power levels than passive tags, allowing them to be more effective in "RF challenged" environments like water (including humans/cattle, which are mostly water), metal (shipping containers, vehicles), or at longer distances. Many active tags have practical ranges of hundreds of meters, and a battery life of up to 10 years.

The potential of RFID technology within the beef industry and in association with other technologies (e.g. walk over weighing) provides the ability for automated drafting at watering points and condition monitoring.



Different types of coupling for RFID systems

4.3.4 Magnetic coupled transponder systems

4.3.4.1 125 kHz

These are the most common transponders available today, manufactured by a wide range of suppliers.

Generally operating at frequencies typically in the order of 125 KHz, the tags are characterised by antenna systems that comprise of numerous turns of a fine wire around a coil former to collect energy from a reader's magnetic field. Due to the magnetic method of coupling, range is limited generally to a number of inches, being determined by the fields generated between the effective North and South pole of the reader. Magnetic Tags are manufactured by many suppliers and find application in tagging animals, labelling gas bottles, electronic automobile key identification, and factory automation.

Different forms of communication are used by the different manufacturers. Typical methods are to use the energising signal at a frequency of 125 kHz and to receive data back from the transponder by:

- receiving data back from the transponder at half the frequency of the transmitter link while the transmitter operates in a CW mode.
- using the transmitter in pulse mode, and to transmit the data back immediately the transmitter signal stops, namely on the flyback while the tag energy is decaying when the energy is removed
- by letting the tag load the energising field, with this fluctuating load being sensed by the changes occurring on the energising field

Issues around magnetic coupling are that the frequency is low, the energising field is very much stronger than the returned data field strength, that it is difficult to create filters with sufficient tuning to separate the transmit and received signal while both are present, that the tags have very limited energy storage capability, meaning that the energising field needs to be applied in a uniform continuous manner, or data can be received back in that short period of time after the energising field is removed (flyback)

Typical operating distances for 125kHz transponders is 2cms. The magnetic fields propagate through water and with the correct alignment, the transponders can be buried below the surface of metal items that are to be identified. The smallest transponder in this form is a glass sleeve 11 millimetres long and 1 millimetre in diameter. This technology now finds application in identifying pets, car keys for ignition systems, labelling gas bottles and in a few crazy applications like being injected into humans to verify identity. A bolus version which can be swallowed by a bovine animal and which lives in the stomach of the animal is also popular.

4.3.4.2 13.56Mhz

Since 1998 a new series of magnetic coupled tags has been available which operates at 13.56Mhz , not needing the high number of turns on the 125kHz transponder antenna and hence are cheaper to manufacture. The tags comprise of a small coil of a few turns, often etched on a flexible printed circuit substrate, and to which a single chip is bonded. These transponders are typically the size of credit cards but might be as small as 1.5cm by 1.5cm in area and couple their energy to the reader via magnetic propagation. By the reader continuously providing an energising field, which can be modulated, the tags can extract energy and data from the reader and communicate back to the reader. Such tags often have read/write capabilities and often anti-collision properties to allow for many tags to be in the reader beam at the same time. The reading and writing distance of such tags is limited by the magnetic means of propagation to typically 50cms, but some manufacturers claim 1 meter operating range. These tags seem to be positioning to replace the more difficult to produce 125KHz tags which required coil winding facilities.

Almost all magnetic based transponder systems are passive, that is they get their energy from the reader's energising field.

Transponder systems operating on magnetic coupling principles operate at frequencies as high as 29MHz.

4.3.5 Electric coupled transponder systems

Electric field coupled transponders generally provide vastly increased ranges over their magnetic counterparts. Rather than being limited to the ranges of the lines of force emitting from a magnetic field generator, they use the electric field propagation properties of radio communication which radiate out from the energising antenna, quartering in signal strength every doubling of distance travelled, to convey energy and data from the reader to the transponder and data from the transponder to the reader.

Electric field propagation requires antenna systems that are typically half a wavelength of the operating frequency in size (150cm at 100MHz,15 cm at 1GHz, 5 cm at 2.5Ghz and 2.5cm at 5.8Ghz). This causes practical limits to how low a frequency to start using E-field propagation methods due to the size of the antenna. (UHF tags refer to tags that operate in the 860 - 915 MHz frequency range)

Higher operating frequencies require more expensive components and loose the ability to transfer energy at a rate of the inverse of the wavelength squared. (A 2.45GHz system would need seven times the energising fields needed by a 915 MHz system)

In addition the energy density of a signal radiated using electric field coupling, decreases as the inverse of the distance squared between the source and the transponder. Whereas sensitive receivers can compensate for this loss of energy for the data communications over long distances, passive transponders which use the reader's energising field as a source of power are practically limited to 10 to 15 meters. Beyond that distance (which reduces drastically with increased frequency to less than 1 meter at 2.5GHz) it is necessary for the tags to use an external battery as a source of power (hence become active transponders).

Electric field tags are available in many different configurations and price ranges, particularly dependant on the complexity of the transponder. If the transponder is a read/write transponder and is required to operate beyond the range of passive transponders, the receiver circuitry onboard can be expensive and difficult to construct particularly if frequency stability is needed with temperature.

However the invention of the backscatter modulation principle at Lawrence Livermore Laboratories in the 1960s and the skills of semiconductor designers to shrink all features into cheap integrated circuits has meant that electric field type tags in a read only mode can be made extremely cheaply, most probably for less than 15 US cents in high volume. Such a tag would be passive, have no onboard tuned circuits, be read only, consist of a single integrated circuit and a simple antenna, would operate at any of a range of frequencies, be temperature insensitive, and would broadcast a large data value when illuminated by a reader's energising field. In such a system the reader is complex because it provides the frequency stability, the energy of the system, and the receiver selectivity to receive the weak return communications, but the tags are very cheap. This is ideal for the situations where there is one reader and many tags.

Electric field tags need to operate in an ordered spectrum management system as their radiated energy (particularly from the reader) can be detected by other sensitive receivers far away and cause possible interference.

Recent developments in passive tag technology see the amount of power needed to power up the tag dropping dramatically. The reader radiates energy from it’s transmit antenna, some of which is collected by the tag in an area around its antenna called the "antenna's aperture". The size of this area is dependant upon the characteristics of the tag antenna and the operating frequency of the system, (e.g. a 915MHz dipole has a 134cm2 aperture).

Traditionally a 5 volt logic circuit on a half wave dipole in a transponder would need 55mw of RF energy to operate while recent developments see this amount of power dropping to less than 200 microwatts, thereby dramatically reducing the power needed to be radiated by the reader for the energising field and increasing the range over which passive transponders can operate effectively. (260 Times lower power giving 260 times battery life of reader or 16 times the operating range).

Electric field tags are used in transponder/smart card systems for toll road applications. Here the tags are active (that is they have a battery) but only consume battery power after the tag is "activated" by passing through a high energy activation field. Thereafter the tag can send/receive data with an overhead reader and can adjust the data representing the balance remaining in the smart card after the toll fees are deducted. Such applications are implemented in the 2.45GHz frequency band and more recently in the 5.8GHz band.

A separate category also exists of "active" tags (battery powered). These tags are "beacon" tags, that is they are not interrogated by a reader, but wake themselves up from a low power "sleep mode" periodically and broadcast their identity before returning to "sleep mode". By broadcasting on a fixed frequency, a sensitive receiver tuned to that frequency and within close proximity to the tag will receive the identity message. This type of transponder offers ranges up to hundreds of meters, but is not suited for situations where the location of a tag is being determined to a couple of meters range, or where very many tags are present in the reader zone. The range of the systems is dependant on the height of the transponder and the reader above the ground. A common version of such a tag is the remote controlled operation of an electric gate or garage door. Encryption technology has also been added to these systems to stop unwanted tags being accepted as valid codes by the reader.

Despite the hurdles, the greater range, higher data rates and new technologies make these transponders suitable for a great number of applications.

4.3.6 Livestock management

Apart from traffic management systems, many people are most familiar with RFIDs as the basis of domestic pet registration schemes.

Some jurisdictions in Australia, for example, mandate sub dermal 'chipping' of cats and dogs as part of pet registration schemes. The tags are inserted by veterinarians as a condition for licensing of the beasts, replacing detachable collars and tattoos that were not robust, easily identifiable and readily integrated with government/private databases. In practice performance has been limited by non-compliance (with estimates that upwards of 40% of Australia's seven million companion animals are unregistered) and implementation teething pains, with disagreement about standards and competing registries.

The US Department of Agriculture for example announced moves in 2004 towards "giving every cow in the United States its own unique identification number"; with an official announcing "We want to allocate an individual identification, just like you and I have Social Security numbers". The primary rationale appears to be quarantine and contamination management, with claims that tagging can provide 'paddock to plate' identification and facilitate extension of projects such as Heritage Foods in the US, which offers a tracking number with every piece of turkey sold (the number provides consumer access via the web to details of the bird's medical and feed history).

The Australian Sheep Industry Co-operative Research Centre's Remote Individual Animal Management (RIAM) system uses RFIDs as the basis for remote automatic logging and weighing of sheep. Tagged sheep are automatically logged and weighed as they move through a race from one field to another or to feed or drink. It is envisaged that automatic gates will in future be linked to the walk-through scales, with underweight animals being separated from their healthier peers.

See Appendix 3 for additional RFID information.

4.3.7 Remote sensing and aerial imagery

Imagery from satellites is becoming a useful tool for yield prediction in cropping, for quantifying areas and differentiating between crops, quantifying frost and fire damage and monitoring extreme events e.g. Flooding and droughts. Aerial imagery provides higher resolution multi-spectral images and provides more information to assess the variability within and between paddocks and can be used in the management of nitrogen of fertiliser, detecting disease or insect damage. This technology has potential to also monitor pasture condition. The question for the beef industry is whether these technologies are cost effective.

There are a number of suppliers of satellite images where imagery type e.g optical (panchromatic or multi-spectral) or radar, the spatial resolution and revisit period affect the price. Examples currently used in agriculture are:

- LANDSAT5 which uses optical imagery with spatial resolution of either 15 or 30 metres for panchromatic or multi-spectral respectively and a revisit period of 16 days. (Full scene approximately $1200)
- IKONOS which uses optical imagery with spatial resolution of either 1 or 4 metres for panchromatic or multi-spectral respectively and a revisit period of 3.5 - 5 days. (Approximately $25/km2 with a minimum area purchase).

Commercial companies involved in precision cropping will supply satellite imagery for pasture growth comparing one pass to another for a 625 km2 area for about $500.

Aerial imagery is available commercially and has approximately 1 - 2m resolution for multi-spectral (this resolution is dependant on the height the plane flies and is not limited to 1m). The cost of aerial imagery (typically $3 - $4/hectare) is dependant on the distance the plane has to travel and any imagery processing/geo-referencing requirements which could lead to thousands of dollars for a set of images for a particular date. Typically the cost for

A third option which is being investigated for agriculture is the use of Unmanned Aerial Vehicles (UAV). The DPI&F is doing trials to evaluate the potential of this technology for monitoring crop health/damage, water supplies and stock management. The use of UAVs is a low cost solution for aerial imagery. The system would involve the use of GPS and an autopilot system to fly to way-points to capture images. This review has prompted discussions between Queensland DPI&F and the Australian Research Centre for Aeronautical Automation (ARCAA) to initiate a student project on the use of UAVs to assist with mustering.

4.3.8 Walk Over Weighing

Traditionally in rangelands environments opportunities for intensive management of livestock are fairly limited due to the extensive nature of the environment. Due to distance, time and labour issues, animal performance can only be monitored infrequently at best and must be tied in with other husbandry operations.

Walk Over Weighing (WOW) systems were investigated in the mid to late 1980's and their potential is finally being realised as a valuable tool for condition monitoring. By incorporating WOW with existing technologies such as RFID, wireless telemetry and automatic drafting gates the ability for remote animal management becomes viable.

Bill Murray (NSW DPI) is researching and having success developing a WOW system for the Sheep CRC. The technologies in this system are directly transferable to the beef industry but will require further development to cater for differences in animal husbandry. Bill's work with Tru-Test to develop a weighing system that interfaces with an RFID reader is leading the way to achieving a remote drafting and conditioning system.

4.3.9 Data Transmission

The transmission of data from a sensor to a displaying or recording device can be via a hardwired connection where a physical conducting path is present or a wireless connection.

4.3.9.1 Wired Connection

There are a number of issues with a wired connection which make unusable e.g.:

- Cost
- Losses due to resistance of wire

- Losses due to the impedance of wire for AC signals.
- Susceptibility to electrical noise
- Potential for damage

Transmitting data over cables for long distances is not viable compared to wireless systems due to costs.

4.3.9.2 Wireless connections

Wireless Data - How It Works (reference Elpro Technologies Industrial Wireless Handbook 2006)
Wireless data involves modulating, or coding conventional binary data ("1's and 0's") onto a radio frequency carrier. The wireless data is transmitted as a radio message, comprising;

- the data,
- additional information to control the message handling and
- a "lead-in" transmission at the beginning of the message to allow receivers to identify the type of radio transmission and to lock-on and synchronize with the transmitter.

Data can be modulated using a variety of techniques. Receivers de-modulate the radio message to re-create the original data.

4.3.9.3 Radio Bands and Channels

The use of wireless devices is heavily regulated throughout the world. Each country has a government department responsible for deciding where and how wireless devices can be used, and in what parts of the radio spectrum. Most countries (but not all) have allocated parts of the spectrum for open use, or "license-free" use. Other parts of the spectrum can only be used with permission or "license" for each individual application.

Most wireless products for short-range industrial and commercial applications use the license-free areas of the spectrum, to avoid the delay, cost and hassle of obtaining licenses. The license-free bands are also knows as ISM bands - "Industrial, Scientific & Medical". In many countries there are several ISM bands available, in different parts of the spectrum.

The radio spectrum is split into frequency "bands" and each band is split into frequency "channels". The width of each channel is normally regulated.

The channel width dictates how fast data can be transmitted - the wider a channel, the higher the data rate.

The common frequency bands for industrial wireless applications are:

- 220 MHz band in China - licensed
- 433 MHz band in Europe and some other countries - license free
- 400 – 500 MHz - different parts are available in most part of the world as licensed channels
- 869 MHz band in Europe - license free
- 915 MHz band in North and South America and some other countries - license free
- 2.4GHz band allowed in most parts of the world - license free

Higher frequency bands are wider, so the channels in these bands are also wider, allowing higher wireless data rates. For example, licensed channels in the lower frequencies (150 –

500MHz) are often regulated to 12.5 KHz, whereas channels in the license-free 2.4GHz band can be hundreds of times wider.

However, for the same RF power, lower frequency gives greater operating distance. With wireless data, there is always a trade-off between distance and data rate. As radio frequency increases, the possible data rate increases, but operating distance decreases.

4.3.9.4 RF Measurement Units

Radio frequency signals have two common measurements - frequency and “strength”. Many signals are a mixture of different frequencies and different strengths.

Frequency is measured in Hertz (Hz). The radio spectrum is broken into groups, with names such as HF (“High Frequency”), VHF (“Very High Frequency”), and UHF (“Ultra High Frequency”). Graphically the radio spectrum is illustrated with a logarithmic scale rather than linear.

Industrial wireless products are found in the upper VHF and UHF frequencies. The most common measurement of RF strength is in mW (milli Watts) of RF power. Again, strength is expressed in a logarithmic scale using decibels (dB). RF signal strength (or RF “signal”) is expressed as “dBm”, with a reference of 1mW of RF power. That is, 0dBm = 1mW RF power. RF signal strength in dBm is the logarithm of the RF power in mW.

dBm = 10 log10 [RF Power in mW]

Being a log scale, doubling signal strength adds another 3dB. So increasing 4 times adds 6dB (2 x 3), increasing 8 times adds 9dB (3 x 3). Similarly halving a signal removes 3dB.

4.3.9.5 Noise and Interference

Radio noise is caused by both internal and external factors. Internally, there is “thermal” EMF noise caused by random electron movements in components, as well as harmonic noise generated by the RF circuitry. External sources are natural and man-made.

Radiation from the sun (“solar flares”) is a large source of noise across the radio spectrum, with variable effect at different times. Lightning is another natural source of noise. All electrical and electronic equipment produces radio frequency (RF) harmonics, however the noise amplitude of electrical power equipment at the frequencies used for industrial wireless products is extremely small and can be ignored. Harmonics from other radio sources such as television, broadcast radio services, wireless cellular telephones etc cannot be ignored and is a significant noise source.

“Radio Interference” is noise caused by other wireless transmissions on the same channel or on nearby channels.

The sum of all noise sources is a volatile mix of varying amplitudes. Over a short period of time, the noise level on any radio channel will have peaks and troughs about an average level, with the amplitude at any instant following a random probability function. Over longer periods of time, the noise pattern will be the same; however the average noise level will change according to what is happening in the surrounding environment.

Noise levels in most areas are between –110dBm and–130dBm (that is, 10-11mW to 10-13mW). A level of –100dBm is high and –90dBm is very high.

4.3.9.6 Signal to Noise Ratio (SNR), Fade Margin and Bit Error Ratio (BER)

A radio receiver tuned to a particular frequency channel will receive whatever is transmitted on that channel plus any background noise. If the strength of a transmission is significantly stronger than the noise, then the receiver is able to effectively ignore the noise - the transmission (normally called the "signal") has a good-signal-to-noise ratio. If the signal is of similar strength as the background noise, the receiver will not be able to discriminate the signal from the noise - this is a poor-signal-to-noise ratio or SNR.

When a data message is modulated onto a RF signal, the ability to demodulate the message depends on the background noise. As a signal gets closer to the noise level, the demodulated data has more errors, as the noise makes it harder to determine if a demodulated bit of data is a 1 or 0. These errors are called "bit-errors", and the error rate (errors per total bits) is the bit-error-ratio or "BER".

The sensitivity of a radio receiver is the lowest RF signal that it can detect reliably - generally quoted at a specified BER. The "data sensitivity" is the lowest RF signal that the receiver can demodulate a data message with very low level of external noise.

Data sensitivity is normally expressed at a particular BER; for example, -108dBm @ $1x10^{-6}$. This means that the receiver can demodulate data from a –108dBm signal with only 1 bit-error per million bits - provided the noise is much less than –108dBm.

A transmitted signal can vary in strength. During rain or fog, the radio signal is attenuated (decreased) by the denser air. In a thunder storm, the transmitted signal will decrease, and the noise level will increase - this could turn a low BER into a high BER.

A SNR of 5dB means that the average signal measurement is 5dB stronger than the average noise level. Unfortunately radio noise is often much less than receiver sensitivity, so SNR is not particularly relevant.

A more common term that is relevant is the "Fade-Margin" - how much can a radio signal decrease (or "fade") before the receiver can no longer demodulate data. Fade margin is the difference between the transmitted signal and noise or receiver data sensitivity, whichever is greater. It gives a measurement on how much the signal needs to "fade" before it becomes unreliable. The fade margin should be measured on a fine day.

For modern industrial wireless products, a fade margin of 10dB is adequate - this gives enough margin for loss of signal or increased noise during poor weather of high solar activity. An installation will work reliably with a lower fade margin, however not all of the time.

4.3.9.7 Data Rate Effects and Wireless Reliability

For each data modulation method, the ability of the receiver to demodulate data from the received radio signal decreases as the data rate increases - that is, BER increases as the transmitted data rate increases, due to receiver demodulation operation. However "demodulation BER" is not the only factor influencing overall data reliability.

Because instantaneous noise closely follows a random probability function, any and every wireless message is vulnerable to random noise "attack" that can corrupt individual bits. Forward-error-correction (FEC) techniques can be used to recover the corrupted bits. For messages without FEC, the whole message becomes corrupt if one bit is corrupted. So the probability of a corrupted message relates to its "air-time" - the overall transmission time of the message. This depends on the length of the message (number of bits) and the transmitted data rate. The longer the message, the higher the probability of message corruption, but the higher the data rate, the probability decreases. So higher data rate has two effects; increasing demodulation BER but also reducing the risk of message corruption.

For reliable operation, all wireless messages need integral error-checking to check the integrity of the overall message. Message recovery is also required in the event of corruption. This is normally in the form of a message acknowledgement protocol with corrupted messages being re-transmitted, or messages being continuously transmitted such that occasional corrupted messages can be ignored.

Summarizing the effects:

- BER increases with data rate because of receiver demodulation errors
- The probability of message corruption during transmission decreases with data rate.
- The probability of overall message corruption decreases with shorter messages.
- FEC functionality built-into the messages improves the rate of successful messages.

Wireless products with short messages such as Wireless I/O have a reliability advantage over Wireless Modems which transmit much larger amounts of data.
Products which implement FEC techniques also have an advantage - this allows messages to be transmitted at a higher data rate, with lesser degradation of reliability.

4.3.9.8 Reliable transmission distance

How far will a radio signal transmit reliably? A radio signal is transmitted at a certain signal (power) level, but received at a much lower level. Radio signals are attenuated (decrease) as they pass through air or other media.

The amount of signal loss over the radio path determines how far a radio signal will travel. When a radio signal falls below the data sensitivity, then it is no longer received reliably. When the radio signal falls below the “fade margin”, the signal becomes marginal.

There are many factors which effect signal power levels and signal attenuation:

4.3.9.9 RF Power

“If you transmit more radio signal, then the signal will go further” - this is a fairly obvious statement. It means that if you increase the RF power level at the transmitter, then the power received at the receiver will increase. But how does this relate to distance?

Radio signals through a constant media attenuate proportionally to the square of distance. That is, in a clear radio path through air, if you double the distance, then the received signal level will decrease to ¼ (or –6dB). Similarly if you halve the distance, the received signal increases 4 times (or +6dB).

The same relationship exists with transmitter power:

$$d_2 = d_1\sqrt{\frac{P_2}{P_1}}$$

where *d* is distance and *P* is RF power as RF power increases, distance increases by a square-root effect where d is distance and P is RF power.

To double reliable distance, you need to increase power level four times - i.e. you need to increase power by 6dB. Or if you halve power levels, the distance will decrease to approx 70%.

4.3.9.10 Receiver sensitivity

Improving receiver sensitivity has the same effect as increasing transmitter power. Improving receiver sensitivity by 1dB can increase distance up to 12%.

Note: be careful with data sheet specifications. The data sensitivity of most modern products is very similar - however sensitivity is specified in many different ways and is difficult to compare between products.

4.3.9.11 Frequency

As radio frequency increases, the effective “aperture” of an antenna to receive a radio signal decreases, with the same effect as increasing distance - that is, received signal decreases with the square of frequency. Over the same radio path and using the same type of antenna, the received signal decreases by a square relationship as the frequency increases. If the frequency doubles, the signal drops to ¼ etc.

As distance is also related to the square of radio signal, then the relationship between frequency and distance is inversely proportional: as frequency increases, reliable distance decreases proportionally

$$d_2 = d_1\sqrt{\frac{f_2}{f_1}}$$

where d is distance and f is frequency

The “loss” effect of increasing frequency can be overcome by using a higher gain receiving antenna. Because antennas are physically smaller at higher frequencies, it is easier to increase gain at higher frequencies. This is a simple achievement in one-way wireless systems, however in most two-way systems, the receiving antenna is also the transmitting antenna. In this case, radio regulations limit the RF power which can be transmitted from the antenna, which limits the antenna gain.

Another factor with increasing frequency is increasing signal attenuation through different media. As frequency increases, signal losses through air, walls, trees etc increases, and the ability to diffract around obstacles decreases. All in all, higher frequency has a significant effect on operating distances.

4.3.9.12 Nature of the radio path

Obstructions in a radio path have a major effect on the reliable distance.

The frequencies used for industrial wireless products are often called “line-of-sight” frequencies. But this doesn’t mean that line-of-sight is required for reliable operation.

“Line-of-sight” means that the transmitted radio signal will radiate in straight lines, instead of curving around the earth’s curvature, as happens at lower frequencies.

Radio signals will pass through some obstacles (for example, buildings) and will also reflect from some surfaces (metal tanks/vessels, rock cliffs). Radio signals won't pass through obstacles like hills, however some of the radio signal can diffract (bend) around this type of obstacle.

The general rule is that obstacles decrease the reliable operating distance.

Most wireless products are specified with a "line-of-sight distance" - this is the distance that can be expected to be achieved with no obstacles in the radio path. The curvature of the earth is an obstacle, so in most cases these distances can be only achieved by elevating the antennas above ground level. At normal eye level across a flat plain, the distance to the horizon is 5.5 km (3 miles) however this increases to over 20 km (13 miles) if you are 30 metres (100 feet) above the ground.

Normally, transmission distances will increase if you increase the height of antennas.

Typical line-of-sight distances	**Km**
2.4 GHz 36dBm / 4W WiFi (America/Canada)	3 - 8
2.4 GHz 20dBm / 100mW WiFi (Europe)	0.5 - 1
900 MHz 36dBm / 4W FHSS (America/Canada)	15 - 30
900 MHz 30dBm / 1W FHSS (Australia, Latin America)	8 - 15
869 MHz 27dBm / 500mW FF (Europe)	5 - 10
450 MHz 40dBm / 10W (licensed frequencies)	35 - 100
433 MHz 27dBm / 500mW FF (Europe)	5 - 15
433 MHz 10dBm / 10mW FF (Europe)	1 - 2

Some "rules of thumb" are:

- Distances more than half of the rated "line-of-sight" range cannot tolerate any obstacles in the radio path - you need to establish a true line-of-sight path for reliable operation.
- Distances within 10 – 50% of rated "line-of-sight" range can tolerate some obstacles.
- Distances less than 10% can tolerate a lot of obstacles.
- Obstacles have more of a blocking effect if they are close to one end of the radio path. The overall radio signal spreads out - the dispersion pattern between two antennas looks like a rugby or American football.
- Beware of trees. Although individual trees do not pose much of an obstacle to a radio signal, a group of trees do. Radio signals do not penetrate far into forests or woods. Performance varied depending on season (no leaves or lots of leaves) and weather (wet leaves vs dry leaves present, not wet) are often rated as a 0.2dB/metre loss at 900MHz and 0.4dB/metre loss at 2.4GHz. So even small sections of wood or forest can have a significant effect on a radio signal. If the signal is raised above the trees, then the loss is greatly reduced.

Rain, fog and snow increases radio signal attenuation through air. This has more effect for higher frequencies. Marginal paths which operate reliably in fine weather will fade out during poor weather. Systems with a minimum fade margin of 10dB above receiver sensitivity or noise (whichever is stronger) have enough margin to overcome these effects.

Heavily congested radio paths found on industrial sites and factories are generally reliable because the distances are short. The radio path is made up of many separate paths, some penetrating obstacles, some reflecting from other obstacles. Most products in industrial applications use the license-free ISM bands, and distance performance varies considerably due to the differing frequency/power characteristics of the different ISM bands.

It is possible to estimate the reliability of radio paths using software packages, however the result can be misleading because of obstacles that the package is not aware of. The only accurate way of knowing if a radio path will be reliable is to test.

For short distance paths, this can be done easily and quickly. But for long distance paths, testing can be difficult and take a long time to perform.

4.3.9.13 Multiple path effects

Generally a radio signal is received from multiple paths - sometimes a direct path, plus several reflected paths. Reflected paths are received with a phase difference to the direct signal because reflected signals travel further. The total received signal is a sum of all of these signals.

In some cases the phase differences act to increase the signal, and in some cases, it decreases the signal. This effect is known as “multiple path fading”.

In mobile applications, multi-path fading results in “black spots” where signals fade out and then recover as the mobile antenna moves to another location. In fixed industrial applications, the effect is normally much less serious and is overcome by moving one antenna - generally a small change in antenna position solves the problem.

For high frequency bands, such as 2.4GHz, devices often use two antennas for diversity - if one antenna suffers from multi-path fading, the other will likely have multi-path addition.

4.3.9.14 Antennas

Antennas are carefully designed for a particular frequency to radiate and receive the radio signal. Without antennas very little of the RF energy generated by the wireless device will be radiated. Antennas can be mounted directly to the wireless unit, however are normally mounted separately and connected to the device by coaxial cable.

The coaxial cable attenuates the RF signal, so there is a signal loss in the cable. Antennas can be designed to focus the RF energy in certain directions, in the same way that a lens and parabolic mirror focuses light in a flashlight. In the designed directions, the RF energy is magnified with a specific gain (normally expressed in dB). The gain can be high, with gains of 5 to 10dB (or 7 to 10 times magnification) fairly normal.

The gain of an antenna can be used to compensate for loss in a coaxial cable, and to also increase the effective power radiated from the transmitting antenna. In the same way, antennas magnify the signal received at the receiving antenna.

So, high gain antennas have the same effect as increasing RF power at the transmitter, and improving receiver sensitivity at the receiver, both of which increase reliable distance.

Selecting the right antenna for a particular radio path, and correct installation, is important, and can make the difference between reliable operation and poor operation.

4.3.9.15 RF Noise

In most situations, the background noise level is much lower than receiver sensitivity - often 10 to 20dB lower. In this majority of cases, reliable distance is determined by receiver sensitivity. RF Power (dBm) along a radio path Distance Transmitter Min. signal level for reliable operation using a higher gain antenna increases the effective RF power at the transmitter and reduces the effective minimum signal level at the receiver.

When the noise level exceeds receiver sensitivity, then it is this which determines reliable distance. High noise level occurs normally when an antenna is mounted near other radio antennas. In these cases, the operating distance can be easily increased by moving the antenna to a better location.

4.3.10 Fixed Frequency vs Spread Spectrum

Generally, industrial wireless communications uses either fixed frequency radio channels or a spread spectrum radio band.

4.3.10.1 Fixed Frequency, Licensed vs license-free

“Fixed frequency”, as the name implies, uses a single frequency channel - radios initiate and maintain communications on the same frequency at all times. Fixed frequency channels can be license-free or licensed. A licensed channel is licensed to the operator of the wireless system by a governing body in each country, such as the Australian Telecommunications Authority (ATA). A radio license protects a channel against other users in a specified geographic area, and also specifies the RF power levels which may be used. Generally, licensed channels allow much higher power levels that license-free channels.

In some regions of the world, license-free bands comprise a number of fixed frequency channels - the user can select one of the channels in the band to use. The problem with license-free fixed frequency channels is that if more than one user in close vicinity uses the same channel, the wireless transmissions are corrupted. If a particular channel is heavily used, another channel can be selected, however this extends commissioning times.

In industrial situations, most fixed frequency bands are at a lower frequency than the spread spectrum bands. Combine the lower frequency with the ability to gain licenses for larger RF power, and fixed frequency is the obvious choice for infrastructure radio over large distances.
However, there are some administrative and technical drawbacks to consider. The delay associated with obtaining a license varies from country to country, and it is not uncommon for the granting of a license to take long periods. Furthermore, with a limited number of channels from which a license can be granted, licenses can be difficult to come by in areas of great demand.

4.3.10.2 Spread Spectrum

Spread spectrum radios use multiple channels within a continuous band. The frequency is automatically changed, or transmissions use multiple frequencies at the same time, to reduce the effects of interference.

While there are several types of spread spectrum techniques, the two most common are Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS).

Spread spectrum allows a large number of wireless systems to share the same band reliably. With a band of fixed frequency channels, the reliability of a system is dependant on no other system using the same channel at the same time. Spread spectrum provides a method of interleaving a large number of users into a fixed number of channels.

4.3.10.3 Types of Spread Spectrum

Frequency Hopping Spread Spectrum (FHSS) has the frequency of the transmitted message periodically changed (or hopped). The transmitter hops frequencies according to a pre-set sequence (or hop sequence). The receiver either stays synchronized with the transmitter hopping, or is able to detect the frequency of each transmission.

FHSS can hop rapidly, several times per message, but generally it transmits a complete message (or data packet) and then hops. Each transmitter hops to a particular hop-sequence, which it chooses automatically or is user-configured. Because the hop-sequences of different transmitters are different, the hopping of a “foreign” transmitter exhibits statistical randomness (though not truly random).

FHSS hopping sequences are pseudo-random, in that the probability of a foreign transmitter hopping to a particular channel appears to be random.

If more than one system hops onto the same channel, a “hop-clash” event, then those radio messages are corrupted. However when the transmitters hop again, the probability that both transmitters will hop to the same frequency a second time is very remote.

Direct Sequence Spread Spectrum (DSSS) differs from FHSS in that the transmitted data packet is “spread” across a wide-channel, effectively transmitting on multiple narrow channels simultaneously. When a data packet is transmitted, the data packet is modulated with a pseudorandom generated key, normally referred to as a “chipping-key”, which spreads the transmission across the wide-band channel.

The receiver decodes and recombines the message using the same chipping key to return the data packet to its original state.

The ability to withstand interference is different between the two techniques. The average power level of DSSS transmissions is much lower than FHSS - DSSS can not tolerate the same level of general background noise that FHSS can. DSSS also has more problems with “multipath fading”, a phenomena caused by the mixing of direct and out-of-phase reflected signals.

FHSS systems can transmit further because of the higher effective RF power. However DSSS can interleave a larger number of systems than FHSS, which eventually breaks down when there are too many hop-clashes.

4.3.10.4 Comparing Different Wireless Types

The following table compares performance between fixed frequency, FHSS and DSSS, assuming the same level of RF power and frequency.

Comparison	Fixed Freq	FHSS	DSSS
Reliable distance	Longer	Longer	Shorter
Data rate / Bandwidth	Low	Medium	High
Effect of Background Noise	Low	Low	High
Effect of Interference from other users	High	Low	Low

DSSS is normally used where high data rate is important. A good example is 802.11 WiFi devices. DSSS combined with the wide bandwidth of the 2.4GHz and 5GHz bands enables a very high data rate, however reliable distance is very short.

Most 900MHz products use FHSS technology as they are used for lower data rate applications where the ability to penetrate through congested industrial environments is important.

4.3.11 Common wireless standards

4.3.11.1 WiFi 802.11

The 802.11 standard specifies requirements for wireless Ethernet devices using DSSS within the 2.4GHz and 5MHz ISM bands. This standard has become popularly known as WiFi (“wireless fidelity”). WiFi devices have been in the market since the late 1990’s, and several 802.11 standards have emerged, from 802.11a to 802.11n. The most commonly used is 802.11b with data rates up to 11Mb/s.

Although WiFi is predominantly a commercial wireless standard, WiFi devices have been used extensively in industry, for high data rates over very short distances. Industrial WiFi units are available with extended temperature ranges, and additional functionality to improve operating reliability.

4.3.11.2 Bluetooth

The “Bluetooth” standard provides FHSS operation in the 2.4GHz band with data rates of 800Kb/s. Distances are very short because of reduced transmitter power. Bluetooth devices are generally used for transferring data between personal computer peripherals and mobile/cellular telephones. Although there are some Bluetooth industrial products, this standard is not commonly used in industry.

4.3.11.3 Zigbee 802.15

Zigbee is a very recent standard, designed predominantly for battery-powered wireless sensors. Zigbee devices can use either 868/900MHz or 2.4GHz ISM bands and have low transmitter powers to suit small imbedded batteries.

An important feature of this standard is a “wireless mesh”, whereby devices pass information from one unit to another.

Zigbee devices are emerging in building management and HVAC systems, and are expected to be used in industrial applications.

4.3.11.4 WiMax 802.16

WiMax is a recent wireless standard for fixed broadband data services operating in the 11 – 66 GHz band. WiMax will generally be delivered through commercial supplier networks, although private networks are also envisaged.

4.3.11.5 Cellular wireless

GSM, GPRS, CDPD, CDMA - these are different cellular standards used for transmitting data. Although they are used in industrial environments for inventory management, they are generally not used for internal plant or factory applications.

4.3.11.6 Security aspects

There is increasing awareness of the security risks of wireless automation and control products. Users question “How secure is a wireless link compared to running wire?” There is a lot of comfort in “wire” as a traditional and well understood medium for transferring data. “Wireless”, in comparison, is a relatively new technology, and is a medium without the physical bounds of wire. Wired data stops at the end of the wire - wireless data can spread through the air.

Security is an important aspect of wireless systems. Considerations need to be made including determining the security concerns with wireless systems.

Most concerns centre around two aspects:
Can a wireless link be deliberately jammed to prevent it working?
Can wireless data be stolen (industrial espionage) or can wireless data be maliciously injected (hacking)?

4.3.11.6.1 Jamming

Deliberate or non-deliberate jamming occurs when another wireless system causes enough interference to prevent your wireless system operating reliably. The degree of difficulty in doing this depends on the nature of the wireless system.

If the primary wireless system has a high fade margin (or a high signal to noise ratio), then the jamming signal needs to be very strong. For short distance applications found in industrial plants and factories, this means that the interfering antenna needs to be close and will generally be easy to locate.

Fixed frequency channels are easier to jam than spread spectrum, although some forms of spread spectrum do not provide a large advantage. Direct sequence devices can be jammed by higher power direct sequence devices using the same wide channel. Frequency hopping provides the best protection against jamming, with asynchronous hopping having better performance than synchronous hoppers.

Synchronous frequency hopping is where transmitters continually transmit a radio message for receivers to stay in hop-synchronism.

Asynchronous transmitters only transmit when there is data to be transmitted, with receivers continually cycling though the hop sequence looking for a transmission “lead-in signature”. Synchronous hoppers can be jammed by a strong fixed frequency signal which causes the receivers to lose the transmitter signal each hopping cycle. However it is difficult to jam an asynchronous hopper.

Another system factor affecting vulnerability to jamming is the duty-cycle of the system. It is difficult to create a jamming signal which is present more than 50% of the time. A system which is transmitting continuously (for example, a polling system) can be jammed much easier than a system which uses a more sophisticated event-driven protocol and transmits with a lower duty-cycle. The lower the duty-cycle of a system, the less vulnerable it is to jamming.

4.3.11.6.2 Hacking

The best protection against wireless espionage or hacking is encryption of the wireless data. Although sophisticated modulation techniques and spread spectrum provide a high level of protection, this protection disappears if the offender uses the same type of wireless device (with the same modulation or spread spectrum technology) as the target system.

Most modern wireless devices provide some degree of security encryption. There has been a lot of publicity about the weakness of the WiFi WEP encryption, which transmits the encryption keys as part of the encryption scheme. However WEP was not intended for secure industrial application, and there are many other encryption methods which provide very secure protection.

AES (Advanced Encryption Standard) is generally recognized as an “unbreakable” scheme, although this standard requires heavy computing resources and can significantly slow down the operation of wireless devices. Many proprietary encryption schemes provide the same degree of protection without the heavy computing resources - the fact that these schemes are not open to continuous scrutiny and testing gives them a higher level of inherent protection.

Security protection does not need to be 100% secure - the protection needs to make it hard enough for malicious offenders that they will look for an easier alternative to achieve their goals. Modern wireless systems if properly engineered, can provide similar or higher security protection than traditional wired systems.

4.3.12 Antenna basics

Antennas are designed and built to suit a particular frequency or frequency band. If you use an antenna designed for a different frequency, then it will only radiate a small portion of the generated RF power from the transmitter, and it will only absorb a small portion of the RF signal power for the receiver. Using the correct frequency antenna is very important.

Antennas are compared to a theoretical isotropic antenna. This antenna radiates all of the power from the transmitter in a 3-dimensional spherical pattern - very much like a point source of light without any mirrored reflectors.

An isotropic antenna is theoretical only, because in the construction of antennas, the radiation pattern becomes distorted in certain directions.

A “dipole” antenna is manufactured with an active “radiator” with a length equal to ½ the wavelength of the design frequency.

The RF power envelope radiated by a dipole is distorted by radiating more power in the horizontal plane and less in the vertical plane - that is, there is more power radiated to the sides than up and down. The effective RF power to the sides has increased, and the effective power up/down has decreased.

The term “effective radiated power” or ERP is used to measure the power radiated in specific directions. The difference between the effective radiated power and the transmitter power is called the “antenna gain”, and is normally expressed in dB.

Antenna Gain in dB = log10 (PERP / PTX)

The gain of a dipole antenna to the sides of the antenna is + 2.14 dB. This means the effective radiated power to the sides of the antenna is 2.14dB more than the power from the transmitter. The gain in the up/down direction will be negative, meaning that the effective radiated power in these directions is less than the power from the transmitter.

A dipole mounted vertically transmits an RF wave in the vertical plane - this is called vertically polarized. If the antenna is mounted horizontally, then the RF wave will have horizontal polarity.
The radiation pattern can be distorted further by connecting multiple dipole elements together. These antennas, known as “collinears”, have a higher gain to the sides and a more negative gain up/down.

Collinear antennas are normally manufactured with gains of 5dB, 8dB or 10dB compared to the transmitter power. When antenna gains are expressed as a comparison to the transmitter power, it is called “isotropic gain”, or gain compared to an isotropic antenna. Isotropic gains are expressed as “dBi”.

Another common way to express gain is “as compared to a dipole” - these gains are expressed as “dBd”. The difference between dBd and dBi is the intrinsic gain of a dipole, 2.14dB (normally rounded to 2dB).

dBd = dBi - 2

Be careful with antenna gain specifications - manufacturers do not always specify if they are using dBi or dBd.

Dipole and collinear antennas are called omni-directional as they transmit equally is all directions in the horizontal plane. Normally omni-directional antennas are used for intra-plant applications, where the radio path lies completely within an industrial site or factory. The radio path is often made up of strong reflected signals over relatively short distances and the direction of incoming signals is not always obvious.

Directional antennas distort the radiation patterns further and have higher gains in a “forward” direction. These antennas are often used for longer line-of-sight radio paths found in intra-plant applications.

A Yagi antenna has an active dipole element with “reflector” elements which act to focus power in a forward direction.

Yagis are normally available from 2-element up to 16-element Yagis. The more reflector elements added, the higher gain in the forward direction and the lower gain to the sides and rear. Also, as more elements are added, the directional angle becomes smaller as the gain is more tightly focussed.

Yagis are mounted with the central beam horizontal and the orthogonal elements either vertical or horizontal. If the elements are vertical, then the antenna is transmitting with vertical polarity; if the elements are horizontal, the polarity is horizontal.

Antennas in the same system should have the same polarity. For higher frequency Yagi antennas, it is physically possible to add side reflectors to increase the gain further. For 2.4GHz devices, parabolic reflectors around the dipole element yield extremely high gains and extremely narrow transmission beams.

The simplest antenna commonly used is a "¼ wave whip" antenna. These antennas are simply a ¼ wavelength conductor, normally mounted directly to the wireless device. They are "ground-dependant" antennas in that they need an external reference plane to efficiently radiate power. These antennas are nominally a unity gain antenna, however gain depends on the installation and often the installed gain is approx –2dBi.

Antenna Type	Omni / Directional	Gain (dBi)
¼-wave Whip	Omni	-3 to 0
Dipole	Omni	2
Collinear	Omni	5, 8 or 10
Yagi - 2 to 16 elements	Directional	4 to 16
2.4GHz Parabolic	Directional	16 to 30

4.3.13 Coaxial cables and connectors

Coaxial cables have an inner conductor insulated from a surrounding "screen" or "shroud" conductor - the screen is "grounded" in operation to reduce external interference coupling into the inner conductor. The inner conductor carries the radio signal.

Industrial wireless devices are designed to operate with a 50 ohm load - that is, the coaxial cable and antennas are designed to have a 50 ohm impedance to the radio, at RF frequencies.

At the high frequencies used in wireless, all insulation appears capacitive, and there is loss of RF signal between the inner conductor and the screen. The quality of the insulation, the frequency of the RF signal and the length of the cable dictates the amount of loss.

Generally, the smaller the outer diameter of the cable, the higher the loss; and loss increases as frequency increases. Cable loss is normally measured in dB per distance - for example, 3 dB per 10 metres, or 10db per 100 feet.

The following table shows the losses of typical types of coaxial cables:

Coaxial cable	**Outer diameter (mm)**	**Loss (dB per 30 m)**		
		450 MHz	**900 MHz**	**2.4 GHz**
RG58C/U	5	13.5	18.2	
RG58 Cellfoil	5	6.9	9.0	16.5
RG213	10	5.0	7.4	14.5
LDF4-50	16	1.6	2.2	3.7

Cables need special coaxial connectors fitted. Generally connectors have a loss of 0.1 to 0.2 dB per connector.

4.3.14 The effect of gain and loss

Using a high gain antenna has the following effects at the transmitter:

- Increases the effective transmission power in certain directions, and reduces the power in others.
- Gain compensates for loss in coaxial cable.
- Makes the antenna more directional at the transmitter - a good effect for reducing unwanted RF radiation in non-required directions.

RF power generated by a transmitter is initially reduced by the coaxial cable, and then increased by the antenna gain.

Transmit power = T dBm

Coaxial loss = C dB

Antenna gain = G dB

Effective radiated power (ERP) = T – C + G dBm

Note: Care must be taken that the final effective radiated power is less than the regulated amount. In some countries, there are limits on the gain of antennas, as well as the final ERP.

At the receiver, high gain antennas have the following effects:
Increases the received signal from certain directions, and reduces the signal from others. Gain will also increase the received external noise. If the increased noise exceeds the sensitivity of the receiver, then the gain improvement has been negated - that is, in noisy environments, antenna gain can have little effect at the receiver, but in non-noisy environments, it can.
Gain compensates for loss in coaxial cable.

Making the antenna more directional reduces unwanted RF noise in non-required directions, but has the negative effect if you are relying on reflected signals from various directions.

4.3.15 Selecting antennas / coaxial cable

Normally antennas and cable types are selected following a radio test for a proposed installation. The test will be done with specific antennas and cables and the results of the test will indicate whether higher gain antennas or lower-loss cables are required.

For example :
If a test yields a fade margin of 5dB, then you know that by inserting an extra 5dB antenna gain, or removing 5dB coaxial loss, will increase the fade margin to 10dB. The gain can be inserted at either the transmitter or receiver end, or both.

RF signal = R dBm

Coaxial loss = C dB

Antenna gain = G dB

Effective received signal = R – C + G dBm

If a test shows that net antenna/cable gain of 6 dB is required for reliable operation on a line-of-sight path, and a cable length of 10 metres is required at both ends of the link to give line-of-sight, then you can select which cable to use, and then select the antennas to give a net gain of 6dB.

4.3.16 Antenna mounting

If an antenna is not correctly installed, it will not provide optimum performance, reducing RF power radiation.

4.3.16.1 Whip antennas

Whip antennas (¼ wavelength) are normally connected directly to the wireless device. These antennas are “ground-dependant”; that is, they need to be installed onto a metallic plane to “ground” the antenna. Without a ground plane, the antenna will have reduced radiation. For 900MHz and higher frequencies, the required ground plane is small and the wireless unit itself is normally sufficient.

If the whip antenna is connected via a coaxial connector (as opposed to a fixed connection), some weatherproofing technique is required if the installation is outside. The wireless unit and antenna can be installed inside a weatherproof enclosure.

If the enclosure is metallic, then most of the RF energy will be absorbed by the enclosure, although this is still an acceptable installation if the radio path is short. A better installation is to use a non-metallic enclosure which will have little blocking effect on the RF signal. Note: make sure the mounting plate in the enclosure is also non-metallic.

This mounting method is a good installation for short distance applications - the antenna is not vulnerable to mechanical damage as it does not protrude outside the enclosure.

4.3.16.2 Dipole and collinear antennas

These antennas are connected to the wireless unit via a length of coaxial cable. If the cable is larger than 6mm diameter (¼ inch), do not connect the cable directly to the wireless unit. Thick cables have large bending radii, and the side-ways force on the unit connector can cause a poor connection. Use a short “tail” of RG58 between the thick cable and the wireless unit.

The polarity of these antennas is the same as the main axis, and they are normally installed vertically. They can be mounted horizontally (horizontal polarity), however the antenna at the other end of the wireless link would need to be mounted perfectly parallel for optimum performance. This is very difficult to achieve over distance. If the antenna is mounted vertically, it is only necessary to mount the other antennas vertically for optimum “coupling” - this is easy to achieve.

Dipole and collinear antennas provide best performance when installed with at least 1 to 2 “wavelengths” clearance of walls or steelwork. The wavelength is based on the frequency:

Wavelength in metres = 300 / frequency in MHz

Hence, antennas at 450MHz need a clearance approx 1 metre, 900MHz requires 0.5 metre and 2.4GHz 15 cm.

Antennas can be mounted with less clearance, however the radiation from the antenna will be reduced. If the radio path is short, this won’t matter.

It is important that the antenna mounting bracket to well connected to “earth” or “ground” for good lightning surge protection.

4.3.16.3 Yagi antennas

Yagi antennas are directional along the central beam of the antenna. The folded element is towards the back of the antenna, and the antenna should be “pointed” in the direction of the transmission.

Yagis should also be mounted with at least 1 to 2 wavelengths of clearance from other objects. The polarity of the antenna is the same as the direction of the orthogonal elements. For example, if the elements are vertical, then the Yagi will transmit with vertical polarity.

In networks spread over wide areas, it is common for a central unit to have a omni-directional antenna and the remote units to have Yagi antennas. In this case, as the omni-directional antenna will be mounted with vertical polarity, then the Yagi’s need to also have vertical polarity.
Care needs to be taken to ensure that the Yagi is aligned correctly to achieve optimum performance.

Two Yagis can be used for a point-to-point link. In this case, they can be mounted with the elements horizontally to give horizontal polarity. There is a large degree of RF isolation between horizontal and vertical polarity (approx -30dB), so this installation method is a good idea if there is a large amount of interference from another system close by transmitting vertical polarity

Mounting near other antennas

Avoid mounting an antenna near any other antenna. Even if the other antenna is transmitting on a different radio band, the high RF energy of the transmission from a close antenna can “deafen” a receiver. This is a common cause of problems with wireless systems.

Because antennas are designed to transmit parallel to the ground rather than up or down, vertical separation between antennas is a lot more effective than horizontal separation. If mounting near another antenna cannot be avoided, then mounting it beneath or above the other antenna is better than mounting it beside. Using different polarity to the other antenna (if possible) will also help to isolate the RF coupling.

4.3.16.4 Coaxial cable

If a coaxial cable connects to the antenna via connectors, it is very important to weatherproof the connection using sealing tape. Moisture ingress into a coaxial cable connection is the most common cause of problems with antenna installations.

A three layer sealing process is recommended - an initial layer of adhesive PVC tape, followed by a second layer of self-vulcanising weatherproofing tape (such as "3M 23 tape"), with a final layer of adhesive PVC tape.

Allowing a "loop" of cable before the connection is also a good idea. The loop takes any installation strain off of the connection, and also provides spare cable length in case of moisture ingress into the connectors later; in which case the original connectors need to be removed, the cable cut back and new connectors fitted.

Avoid installing coaxial cables together in long parallel paths. Leakage from one cable to another has a similar effect as mounting an antenna near another antenna.

4.3.16.5 Lightning surge protection

Power surges (also known as "voltage surges") can enter wireless equipment several ways - via the antenna connection, via the power supply, via connections to equipment connected to the device, and even via the "ground" connection.

Surges are electrical energy following a path to "ground" or "earth". The best way to protect the wireless unit is to remove or minimize the amount of energy entering the unit. This is achieved by "draining" the surge energy to ground via an alternate path.

Wireless devices need to have a solid connection to a ground point, normally a earth-electrode, or several earth-electrodes if the soil has poor conductivity.

A "solid connection" means a large capacity conductor, not a small wire. All other devices connected to the wireless unit need to be grounded to the same ground point. There can be significant resistance between different ground points, leading to large voltage differences during surge conditions. Just as many wireless units are damaged by earth potentials as direct surge voltage.

It is very difficult (put not impossible) to protect against direct lightning strikes, but fortunately, the probability of a direct strike at any one location is very small, even in high lightning activity areas. Unfortunately, surges in power lines can occur from lightning strikes up to 5 km away, and electromagnetic energy in the air from lightning activity long distances away can induce high voltage surges.

4.3.16.6 Antenna connection

Electromagnetic energy in the air will be drained to ground via any and every earth path. An earth path exists via an antenna and the wireless unit. To protect against damage, this earth-path current must be kept as small as possible. This is achieved by providing better alternate earth paths.

Where an external antenna is used, it is important to ground the antenna to the same ground point as the wireless unit. Antennas are normally mounted to a metal bracket - connecting this bracket to ground is satisfactory. Surge energy induced in antennas will be drained via the grounding connection to the antenna, via the outside shield of the coaxial cable to the ground connection on the wireless unit, and via the internal conductor of the coaxial cable via the radio electronics.

It is the third earth path which causes damage - if the other two paths provide a better earth path, then damage can be avoided.

When an antenna is located outside of a building and outside of an industrial plant environment, external coaxial surge diverters are recommended to further minimize the effect of surge current in the inner conductor of the coaxial cable.

Coaxial surge diverters have a gas-discharge element which breaks down in the presence of high surge voltage and diverts any current directly to a ground connection. A surge diverter is not normally required when the antenna is within a plant or factory environment, as the plant steelwork provides multiple parallel ground paths and good earthing will provide adequate protection without a surge diverter.

4.3.16.7 Cable protection

Cable protection is required to prevent animals and elements from deteriorating or damaging cables. Polyethylene pipe is the most readily available cable protection in most circumstances, but a more sound method of cable protection is electrical conduit or where extreme conditions are likely to be encountered, a product called anaconda may be used. Anaconda is a reinforced, galvanised steel band with spiral wound, latched profile, a continuous copper conductor and extruded plastic sheath. See figure below

4.3.16.8 Connections to other equipment

Surges can enter the wireless unit from connected devices, via I/O, serial or Ethernet connections. Other data devices connected to the wireless unit should be well grounded to the same ground point as the wireless unit.

Special care needs to be taken where the connected data device is remote from the wireless unit requiring a long data cable. As the data device and the wireless unit cannot be connected to the same ground point, different earth potentials can exist during surge conditions.
There is also the possibility of surge voltages being induced on long lengths of wire from nearby power cables. Surge diverters can be fitted to the data cable to protect against surges entering the wireless unit.

4.4 Remote management technologies currently used or researched in the Australian grazing industry

Current technologies and their adoption by the Queensland grazing industry occurred in the following eras (McKeon et al 2004):

- Electric bore pumps in 1940’s
- CB/UHF radios in the late 1970’s
- Electric fences in the mid 1970’s
- Computers in the late 1980’s

- Liveweight scales in the 1980’s
- Solar pumps in the 1980’s
- Satellite and mobile phones in the 1990’s

Potential benefits of remote management technologies
- Communications
- Workplace health and safety
- Efficient acquisition of management information
- Reduction in production costs e.g.: labour, vehicles, time.

4.4.1 Communications

CB and UHF radio systems have long been a reliable method of communication around the property and surrounding areas. Apart form the safety aspect of having neighbours on hand, privacy can be an issue.

At present many producers use the mobile telephone network as their main on-farm communication system. Late model mobile phones include email options and current data management systems developed for remote management include SMS or email options. Some remote management equipment has the ability to send your mobile or computer an email for alarm notification.

4.4.1.1 Ultra High Frequency (UHF) radio

UHF radio has been used extensively on properties around Australia for over twenty years. While the use of the 433MHz frequency UHF band has a number of significant advantages for the use of data transfer, there are also a number of disadvantages.

Because UHF has been extensively used for voice communications on properties around Australia for two decades, most properties utilise the band as their primary source of on-farm communication medium. This has led to the installation of repeater stations on extensive properties for efficiency, practicality and occupational health and safety (OH&S) purposes.

But while widely accepted and relatively well understood, there are disadvantages to utilising UHF radio technology for the transfer of data on-farm;
Firstly, the bandwidth of data transfer is relatively low; While bandwidth issues may be partially overcome by employing the use of Selcall as a transfer language, currently adopted UHF transfer methods in their present form are incapable of delivering required bandwidth for high quality live images and streaming video.

From Wikipedia: Selcall (selective calling) is a type of squelch protocol used in radio communications systems, in which transmissions are preceded by a brief burst of sequential audio tones. Receivers that are set to respond to the transmitted tone sequence will open their squelch, while others will remain muted. Most Selcall systems utilise a sequence of five tones, each of which can have any of ten frequencies, plus two extra frequencies for 'group' and 'repeat'. This provides almost 100,000 different sequences, plus a broadcast mode allowing multiple receivers to be addressed.

4.4.1.2 Satellite

Satellite communications are also becoming an affordable option for example Globalstar has enhanced its satellite data offering, launching a new packet data tariff that brings the cost of data transmission for short data bursts down to as little as 4c for the 1st ten seconds. This new packet data service allows telemetry applications to send a short burst of data (of less than 10 seconds and approximately 4 k/bits in size) at the 4c data rate.

Globalstar's Data everywhere® Duplex service is ideal for Remote Monitoring and SCADA applications or any other application where two-way, real time data services or supervisory control is required.

Satellite Data plans provide affordable, cost effective data rates for real-time, bi-directional data communication on the GSP1620 modems. And as of August 2006 Globalstar data plans now have all round better value with cheap packet data call rates, no flagfalls and a huge reduction in the price of “short burst” packet data calls of 10 seconds or less.

All satellite data calls are billed in 10 or 30 second increments as indicated above. All prices are GST inclusive. $200 connection fee applies to all plans. Connection fee is waived when a new modem is purchased together with a Data 30 plan or greater.

Data Plan	Monthly Access Fee	Included Calls	Asynchronous Data Calls (*Outgoing and Incoming*)	Packet Data	
Data 30[7]	$30	$10	60c per 30 secs	4c per 10 secs for the first 10 seconds	16.67c per 10 secs after the first 10 seconds
Data 60[8]	$60	$40	50c per 30 secs	4c per 10 secs for the first 10 seconds	13.33c per 10 secs after the first 10 seconds

4.4.1.3 Data transfer alternatives

Alternatives may also include post-processed images – i.e. data collected by a remote vehicle, requiring an evaluation each application according to time relevance. Reliance on numbers only. Development of higher bandwidth data transmission capable of very long range transmissions

4.4.1.4 Workplace health and safety

Reducing time employees working alone in remote locations minimises potential for accidents, snake bite etc. Use of remote monitoring can limit or eliminate the use of helicopters/gyrocopters also reducing risk of injury from accidents.

4.4.1.5 Efficient acquisition of management information

Farm management decisions are based on information and knowledge based on experience or formal training. The acquisition of data through remote sensing is the most efficient method of collecting information. Having trust in remotely sensed data will be a major stumbling block in the adoption of RMT’s and will be overcome as confidence increases and the benefits are realised. A 2003 survey showed that 86% of producers have access to the internet and 67% have a broadband connection with 75% using meteorological sites for farm management decisions.

4.4.2 Packaged options

Remote management technologies currently being used by the Australian grazing industry include:

4.4.2.1 Observant

Observant utilises a 5W UHF radio (450 – 490MHz) for transmission distances exceeding 25 km line-of-sight. Each C1 unit can act as a repeater allowing for unlimited range.

Each C1 unit has 4 digital inputs which can be used to monitor a particular state (e.g. On or off) or count pulses from a pluviometer or frequencies up to 1kHz eg. engine revs. It also has 4 digital outputs that can supply up to 1.0 A continuous for operating solenoid valves or relays (e.g. For switching pumps or irrigation systems on & off).

The C1 also has RS232 and RS485 serial ports and communicate via the MODBUS protocol. RS485 is a two wire serial interface which allows up to 32 devices to be connected over a maximum distance of 1200 metres. As MODBUS is an industrial data protocol a number of sensors are commercially available and Zigbee RF mesh network systems will become available using this protocol. What this means in the future for Observant is that the system can be flexible with wired and wireless sensors.

Currently the following devices are supported:

- L1 Observant water level sensor
- M1 Observant motor controller
- Mono SMC Solar Pump
- Pakton electric fence monitor
- Axis digital camera
- PFSA Nutridose water medicator
- Rain gauge
- Flow meter
- GPS vehicle tracking

As the software can be modified through an internet remote access gateway the flexibility and adaptability of each system can evolve as new technologies emerge.

The system is configured as a stand alone unit with solar panel, battery and antenna on a post. The aim is to minimise installation time and cost by providing cabling and sensors which are virtually plug and play and requiring minimal technical knowledge to install. This may be a little way off as knowledge of radio signal propagation and onsite testing is required to ensure reliable telemetry between remote sites.

Additional considerations in the development process include the requirement to address occupational health and safety requirements with remotely operated machinery, the simplification of customising software, development of a portable terminal to be used in the field by the boreman, and expertise capacity to facilitate the design and maintenance of such systems on a commercial scale.

4.4.2.2 GME electrophone

The GME Telemetry System is built around several major components:

- The TX3600T UHF telemetry transceiver
- A CIU Control Interface Unit and
- The 'Super-Vise' control software program.

A typical system comprises a Base Station (fixed or mobile) and a number of outstations with TX3600T transceivers providing the radio link. The system is controlled at the Base Station either by the 'Super-Vise' software installed on a PC or with an RCU3600 remote control display head. Up to 99 outstations can be controlled and monitored from a Base Station.

The CIU (Control Interface Unit) provides a protected interface between the outstation transceiver's ports and any external sensors or remote control functions. An outstation's CIU can action up to 8 output commands and accept up to 8 ON/OFF inputs, of which 4 may be analogue.

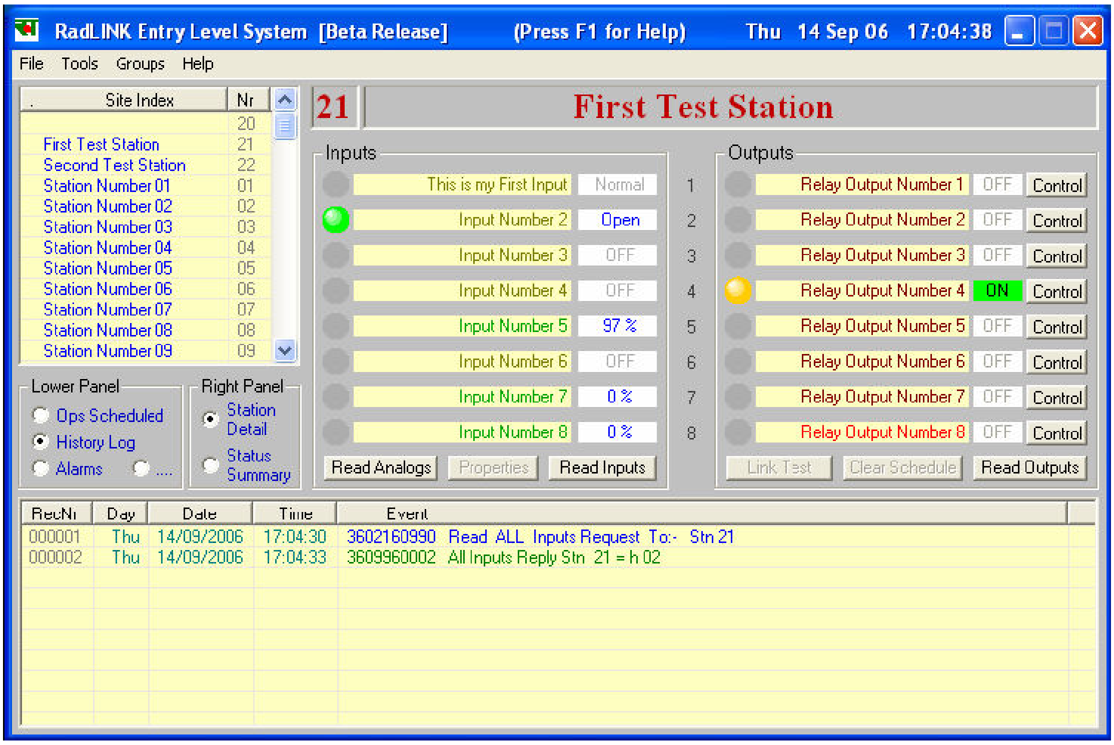
The Super-Vise software can also confirm the status of an outstation's TX3600T radio by interrogating sensors built-in to the transceiver. The following parameters can be measured:

- Received signal level.
- Internal temperature of the transceiver.
- Transmitter output power.
- Site battery voltage.

GME's Telemetry System operates in the popular 450 - 520 MHz UHF band. This means that if the path between the Base Station and an outstation can achieve a reliable signal level, ranges of up to 100 km can be attained. However, if the path is blocked by the topography of the land or to a lesser extent by trees, the range can be reduced to several kilometres.

Over long distances or difficult terrain, the TX3600T's full 5 Watt output power will maintain a reliable radio link. For shorter distances a selectable 1 Watt output power option is available.
The following examples are typical applications for the GME Telemetry System:

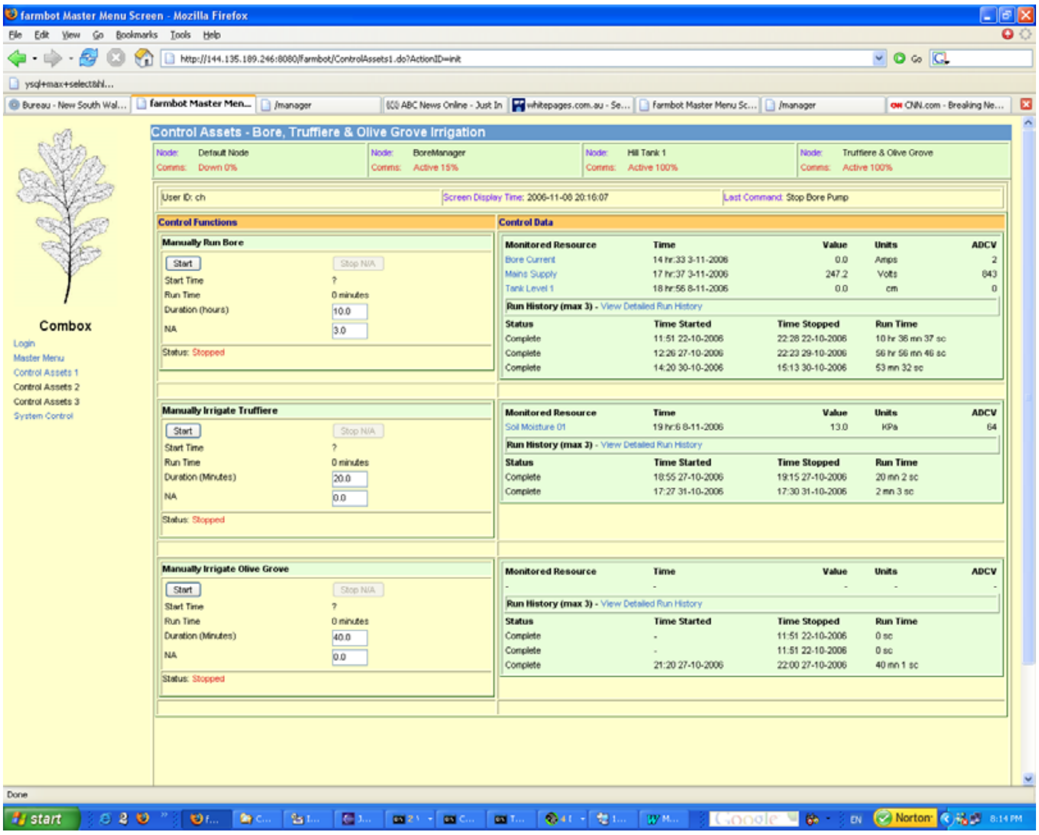
- Switching Pumps or Irrigation systems ON & OFF.
- Starting Generators and monitoring Temperatures, Pressures and Voltages etc.
- Monitoring Dam and Tank levels.
- Real time monitoring of Security devices with an instant alarm if a break-in occurs.
- Monitoring and controlling the operation of Electric Fences.
- Remote reading of Instruments such as Weather and Water Flow Gauges etc.
- Monitoring the status of Gates at remote locations.

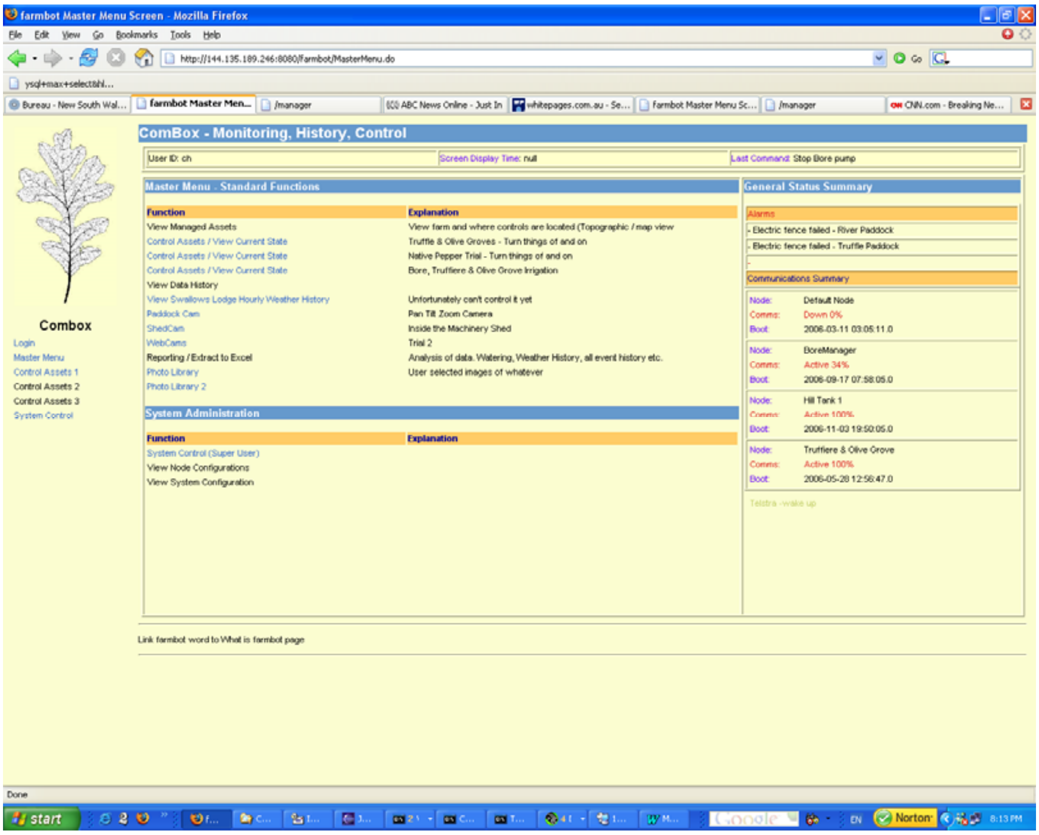


The 'Super-Vise' control software program shown in the above figure is the latest version from RadLINK to support the GME Electrophone telemetry system. It provides a visual indication of all inputs and outputs for each station on one screen and allows each input and output to be allocated real names to represent the physical parameter being monitored or controlled. This software also includes the ability for automatic scheduling of tasks e.g.: starting and stoping pumps and records a historical log of events which would assist with maintenance scheduling and reporting.

4.4.2.3 Innovative farming

Innovative farming is a primarily a software development company with an interest in the development of remote monitoring technology. A prototype package has been developed and is currently being trailed on the developers' property. Data is collected using standard off-the-shelf sensors, transmitted via the GSM network and displayed on 'farmbot' software as below.


farmbot Master Menu Screen - Mozilla Firefox
Control Assets - Bore, Truffiere & Olive Grove Irrigation
Combox
Control Functions
Control Data
Manually Run Bore
Manually Irrigate Truffiere
Manually Irrigate Olive Grove
Monitored Resource
Run History (max 3) - View Detailed Run History


farmbot Master Menu Screen - Mozilla Firefox
ComBox - Monitoring, History, Control
Combox
Master Menu - Standard Functions
General Status Summary
System Administration
Communications Summary

4.5 Key manufacturers and installers of remote management technology equipment

4.5.1 Semfios

47 Boyd Street
Corrigin WA 6375
08 9063 2068

Western Australian based company Semfios offer a number of remote monitoring packages including a UHF ‘Vocacell’ system which transmits voice recorded water level sensor readings at specified time intervals. At a cost of around $420, this is a low cost solution which may suit some producers.

Semfios also produce a WiFi style system operating 2.4GHz costing $1500 for each end plus installation. This system reportedly has capacity to deliver streaming video images, water level data and switching capability. According to Semfios, only one of these systems has been installed to date in Corrigin WA.

Semfios field unit

4.5.2 Capricorn Communications

320 Richardson Rd.
North Rockhampton, 4701
07 4926 1172

Rockhampton based Capricorn Communications specialise in communications and data transfer with almost 30 years of experience. They supply Tait, Tigg, Nexion, Omnitronics, Trio and Zetron remote monitoring and telemetry equipment which is mostly geared toward industrial applications.

4.5.3 BIGMate Monitoring

27-52 LenShield St,
Mackay 4740 QLD
1300 138 963

BIGmate specialises in providing monitoring services and management information to owners of high value assets. With a background in mining, BIGmate specialise in sourcing and developing components to tailor-make a system to suit the needs of customers.

The majority of business BIGmate has been involved in is within the trucking industry relying on GPS technology and mobile telephony networks for positional data and data transfer respectively.

4.5.4 Stockman Electronics

3 Young St,
Burra,
South Australia 5417
08 8892 2708
Primary Contact: Tim Stockman

As a sole operator, Tim Stockman is a central figure in remote management technology systems and installation in Australia. Being a distributor of both of the major players in this market, that is Observant and GME Electrophone, Tim has an understanding of the strengths and weaknesses of both systems and has assisted both of these organisations to develop their product.

Having installed dozens of monitoring sites and with 13 years experience, Tim believes there is no ‘one-size-fits-all’ solution but system simplicity is fundamental to uptake. The use of either system requires a needs analysis approach where all of the operating environment variables and system requirements are taken into account.

Installation integrity is paramount to reliability according to Tim, he has developed float switches which are less prone to damage and investigated numerous methods of protecting cables, using polyethylene pipe, electrical conduit and a product called ‘anaconda’ (see Treotham Trading). Tim has also developed and installed robust conductivity style flow sensors which adapt to the GME system.

4.5.5 Observant

Lvl 2 106 Victoria St,
Fitzroy,
Vic 3065
03 8415 0288
Primary Contacts: Simon Holmes a Court, Matthew Pryor

Observant are a major player in the development of remote management technologies. With around a dozen full-time staff, Observant have worked closely with industry to tailor a suite of products fitting the requirements of Australian beef industry.

With 7 resellers nationally and over 50 units in operation over 8 properties, Observant have grown quickly over the last four years. Observant aim to provide high levels of precision to support management decisions and use an open architecture to allow integration with other systems.

Capable of adapting to most requirements, the observant system generates data at a higher level of precision than is available with any other package, is soundly engineered and well constructed. More details of the Observant package can be found in section 4.4.2.1 relating to the technical specifications of the system.

As a relatively small operation, Observant have demonstrated a willingness and ability to react to the requirements of the industry. With a philosophy of creating industry partnerships, Observant have worked with manufacturers of water medication systems, weighing systems and pumping equipment manufacturers.

Because each site may utilise a range of components, Observant must tailor their software for each installation. While this adds a level of complexity, it also allows Observant system engineers to understand the installation, requirements and assists in problem-solving each installation.

A component based approach to system design is also verging on a 'plug-and-play' package where component failure can be easily addressed by interchanging components as required for servicing or repair. All components utilise standard cables and connections for this purpose.

Observant installation at Pigeon Hole Station

4.5.6 Rubicon

8 Telford Drive
Shepparton,
Vic 3632
03 9832 3000

Rubicon Systems Australia Pty Ltd provides specialist operational technology to the water and broader utility markets. Rubicon solutions integrate operational data through open and standard IT platforms to fully exploit the capabilities of enterprise wide computing environments. Rubicon technology provides organisations with real time tools to improve business efficiencies, better manage resources, and enhance customer service programs. Rubicon is focused on delivering end-to-end solutions to resource management organisations and the water market. Rubicon expertise includes:

Resource Management Solutions including; Open and standard IT platforms, Demand Management, Planning/scheduling systems, Data Warehouse systems, IVR and WEB based modules, Network modelling, Event management systems and Total Channel Control Systems

Controls including; Advanced SCADA systems, Remote monitoring, NFM and SNMP networks, Motorola MOSCAD specialists, Network/systems integration, Open standard platforms and Legacy system integration

Water Technology including; Gates and actuation, Flume-Gate manufacture, Flow measurement, Engineering design, Field Installation, Instrumentation and R&D programs

Of most relevance, Rubicon supply remote management and telemetry equipment to the horticulture industry. Several installations were inspected in the Shepparton area. These horticultural applications used RF and GSM mobile telephony for data transfer. Cable protection and installation integrity was observed not to be a high priority.

4.5.7 GME Electrophone

Sydney NSW
02 9844 6666

With around 225 employees, GME Electrophone is a relatively large organisation and is a well respected name in the voice communications industry.

Being familiar with the development of communication systems used in transport, agriculture, aviation and mining, GME electrophone have been providing telemetry systems for over ten years.

GME and Observant are the two major players in the remote monitoring and control business in rural Australia. The GME system being more simple than the Observant system, but not as capable of sending large volumes of data due to the reliable, but low precision data collection and transmission formats.

The GME system, which uses 'Selcall' (see section 4.4.1.1) is capable of higher transmission distances (20-25km) than voice channels (and because of the use of 9 tonal ranges effectively delivers 9-times the bandwidth. The other benefit of the GME system is its integration with existing UHF radio repeater networks on expansive properties, this permits very large transmission distances particularly if these repeaters deliver property-wide coverage. (see Quinyambie case study section 4.2.4)

The simplicity of GME systems is likely to suit many operators who do not require precision. With updated software to be released in 2007, additional ease of use is expected. But at equivalent prices to the more precise Observant system, GME may need to review pricing to maintain competitiveness.

Components of the GME Electrophone system

4.5.8 Innovative Farming (combox)

Level 25, Northpoint, 100 Miller Street,
North Sydney 2060 NSW
02 9459 3300

Innovative farming is the agricultural arm of a software development company called Object Oriented based in Sydney. But with directors having agricultural interests 250km away at Muloon, a system was developed and is being trialled to address farm security issues.

Prototypes are being used to integrate the system with tag readers at water points, tank water levels and weather monitoring, the Combox solution is a mains-powered solution on a not-so-isolated property.

4.5.9 Conlab (T-Box)

Contact: Motti Gill
Level 1, Suite 13, 1020 Doncaster Road,
Doncaster East Vic 3109 VIC
03 9842 7711

Conlab Pty Ltd, an Australian company established in 1988 specialising in the supply and support of hardware and software products including Wireless, Telemetry and SCADA systems, that individually, or integrated, meet our customers systems requirements.

Past installations include irrigation control systems for the horticulture industry and water quality monitoring over the GSM network for the oyster industry.

Conlab also supply WiFi Ethernet hardware components including a WiFi link valued at around $1100 which when coupled with a $500 IP camera and a power supply could provide low cost real time images over distances up to 10km.

4.5.10 Telstra Countrywide

2/28 Honeysuckle Drive
NEWCASTLE 2300 NSW
Phone: (02) 49 858938

Telstra are well remembered for their 2000 advertising campaign depicting sheep passing through a remotely operated gate by a farmer on a computer screen many kilometres away. The advertisement went on to show the same farmer watching live footage of his sheep drinking from a water trough.

The advertisement raised a lot of interest amongst livestock producers. but according to industry experts was misleading - because at the time, Telstra did not have a system installed that actually did these things.

Telstra today have a number of demonstration sites which are using off-the-shelf technologies to demonstrate the capability of their mobile telephony system. Depicting real-time video, remote control of pumps and system monitoring, the demonstrations are as impressive as the 2000 advertisement. It should be remembered that as with other systems, a comparable investment in hardware is required, as most of the components are similar. The major difference to other package systems is that there are ongoing costs associated with the use of the Telstra network to convey data.

And while mobile telephone coverage is at best limited for the majority of northern beef producers, some who have coverage utilise the mobile telephony service for SMS based dial-up weather monitoring services.

The introduction of the NextG network to replace the CDMA network will deliver higher bandwidth solutions to producers who have adequate coverage. This could conceivably provide data, still and video images however the cost is likely to be relatively high and would still require packages to be sourced or developed to utilise this network as they are not available from Telstra.

4.5.11 Maxon

36A Gibson Avenue Padstow
NSW 2211 AUSTRALIA
02 97072000

Maxon supplies a product of interest for Northern beef producers with mobile telephone coverage: the ‘ChatterBox’ utilises a CDMA modem Telstra’s CDMA network to provide two-way communications access with your remote assets or equipment. The chatterbox permits connection of electronic equipment for monitoring or switching.

4.5.12 Sony Australia

Head Office
33-39 Talavera Rd
North Ryde NSW 2113
02 9887 6666

Sony Australia has expertise in image capture, consumer and professional closed circuit television and has advertised remote monitoring solutions in publications including ‘Outback Magazine’. But investigation of these solutions indicates reliance on mobile telephony networks for data transmission. As previously discussed, mobile telephony coverage is not accessible for the majority of northern beef producers and as a result the Sony solution is not considered a serious player in the remote monitoring

4.5.13 TREOTHAM Trading Pty. Ltd.

P.O. Box 907
Brookvale NSW 2100
02 99071788

Treotham trading are listed importers of ‘Anaconda’ cable protection piping produced by Helukabel of Germany. Primarily supplying the automotive industry, other products include cable glands and cable supplies.

Anaconda cable protection

4.5.14 V.E. Biosciences Pty Ltd

07 3374 3353

V.E. Biosciences have developed a remote method of animal health application using a compressed CO2 application system in a method not dissimilar to recreational paint-ball guns. The application method permits animals to be treated in-situ without the need and expense of mustering. This technology relies on animal gatherings at one point (for example a watering point), a memory of which animals have been treated and the assumption that all animals will congregate to the same point.

During research, the treatment system has been used in conjunction with an optimised antiparasitic programme only on smaller experimental herds farmed on a relatively extensive basis.

4.5.15 Pacific Controls Pty Ltd

Systems Application Sales Engineer
07 3907 9200
Primary Contact: Peter Lee

Pacific controls have been developing remote monitoring and control systems for industry and infrastructure and have well developed hardware and software packages that have been used in water infrastructure control. To date Pacific Controls have not applied a system to a remote beef operation but have indicated their interest in doing so.

4.5.16 Call Direct Cellular Services

Suite 145 National Innovation Centre
Australian Technology Park
Eveleigh 1430 NSW
02 9209 4196

Call Direct Cellular Services designs, manufactures and distributes a range of modems and remote monitoring products for use with GSM, UMTS and CDMA mobile phone networks.

4.5.17 V-TOL Aerospace

18/1645 Ipswich Rd
Rocklea Qld
07 32752811
Primary Contact: Peter Hill

V-TOL Aerospace Pty Limited is a Brisbane based firm specialising in advanced robotic aircraft and communications and information technologies. It has recently teamed up with US military firm Cyber Defence Systems (CDS) and together are promoting the first UAV system designed for civil and commercial markets.

4.5.18 UAV Vision

0412 464 684
Primary Contact: Grant Hughes

UAV helicopters with cameras mounted; used for surveillance, security and inspection.

UAV Vision CamClone Turbine Rotorcraft

4.5.19 Boeing Australia

07 3306 6399
Primary Contact: Karinne Logan

Recently awarded a contract to provide UAV reconnaissance and surveillance services to the Australian Army using the ScanEagle autonomous unmanned aerial vehicle.

4.5.20 Aerosonde

Unit 1
585 Blackburn Road
Notting Hill, Victoria
03 9562 2622

Currently providing UAV aerial services for ecologica / biological, military and metrological purposes.

4.5.21 HELImetrex

Unit 2 / 8 McILwraith Street,
Everton Park, QLD 4053

Services include UAV aerial photography and video, survey and planning, monitoring and inspection.

4.5.22 Farm & Business Communications

49 Stephens Street,
Booleroo Centre
South Australia 5482
08 86672268

Farm & Business Communications specially manufacture systems for the remote starting of Diesel Pumps and the Monitoring of Tank levels via Radio.

4.5.23 Laura Water Systems (formerly Blackmore Water Systems)

20 Herbert St Laura 5480
08 8663 2422

Currently installing A GME system for the Desert Channels Queensland demonstration site.

4.5.24 Manufacturers of scales and panel readers:

AgInfoLink – 02 6732 2298

Animal Life ID – 07 3823 2130

Austock Rural – 07 3216 4828

Boontech – 03 5424 8482

Allflex Australia – 07 3245 9100

Iconix – 08 9434 0000

Ruddweigh (Gallagher)– 03 9308 7722
Involved in early research of Walk-over weighing

Tru-Test 1800 641 342
Currently involved with the development of walk-over weighing in conjunction with Bill Murray (Sheep CRC).

4.5.25 TekVet

Primary Contact: Doug Jardine
0011 1 801-638-5020

TekVet and IBM have worked jointly on a health and positioning tag (see photo below) to monitor animal health (temperature) and position through a network of sensors. Data is collected and sent via satellite where it is processed and stored by IBM.

4.6 Research conducted, proposed and research capacity

Break down into areas of expertise by technology components

4.6.1 Heytesbury

Unit 6, 90 Ross Smith Avenue,
Fannie Bay NT 0820 NT 08 8982 9999
Key Contact: Steve Petty

Heytesbury, as owners Pigeon Hole station have been closely associated with the remote management project conducted there but have also been involved with pasture growth modelling research and water medication research.

Heytesbury clearly have a thorough understanding of the science and economics behind beef production and have demonstrated an open approach to collaboration with researchers to deliver positive outcomes for both parties.

4.6.2 NT Dept Business, Industry & Resource Development

PO Box 1346,
Katherine NT 0851 NT 08 8973 9746
Key Contact: Neil MacDonald

The department have been active in facilitating rather than conducting research in this area. As partners in the Pigeon Hole project – they see this technology as a management tool with staffing and bores management of primary interest.

4.6.3 Desert Knowledge CRC (DKCRC)

Heath Road,
Alice Springs, NT 0870
Key Contacts: Mark Ashley and Craig James

The Desert Knowledge CRC (DKCRC) have been active facilitators of communication relating to remote management technologies with inclusion and discussion of the technologies at field days and in forums.

According to the DKCRC, affordability of the system is key to adoption. Particularly for expansive family operated properties without the financial backing of a corporate organisation.

The DKCRC point out the need for installation and servicing expertise required preferably with local knowledge in an effort to maintaining regional communications businesses.

Development of a ‘broadband over UHF’ system is being researched collaboratively with the University of Wollongong.

The DKCRC see remote water management tools as the path to best value for an investment in the technology. The next step for this technology is the development of bolt-on components including walk-over-weighing.

4.6.4 Western Australian Department of Agriculture

Key Contact: Robert Rouda
Dr Rouda has previously been involved in work relating to virtual fencing technology and while not currently working in this area, maintains interest in the technology.

4.6.5 CSIRO Autonomous Livestock Systems

JM Rendel Laboratory, Ibis Avenue,
Rockhampton, QLD 4701 QLD 07 4923 8125
Key Contact: Dave Swain

With four permanent staff, two technicians, one post-doctorate student and three other students, CSIRO Rockhampton has extensive knowledge and facilities capable of delivering information relating to animal interactions, behavioural characteristics and social behaviour. Much of the equipment and facilities have already been put in place have been utilised for pilot projects of this nature. Additional capacity comes through collaborations with CSIRO's ICT group at Pullenvale QLD.

Animal interaction research capacity includes monitoring calf-cow pairs for maternal aspects, bull libido, time of conception (permitting more accurate birth predictions) and diseased animal interactions (for disease trace back).

Other areas of expertise at the JM Rendell Laboratory and Belmont Research Station include 'on animal control' which includes aspects of virtual fencing and remote mustering. This work is conducted in conjunction with Dean Anderson from the United States Department of Agriculture (USDA) Work is also being conducted in the area of walk-over weighing in conjunction with Bill Murray, Sheep CRC.

These programmes are primarily directed by economic, animal health, disease trace back and management benefits.

4.6.6 Sheep CRC

Chiswick Research Station
Armidale NSW 2350
02 6880 8050
Primary Contact: James Rowe

The Sheep CRC has interest in the area of remote management with Bill Murray working on walk-over-weighing systems in conjunction with commercial affiliates Tru-Test.

A common interest in the development and implementation of remote management technology is evident, indicating opportunity for some of this work to be conducted jointly.

4.6.7 Australian Wool Innovation

Level 5, 16-20 Barrack Street
Sydney NSW 2000
02 299 5155
Primary Contact: George Wauldhausen

While possessing no skills or internal capacity in the area of remote management technology, AWI is interested in the technology for many of the same reasons as the beef industry, namely cost input savings and improved labour efficiencies. It is thought that given the common interest in the development and implementation of remote management technology, opportunity exists for work to be conducted jointly.

4.6.8 NSW Agriculture

Expertise includes Steve Semple (NSW Ag, Orange) who has skills in RFID and auto-drafting equipment.

4.6.9 ARCAA

Australian Research Centre for Aerial Automation
Primary Contact: Rod Walker (Queensland University of Technology)
Members include UAV Vision, Boeing, Aerosonde, HELImetrex, Brisbane Airport Corporation - The DaVinci Precinct and V-TOL Aerospace.

The research aims of ARCAA are to reduce the cost and weight of UAV systems, develop technologies to integrate UAVs into the civil airspace system and develop technologies to address bandwidth constraints for UAVs (high autonomy). Research objectives include the development of a civil autonomous UAV airworthiness framework for approval be Civil Aviation Safety Authority (CASA), development of generic, CASA-approved, UAV platform technologies to allow safe and reliable operations for civilian applications and development of application-specific payloads to meet the requirements of a variety of civilian customers.

To enable these objectives to be met ARCAA aims to explore machine vision, artificial intelligence, autonomous monitoring of the health of onboard systems, automation of aircraft emergency procedures, reliability and safety engineering for UAV systems, Global Navigation Satellite Systems (GNSS) augmentation systems, advanced low-cost inertial navigation units and human factors studies for UAV operational requirements.

The centre also aims to be heavily involved in providing specialised industry guidance through certification of software and hardware of UAV systems for industry, organisation certification for UAV operations, the provision of UAV-related training courses, advice and action on behalf of industry related to government policy on UAVs, industry access, on a commercial basis, to world-class facilities and demonstration and proof of concept projects

4.6.10 Desert Channels QLD

PO Box 601
Longreach Qld 4730 QLD
07 4658 0600
Primary Contact: Coleen James

Desert Channels Queensland has been working to establish a site demonstrating the benefits of remote management technologies on the NAPCo owned Monkira Station. This will be the first of the NAPCo properties to install remote management equipment.

Current plans are to install a GME system in conjunction with some water saving devices including turkey nest evaporation blankets. It is hoped the installation will demonstrate the availability and reliability of remote management technology.

4.6.11 University of South Australia

Centre for Advanced Manufacturing research
University of SA Mawson Lakes Campus SA
08 8302 3632
Primary Contact: Evangelos Lambrinos

With a strong history and background in industrial manufacturing and automation, the University of South Australia is home to the Centre for Advanced Manufacturing Research. More recently the centre was involved in a CRC bid for a Future Advanced Rural Manufacturing (FARM CRC).

The Centre has also developed a continuous positioning system known as ‘Neve’, this system has been developed as a high-end navigation system utilising GPS technology capable of post-processing positional data as required.

4.6.12 National Centre for Engineering in Agriculture

USQ, West Street,
Toowoomba QLD 4350 QLD
07 4631 1347
Primary Contact: Erik Schmidt

The National Centre for Engineering in Agriculture is located at the University of Southern Queensland campus in Toowoomba. The Centre has around 20 full and part time staff operating under a broad range of projects.

Of specific interest are skills in imagery and shape recognition which may be applied to the application of remote management technology to identify and classify animals. Animal classification may be used, for example, to permit cattle only to a water or feed point while denying access to these points for feral animals. Much of this technology has already been developed and has been applied to machinery for visually prompted machine guidance purposes and in the form of the Rugged Outdoor Camera (ROC).

4.6.13 CSIRO, ICT Centre

Technology Court,
Pullenvale QLD 4069 QLD
07 3327 4584
CSIRO Pullenvale
Primary Contact: Peter Corke

The CSIRO facility at Pullenvale is home to CSIRO’s ICT centre. The ICT centre has skills and capacity which have led to the development of sensor networks which have demonstrated their abilities through application in the animal interaction work conducted at CSIRO Rockhampton. Other areas of skill and capacity include UAV’s and imagery.

4.6.14 University of Queensland Gatton

School of Animal Studies
Gatton QLD
Primary contact: Peter Murray
07-5460 1256

Expertise and capacity exists in the area of machine vision. Work is currently being conducted on various forms of animal identification including separation of feral and production stock. Elements of this work is being conducted in collaboration with staff from the NCEA.

4.6.15 Queensland Department of Primary Industries

Key Contacts: Rod Thompson, 0409 725452, Les Zeller 07 4688 1208

QDPI has skills in the areas of UAV's, aerial imagery, relevant electronics and animal interactions. Rod Thompson (Brisbane) has skills in the areas of animal interactions which has relevance in the area of cow-calf relationships and disease traceback.

Les Zeller and Troy Jensen (Toowoomba) provide expertise in agricultural engineering and precision agriculture. Les Zeller has specialist skills in the development of agricultural electronics which includes RFID systems and bolus retrieval, cattle flight recorder, electronic nose research, dynamic olfactometer development, GPS and weighing systems. Troy Jensen is involved in the development of a low cost aerial imagery system using UAVs which can be used for crop/forage monitoring, locating stock, monitoring watering points and fence integrity.

4.6.16 University of New England

Key Contacts: David Lamb, 0428 886088

The University of New England are working in four key areas;
Low cost (less than $250) GPS tracking collars used with EM38 data to generate grazing impact models.
Paddock management using digital terrain models with EM38 soil conductivity data with UAV and satellite biomass imagery.
Active NIR/Red crop canopy sensors to detect and map pasture height.
Plant canopy monitoring and data collection using pole sensor arrays in paddocks with capacitance probes (C-probes) and active plant canopy sensors.

4.7 Other industries

Other industries utilising remote management technologies have a number of points of difference for operational requirement to that of the northern beef industry. These industries were investigated to determine the level of use, equipment and technology utilised and potential relevance to the beef industry. While sensor technology is common across both the beef industry and any of these other industries, in most cases, other industries have the advantages of being able to rely on existing power and communications utilities. While the majority of technology used by beef producers is located remotely and needs to be capable of generating power for operation and establishing a communications system over the required distances.

4.7.1 Horticulture

The horticulture industry employs the use of remote management technology to monitor and control water requirements and resources in their operation.

Soil water monitoring using gypsum blocks, pumping and application controls are all remotely monitored and managed. Irrigation control, including frost prevention irrigations are controlled via system control software and are linked to mobile telephony networks to trigger alarms and notifications.

Systems typically use radio frequency and mobile telephony communications systems, are mains powered and developed, installed and maintained by specialist irrigation control engineers. Typical communication distances do not exceed 5km due to the intensive, high value nature of horticultural production.

While some of the flow sensing, control and actuation methods used in the horticultural industry are applicable to use in the beef industry, these have all been adopted already.

4.7.2 Mining

An investigation of mining operations revealed the use of remote management technologies to track and manage the logistics of expensive heavy equipment. Using radio frequency communications and Geographic Positioning Systems (GPS), positional data is linked with a Geographic Information System allowing mine managers to pinpoint machinery operations, speed and status.

The data collected is similar to that which would be used if wanting to monitor the movement of livestock, but because of the expensive nature of the technology required, the cost of doing so would, at present prices (estimated to be $15,000 per machine), would be prohibitive.

As with the horticultural industry, most data collection and communication systems utilise mains power.

4.7.3 Dairy Industry

Utilisation of remote management technologies in the dairy industry include the use of RFID tags to monitor the volume of milk delivered for each cow, feed rations are also individually delivered according to animal ID and milk delivery history.

These systems require the use of an integrated herd management software package which may be applicable to the beef industry if individual animal weight gains are to be monitored according to individual animal ID.

Industrial
Industrial remote management systems have been used for over two decades. In applications where operating environments are harsh, sensor and cabling protection are features which are shared by the requirements of the beef industry.

Industrial applications utilise radio frequency communications, typically over shorter distances than that required by the beef industry. System control software is often used, a feature applicable to the beef industry, in most cases this involves adaptation and customisation of an off-the-shelf package by systems control specialists. Similarly, systems are installed, monitored and repaired in-situ by specialists.

4.7.4 Transport

Due to the expensive nature of the equipment utilised in the transport industry, similar requirements to that of the mining industry apply. Maximising the efficiency of vehicle movements and coordinating logistics primarily requires real-time positional information.

In difference to a mining operation, where operating boundaries exist, the transport industry must monitor vehicle movements over large areas. This prohibits the use of radio frequency data transmission, but because mobile telephony networks follow many of our highways and roads, mobile telephony networks are regularly utilised.

4.7.5 Military

Military applications of remote management technologies applicable to the beef industry include UAV's and data transmission methods. Given military operations operate in similarly remote locations without access to power and communication utilities.

UAV's are regularly used for reconnaissance operations and information gathering. Typical starting point for military investment in micro 'drone' aircraft is around $60,000 per unit, this extends to over $500,000 depending on the operational requirement of the aircraft. In addition to the hardware used, significant training is required to instruct operators to use the equipment safely.

While an expensive technology, applications exist within the beef industry depending on the current investment in aerial vehicles.

Most military data transmissions over large distances in remote locations rely on satellite communications. It is expected that in certain instances as discussed in section 4.4.2.1, satellite communications technologies may be applicable to the beef industry.

5 Expected benefits and current challenges

5.1 Benefits

5.1.1 Economic benefits

While economic benefits are calculable for an individual operation, determination of a precise industry-wide economic benefit would be, at best, misleading.

Variables capable of influencing calculated economic benefits include:

- size of operation
- number of head
- metrological patterns
- grazing capacity
- distances to water points,
- value and style of water infrastructure,
- topography and vegetation of operation,
- access to services,
- skill and cost of labour,
- cost of vehicles,
- cost of fuel,
- number of staff,
- location - distance to regional services
- aerial operations requirement and costs
- value of produce

While simplified economic benefits have been demonstrated within the case studies in section 4.2, more general estimates of probable economic benefit have been highlighted in Appendix 2.

5.1.2 Benefits of individual remote management tools

5.1.2.1 Water monitoring and management

Water monitoring and management has the potential to form the backbone of remote management technology implementation. Because it is a common denominator with all operations relying on pumped water sources, once established, can be teamed up with other sensors and components to monitor animal health and implement animal management decisions.

Particular economic benefits will be forthcoming for operations which have expansive grazing areas. These benefits come through improved utilisation of personnel resources particularly specialist boremen, reduced operating costs (personnel, vehicle, fuel), and increased vigilance over watering point integrity.

5.1.2.2 Walk-over weighing

When combined with automatic drafting, RFID for individual animal identification and monitoring, walk-over weighing becomes an efficient method of monitoring, planning and drafting off stock for market or management applications. This may lead to improved animal management and greater knowledge and vigilance of weight gain patterns, giving the producer to the ability to react more quickly to weight movements.

Ultimately this should improve the quality and uniformity of stock presented for market, assist in improving the management of pasture and reduce animal stress through fewer mustering for weighing requirements.

5.1.2.3 Virtual Fencing

Virtual Fencing offers increased benefits for larger more expansive operations through reduced fencing and mustering costs. The implementation of virtual fencing also promised increased efficiencies through more precise control of grazing areas and stock retention systems costing a fraction to maintain in comparison to traditional fencing. Not subject to damage through weather events, virtual fencing may also provide superior animal retention integrity.

In addition to the maintenance cost savings, producers would not be required to outlay the capital cost of fencing infrastructure, providing an opportunity cost saving which may well offset the cost of the implementation of virtual fencing in newly established areas.

5.1.2.4 Remote mustering

Expansive operations requiring significant aerial support for mustering are likely to benefit most from remote mustering technologies. This is expected to come through increased personnel efficiency, cleaner mustering, reduced vehicular and horse requirements. An investment in this equipment may also be applicable to fence and water point visual reconnaissance checks, thereby increasing the potential benefit from an investment in this technology.

In addition to providing a reduced aerial mustering cost, remote mustering may also deliver improved personnel efficiency with a reduction in the time taken to complete the process.

5.1.2.5 Animal tracking

Tracking animal grazing patterns and pasture utilisation may deliver economic benefit through improved pasture use efficiency and reduced mustering costs through knowledge of animal locations.

Improved animal management may also be forthcoming particularly when combined with auto-drafting technologies, allowing animals to be directed to graze specific areas.

improved grazing management may also result when animal tracking data is combined with aerial and satellite imagery or pasture growth models.

Animal tracking would also extended knowledge of animal location and interaction for quality assurance purposes and traceback.

5.1.2.6 Animal interactions

Understanding the social behaviour and interactions between cattle will lead to improved breeder selection and ultimately herd productivity.

Determining the nature of animal interactions would improve understanding of cow-calf pairs, improved EBV data relating to mothering qualities and would permit sire recording.

When combined with auto-drafting technology, animal interaction knowledge may permit automated mothering-up under drafting conditions and may assist understanding of animal interaction and resulting impact on weight gain.

5.1.2.7 Asset and personnel tracking

While seemingly simple, knowledge of asset location ultimately improves the management, utilisation and logistics of controlling the use of resources. In addition, asset and personnel tracking leads to improved OH&S with the ability to monitor and record personnel whereabouts.

5.1.2.8 Aerial monitoring of stock, fences, water and pasture

Potential exists for the use of UAV's to reduce the requirement for personnel and vehicles to visually monitor water, fences and livestock.

UAV's may also be used to monitor pasture density permitting landholders to improved pasture management. With a lower cost of operation, UAV's may also permit more regular visual checks of water, fences and livestock without the requirement for personnel and vehicles.

More regular visual checks of assets and pastures should lead to improved knowledge of problems, breakdowns and damage prior to visits for maintenance or repairs.

5.1.2.9 Satellite imagery and pasture modelling software

As demonstrated in the pastures from space project in Western Australia, improved understanding of pasture management requirements and feed-on-offer permits precision grazing if employed within a rotational grazing operation or virtually fenced property. This leads to improved grazing efficiency and management of pasture.

Improved knowledge of feed on offer leads to better livestock management and can assist in planning the sale of animals according to stocking rates and feed requirements.

The use of satellite imagery has been utilised in conjunction with predictive growth models and rainfall data to improve the understanding of pasture growth patterns leading to an improved understanding and utilisation of pastures.

5.1.2.10 Animal health maintenance and monitoring

Benefits of animal health maintenance through reduced animal health maintenance delivery times. Eartags capable of monitoring animal health may provide early indications of health impairments so they can be addressed more quickly and without risk of disease transmission to other animals. New animal health applications methods including the Vetcap method of applying animal health products may also decrease the time required to muster and treat animals, reducing personnel and vehicle costs and reducing the time taken to administer animal health products.

5.2 Challenges

In order for producers to accept the technology, successful demonstrations and trials are essential. These should aim to demonstrate benefits and reliability of the technology.

Virtual fencing is an example of a technology that was, possibly through over-enthusiasm, over-promised and under-delivered. While this technology has continued to develop in the meantime, damage already done.

To avoid a repeat of the scepticism surrounding virtual fencing, the release of information needs to be controlled to prevent over-promising in the future – by nature producers are sceptics and moderated media may go some way to addressing this

Evident within systems currently available off the shelf, additional levels of redundancy need to be incorporated to ensure equipment failure does not impose additional costs and effort through trying to address not only the repairs and maintenance of equipment or animals, but the technology itself. Ultimately, failure to do this will result in a nett negative benefit and earn the distrust of producers.

One of the biggest challenges as witnessed in installations in place is environment proofing the equipment. Weather, animals, birds – have affinity for chewing cables and components, cables in particular need to be well protected to ensure reliability.

Because the highest economic benefit is likely to come through installation of the technology on the most remote locations first, initial installations will be the most challenging and potentially the most likely to fail. As producers will see these as their first dabble into the technology, the risk of failure is that application of the technology may be deferred if the producer is not inclined to persist.

There currently exists a significant lack of capacity and training available in the implementation of remote management technology. This needs to be developed for remote management technology to be accepted and has some challenges in itself given that most installation locations are remote. Businesses already established in these remote areas need to be utilised electrical contractors may provide an appropriate delivery path as they have good knowledge of installation methods and protection.

An alternative model as provided by Observant relies on a component based system with replaceable plug-and-play components. Thus allowing the producer to keep spares on hand for installation by ringers. Under this model, specialists would still be required for system design and initial installation.

Challenges relating to the use of UAV’s for remote mustering and infrastructure and pasture monitoring include the training of the operators of the UAV’s. Given the expensive nature and assumed difficulty of flying UAV’s begs the question; would producers permit station workers use expensive remote control aircraft or would this be left to specialist contractors?

Given the additional training required to undertake some of the specialist roles brought about by the use of this technology, staff turnover will also affect the success or otherwise of the use of remote management technology in the Northern beef industry. Staff turnovers would inflict the need to retrain staff in the use of these technologies. Potentially, the starting point for this training may be incorporated into educational programmes within agricultural colleges.

As noted in opportunities for investment in Section 7.1.2, the limited bandwidth for data transfer available using currently adopted UHF radio technology is not capable of delivering high quality live images and streaming video. Determining the most appropriate and capable method of data transfer either within existing communication infrastructure, or outside, will required significant investigation and development. While numbers can indicate measured physical properties, producers prefer to see for themselves as it is the ultimate measure of surety.

Lobbying to free UHF channels up to be utilised for data transmission for more than 3seconds every 60 minutes in rural and remote areas is a barrier that must be overcome quickly. It is thought some operators are doing so illegally currently although it is clearly evident their breach of regulations is not affecting anyone.

The data transmission mode chosen as a standard platform will form the backbone of almost all technology utilised in RMT applications, subsequently, it important for this selection to be carefully considered. It may be necessary to build in opportunity for over-capacity for bandwidth and range to carry future communications as applications and components are increasingly used over the network.

6 Success in achieving objectives

Objective 1: Identify and detail the range of remote management technologies currently being used or researched in the Australian grazing industry, including their applications, costs and their realised and potential benefits.

A wide array of technology has been investigated. Field visits to a number of known installations have been conducted, exploring the successes and challenges facing producers and investigating the costs, realised and potential benefits deliverable through the application of the technology. Discussions with producers who are considering the application of the technology in their operation have also been conducted to ascertain the potential for the application of currently and potentially available technologies.

Discussions and field visits to producers have been across a wide range of operation scales, ensuring issues facing all levels of operators in the northern beef industry are addressed. These discussions and visits have investigated the investment and potential for benefits, both financially and from a management perspective within these operations.

Searches and visits to manufacturers, both within Australia and internationally has yielded a long listing of organisations which do, or may be able to, contribute to the pool of available technologies applicable today or in the future. While every effort has been made to identify as many of these technologies as possible, it is by no means an exhaustive listing as new technology continues to evolve.

Literature searches, discussions and meetings with researchers has yielded a comprehensive listing of research work being conducted and proposed in the area of remote management technology. Visits to observe the facilities, research underway and proposed have been conducted with notes detailing the levels of expertise, capacity and facilities of these organisations being listed.

Objective 2: Identify and detail the range of remote management technologies currently being used or researched in other industries that may be of value to the northern beef industry, including their potential applications, costs and benefits.

A range of other industries which currently utilise remote management technologies have been investigated, yielding a listing of technologies currently applied or researched within these industries.

Further investigation of the technology has identified the costs, potential for this technology to be applied to the beef industry, potential challenges in the application of this technology to the northern beef industry and potential benefits which may result.

Objective 3: Produce a list and detail the expertise of those research groups and manufacturers active in the field of remote management technologies.

A detailed listing of manufacturers, research organisations and individuals which are currently active in the field of remote management technologies has been compiled with additional detail regarding the skills, capacity and facilities these groups and organisations bring to the table.

Objective 4: Recommend those technologies most likely to benefit the northern beef industry based on their potential cost, potential benefit and likelihood of reaching commercial production.

Utilising a tabular assessment method, each of the technologies and applications investigated have been evaluated according to the cost of capital investment and installation, potential for financial and management benefits, both to the producer and to the industry.

This tabular assessment has identified the challenges facing the application of the technologies to the beef industry and the key industry contacts with skills and capacity to apply these technologies to the northern beef industry.

7 Conclusions

7.1 Conclusions, recommendations and opportunities

In relation to recommendations for areas of investment for Meat and Livestock Australia (MLA), there appear to be a number of potential opportunities.

7.1.1 Equipment development

At this stage, all of the sensors currently required by the beef industry have been fully developed. These sensors are typically available off-the-shelf for application by manufacturers wanting to capture specific data about the animal or the operation. The only exception to this would be the ‘e-nose’ olfactometer sensors, which still require development to detect particular ‘smells’ .

7.1.2 Data transmission

Data transmission methods however have some shortcomings which may require MLA investment and lobbying as they are a key component of remote management technology development and adoption. The 3 seconds of data transmission per hour regulation has a place in urban areas, but in remote locations should be relaxed as it’s purpose is to minimise airwave congestion and annoyance for listeners. It is quite possible that some systems are already breaching this regulation and MLA has a responsibility to convey the requirements of the industry to the telecommunications regulators on behalf of producers and manufacturers.

Investment in methods of data transmission should investigate utilisation of existing infrastructure (typically UHF radio) to carry higher bandwidth data than is currently available. Work being undertaken at the University of Wollongong in conjunction with the Desert Knowledge CRC may be able to address some of these issues and opportunity for investment exists here. Alternatively investment in improving the range and power consumption of 2.4GHz technology would bring the industry inline with computing, vehicle and machinery manufacturers who are planning to utilise this communications method in future machine telemetry requirements.

7.1.3 Power

The generation of power is the fuel that drives this technology in remote locations. Solar panels are generally well developed as are battery technologies. Challenges exist for power requirements of future technology (including eartags for virtual fencing or GPS tracking equipment) mounted on animals. Investment may involve the development of kinematic style battery chargers or solar power generation equipment which can be mounted on the animal.

On animal sensors may also require additional development of attachment methods. Currently used collars are bulky and ear tags are limited for space. More recently developed over-ear attachment methods have shown to be prone to damage and are not particularly secure.

7.1.4 Equipment trial and demonstration sites

Demonstration sites backed by MLA are fundamental if this technology is to be seen, understood and adopted. Installation of the technology should be geographically spread (potentially five per state), with different sites demonstrating the technologies likely to be most relevant to that geographic area. These sites also provide a platform for manufacturers to prove the application of their equipment allowing the success or otherwise open to public scrutiny.

It is suggested that key producers with technical savvy are engaged to demonstrate the technology, this should provide two key benefits; firstly this ensures the equipment is operational and is utilised to its full potential and; secondly the use of the equipment by key producers generates a positive reputation.

7.1.5 Development of capacity

Building capacity, knowledge and understanding needs to be developed in the first instance if this technology is to be adopted. In many cases producers are reluctant to install this equipment because of a lack of local or available expertise. Capacity could be built within a number of already established organisations and industries including the state departments of Agriculture, local electrical contractors and local communications technology suppliers.

There is an argument that if viable, this technology will drive the development of the required capacity and while this may be true, it will take some time to develop.

An investment in this area in the short term will ‘kick-start’ the application and adoption of technology, ensuring the potential savings delivered by this technology are realised as soon as possible.

7.1.6 Tailored savings calculator

One of the objectives of this investigation was to identify technologies delivering maximum return for investment. But due to the large number of variables, it was evident that the economics of an investment in this technology by a producer will vary significantly across the industry.

Using the services of an economist familiar with the technology, it is recommended that a specific savings calculator or producer assessment sheet is developed. This is crucial for producers wanting to understand the cost benefits an investment in this technology could provide in their operation. In most cases where financial backing may be sought, this economic rationale will also be required to secure the necessary borrowings by the producer and would be key to the understanding of the manager of the financial institution from which they seek these funds.

8 Appendices

8.1 Appendix 1 Technology status matrix

Appendix 1 - available technologies status

Requirement	Solution	Availability	Best Features	Barriers to adoption	Cost	Development Stage	Understanding of technology required	Robustness	Recommendation
Data transfer									
	UHF	Available	Accepted technology already utilised for on farm comunications. Ability to utilise existing UHF repeater systems. Repairs to some components possible by non-specialists. Can utilise Selcall function for extended range and improved bandwidth (GME)	Understanding of system design and signal propogation over terrain. Bandwidth restricted - low quality images transmitted	$400-$2500 per unit depending of system selection, antennae and powering options	Used widely for communcations and has been the adopted platform for both primary packaged systems (GME and Observant)	Minimal to Medium - Understanding of signal coverage requires specialist understanding	Robust	Solid foundation to build system on given use and acceptance of technology. Issues with legalities of data 3 second transmission times over 60 minute period need to be addressed for remote areas
	WiFi Ethernet / WiMax / Zigbee	Available	High bandwidth - capable of live video transmission. Systems used in industrial applications. Zigbee utilises wireless mesh networking between units. Plug and play components available incluidng off- the shelf IP cameras	Lack of expertise for system design and install. Technology not currently used on many farms. Bluetooth, Zigbee have low transmission power	sub $2000 for a Wifi ethernet wireless modem with antennae for transmission up to 20km (requires mains or solar power)	Current uses include 'webcams' on skislopes and traffic monitoring. Extensively used in industry	Medium - most are plug and play units, however power and housing requirements have to be configured.	Not designed for extreme conditions, however may be housed	Could be more widely utilised on small to medium sized properties. Will also provide whole-farm ethernet facility for on-farm communications and internet access.
	'broadband' UHF	Conceptual	As per UHF with improved bandwith to improve data transmission speeds	Product yet to be developed and proven	N/A	Under development	High - yet to be fully developed	N/A	Provides benefits of UHF with extended bandwidth for data and multimedia transmission
	CDMA	Phasing out 2008	Widest ground-based telephony system coverage. Medium bandwidth 9.6kb/s	Phasing out - NextG telephony system coming online	Sub $1000 depending on number of inputs & outputs 2.2c/kb data cost plus 22c connection fee	Phasing out 2008	Medium - knowledge of electronics required	Medium - requires housing	Data ransmission to migrate to Next G
	NextG / 3G	Available	High bandwidth - capable of live video transmission. Promised equivalent coverage of outgoing CDMA telephony system	Poor coverage over many northern beef properties. Limited harward available at time of reporting	Hardware; unknown. Data cost 1.5c/kb casual rate. $5/month for 1Mb, $8/month 3Mb, $29/month 70Mb	New - not yet utilised	Medium - knowledge of electronics required - plug and play units expected in 2007-8	Medium - requires housing	Next G coverage not sufficient for majority of landholders. Ideally suited to smaller holdings in closer proximity to regional centres.
	Satellite	Available	Universal coverage, 9.6kb/sec data transfer rate	Cost relative to UHF data transfer methds	Hardware packaged on plan, data cost $30/month plus ($10 calls included) 16.67c/10 second block or $60/month plus ($40/month included) 13.33c/10 seconds	Used in utilities, transport and weather reporting	Medium - specialist expertise required for system design and installation	Medium - requires housing	While relatively more expensive, economics would indicate savings are still forthcoming. May be the only option for remote areas where UHF coverage does not exist
	GSM	Available	Plug and play units available at a cost of under $1000	GSM coverage predominantly in urban areas with poor coverage in regional areas	Sub $1000 depending on number of inputs & outputs 2.2c/kb data cost plus 22c connection fee	Used in horticulture, irrigation, utilities, transport and weather reporting	Medium - plug and play style units simple to use and could be installed by the producer	Medium - requires housing	Insufficient coverage in required areas - Utilisation of Next G seen as superior
Water Level sensors									
	Pressure transducers	Available	High level of resolution	Effect of silt and sand on operation. Not overly robust	$800-$900	Available, not used	High - relatively complex	Low-Medium	Avoid complexity and look at other solutions
	Ultrasonic depth sensors	Available	Can be surface mounted away from mud etc.	Complexity and lack of robustness	$372 - $1500	Available, not used	High - relatively complex	Low	May not be the best sensor for this application
	Continuity sensors	Available	Simplicity - can be constructed and serviced by non-specialist staff		around $100	Used in Sockman electronics installed systems	Low	High	Recommended as a basic water level / flow sensor where resolution is not required
	Optical sensor	Available	Can provide high resolution	Complexity	unknown	Available, not used	High - very complex	Low	Not recommended
	Float switch	Available	Provides a simple and low-cost water level indication with resolution and reliability	Minimal	$200-$400 depending on depth required	Used on Observant systems	Medium	Robust	Seen as the optimal solution - Must use hall effect sensors for durability
Water quality sensors									
	Turbidity sensor	Available	Determines clarity of water in troughs	Cost exceeds benefits	$600 - $2500	Available	High	Low	Little percieved benefit amongst producers
	pH sensors	Available	Determines acidity of water in troughs or turkey nest.	Not very robust and require regular calibration	$600	Available	Medum	Low	Little percieved benefit amongst producers
	N sensors	Not available		Not available		Not available			
Water flow sensors									
	Continuity style (on pipe output)	Available	Simplicity of desigh - easily repairable on-farm	Require redundancy for reliability, single point resolution does not measure rate of flow	around $100	Available and used	Minimal	Robust	Can be used where simple water presence is required. Should always be duplicated to provide redundancy and improve reliability
	Paddle style	Available	Readily available off the shelf	Moving parts will wear over time and may not be applicable to poor quality water	$200-$00 for common pipe sizes used in the Northern Beef Industry	Available and used	Medium - not an on-farm - servicible component	Medium	Could be used in specific circumstances where rate of flow is required.
	Ultrasonic Dopper	Available	Can tolerate very poor water quality	Cost, specialist installation required	High	Available	High - particulalry prone to incorrect readings if nit installed correctly	Robust	Not suited to use in this application
Cable protection									
	Anaconda	Specialist	Particularly resiliant	Specialist product	$20/m	Available and used	Minimal	Very Robust	Shoud be used in critical installation where animals destroy cables.
	PVC pipe	Available	Readily available	Few	$2/m	Available and used	Minimal	Medium to robust - may be UV prone	Most commonly used - should be used to cover all wiring exposed.
	Polyethylene pipe	Readily available	Readily available	Minimal	$1/m	Available and used	Minimal	High	Could be used in place of PVC pipe, but may not ofer comparable level of protection.
Positional data									
	Global Positioning System	Now	Very precise method of determining animal position. Data is easily overlayed on maps and can be analysed in mapping software.	Poor battery charging technology available & GPS systems have relatively high power requirement. Attachment methods require development. Data transmission potentially difficult depending on intended use of data. Cost for use on every animal outweighs benefits.	Around $1000 per collar	Available commercially	High - large volumes of data collected -	Robust, however additional attachment methods could be explored.	Further development of battery and charging technologies would aid in the devlopment of this
	Proximity or RFID network	Now	Wide range of RFID equipment available commercially. Proximity network testing has been undertaken in animal interaction trials.	Lack of funding for future development	RFID equipment ranges enormously. Proximity network not yet available commercially.	RFID - available commercially. Proximity network trialled with cattle.	High - although data collection and analysis may be automated.	Robust	Additional funding into this development is recommended
Remotely Sensed Images									
	Satellite	Now	LANDSAT5 - uses optical imagery with spatial resolution of either 15 or 30 metres for panchromatic or multi-spectral respectively and a revisit period of 16 days. IKONOS which uses optical imagery with spatial resolution of either 1 or 4 metres for panchromatic or multi-spectral respectively and a revisit period of 3.5 - 5 days	Fixed revisit intervals may not be suitable, image quality can also be hampered by clouds. Images require analysis which, in turn, requirestime, training and understanding.	LandSat5 - (Full scene approximately $1200) IKONOS - $25/sq.km with a minimum purchase area	Currently available	High - specialist expertise in image analysis and Geographic Information Systems required.	N/A	These two satellite imagery tools are available and are used on some larger properties already
	Charter / Remote Aircraft	Now	Higher resolution than satellite. Available at intervals as required by producer. Uses same technology as remote mustering.	Understanding of processes required to capture images and interperet them. Images not precisely georeferenced initially.	Low cost, low level dedicated unit: $2000 (enthusiasts) . Higher cost units available $130,000 - $150,000 for packages	Development completed, now investigating commercial opportunities.	High - specialist expertise in image analysis and Geographic Information Systems required.	Not particulrly robust	Require additional development for this application, however joint development with remote mustering technologies may share some development costs.
	Robust Outdoor Camera (ROC)	Now	Capable of capturing and recognising animal features and shapes	Has not yet been integrated with other technology components utilised for remote management applications	$3000-$4000	Fully developed and used in identifying a range of animals by shape.	High - unless incorporated into automated systems	Robust - as name suggests	A technology component which could be incorporated into other systems including auto-drafting to separate stock at water points.
Weather Sensors									
Temperature	RTD's	Now	Simple and robust - linear output	none	Wire $3/m or made up $45-$70 $240	Available	Minimal	Robust	Will be widely used to measure temperature
Humidity	RH sensor	Now	Simple and robust	None	$200 - $670	Available	Medium	Medium	Will be widely used to measure humidity
Rainfall	Tipping Bucket / Pluviometer	Now	Widely used	May be prone to damage in environment	$ 765 sensor only - ($1745 LOGGER BUILT IN)	Available	Medium	Medium	Will be widely used to measure rainfall
Pump RPM	Magnetic pickup (inductive)	Now	Simplistic	None	$70-$150	Available	Medium	Robust	Recommended for use
	Hall effect	Now	No moving parts	None	$4-$75 (vane type)	Available	Medium	Robust	Recommended for use
Pump fuel level	Pressure transducer / LVDT	Now	Can deliver precise fuel level indications	None	$1200 - $1300	Available	Medium	Medium	Recommended for use

8.2 Appendix 2 Technology application matrix

Application	Capital cost of implementation	Cost per animal	Technologies used	Availability	Relevant to Enterprise scale	Economic benefit	Management benefit	Property benefit	Industry Benefit	Barriers to uptake	Contact
Walk-over weighing	Estimated $15-20,000 initial capital outlay, would also require fencing to direct and isolate stock over platform	Varies according to scale of operation	RFID, Load cells, Scale head, Auto drafting, Solar panels, battery technology + data transfer or post processed, wiring loom protection	All components available individually. Fully packaged system in development stage completed, pending commercial trial.	Medium to Large	✪✪✪ (potentially improved market prices) - reduced requirement for muster and weigh.	High (potentially improved animal management and greater knowledge and vigilance of weight gain patterns leading to the ability to react more quickly to weight movements	Automated monitoring &/or drafting (when used with remote auto-drafting) of stock for market or management applications	Improved quality and uniformity of stock presented for market, improved pasture management. Reduced animal stress - fewer muster and weigh requirements	Reliable operation	Bill Murray, Observant, Tru-test, Ed Charmley (CSIRO Rockhampton)
Virtual Fencing	Not known - will depend on number of animals and scale of property	Prototype still in development	RFID, GPS, solar panels, battery technology, electric and audible stimulus, microprocessor, animal attachment, battery charging technology - potentially kinematic charging	All components available, but system requires miniturisation and further development	relavent to large grazing operations, will depend on cost of developed system	High for large operations, reduced fencing cost, reduced mustering cost	High - efficient control of grazing and mustering, less reliance on physical fencing	Reduced cost of fencing infrastructure, mustering and operating costs. Knowledge of animal location	Medium - Improved management of pastures and grazing, reduced cost of personnel	Tarnished reputation for failure to deliver, yet to be trialled in Australia, high cost of current prototypes	Dean Anderson, Robert Rouda, Dave Swain (CSIRO Rockhampton)
Water monitoring	Integrated packaged options include: Observant; $1195 (base) + from $2425 per trough site. Options for each monitored site include camera ($2415), Motor and pump controller (815). GME; $1149(base) + from $2028 per trough site Options for each monitored site include engine controller ($499), conductivity flow meters (approx $100).	Varies according to scale of operation	Water level sensors, water turbidity sensors, solar panels, battery technology, camera technology, data transfer (low bandwidth required for depth data, higher bandwidth required for images), fluid flow sensors (high volume for water, low volume for medication) wiring loom protection	All commercially available	Medium to Large. Most relevant to expansive grazing operations	High for remote watering points. Dependent on physical size of operation and water delivery method.	Medium - however has potential to be teamed up with other sensors and components to monitor animal health and implement animal management decisions.	Improved utilisation of personnel resources. Increased vigilance over watering point integrity. Reduced operating costs (personnel, vehicle, fuel)	Reduced cost of personnel and equipment to monitor water delivery. Lower pressure to find specialist boreman	Lack of capacity to design and install reliable systems.	Observant, GME, Semfios, Innovative Farming (Combox)
Remote mustering	Over $50,000	Varies according to time required for mustering	Unmanned Autonomous Vehicles (UAV's), data transfer (high bandwidth), camera technology. May also include GPS tracking, and virtual fencing technology components	Blue-sky. Experimental trial	Large particularly applicable to expansive operations	Potentially high, particularly for extensive operations	Medium - Increased personnel efficiency, cleaner mustering, reduced vehicular and horse requirements. Equipment also applicable for fence and water point visual checks	Reduced aerial mustering costs. Improved personnel efficiency	Reduced spending and reliance on helicopters	High cost, questionable reliability, expertise and training availability to pilot the remote aircraft. Risk of damage to aircraft is costly.	QDPI, Peter Corke (CSIRO), Micropilot, UAV Vision, Boeing, Aerosonde, HELImetrex, V-TOL Aerospace
Animal tracking	Depends on number of animals and scale of property	$1500-$2000 for an individual animal GPS logging collar, $10-$15 if integrated into an existing CSIRO style sensor network	GPS, CSIRO sensor network, RFID and data transfer. May also be combined with aerial and satellite monitoring technologies. Attachment methods	Experimental trial completed, commercial trials pending	Large to medium, particularly applicable to extensive holdings and large paddocks	Low to medium economic benefit through improved pasture use efficiency and reduced mustering costs	High - Improved mustering efficiency, improved animal management particularly when combined with auto-drafting technologies	Increased knowledge of animal location aids mustering operators, improved grazing management may also result when combined with aerial and satellite imagery or pasture growth models.	Medium - Extended knowledge of animal location for quality assurance purposes and traceback. Improved grazing and pasture management.	Cost of individual collar. Low relevance to mid-sized operation will not generate sufficient critical mass to reduce the cost of the packages.	David Swain (CSIRO Rockhampton), Peter Corke (CSIRO Long Pocket), Sirtrack
Animal interactions	Depends on number of animals and scale of property	$10-$15 anticipated if integrated into sensor network	RFID, data transfer (low bandwidth), attachment methods	Experimental trial completed sucessfully within sensor network.	All scales depending on accerss to existing data collection networks.	Medium. Improved breeder selection leading to increased productivity	Medium to low - Mothering-up, improved EBV data relating to mothering qualities, sire recording	Improved breeding stock, knowledge of cow-calf interactions, automated mothering-up under drafting	High - Improved understanding of animal interaction and impact on weight gain	Most value is to researchers and breeders.	Davis Swain (CSIRO Rockhampton), Rod Thompson QDPI
Asset and personnel tracking	Expected around $2500	N/A	GPS, Sensor networks, RFID, data transfer (low bandwidth), attachment methods	Commercial availability 2007	Large to medium, particularly applicable to extensive properties	Low - improved asset management and logistics	Medium - Improved logistics and OH&S	Medium - Improved OH&S management, increased asset management	Medium to high - Improved OH&S records and enhanced logistical ability	Cost and necessity to integrate with an existing network.	Observant, Sirtrack, Peter Corke (CSIRO)
Aerial monitoring of stock, fences, water and pasture	Over $50,000	Varies according to scale of operation	Unmanned Autonomous Vehicles (UAV's), data transfer (high bandwidth), camera technology. May also include GPS tracking, and virtual fencing technology components	Commercially available - typically used in military applications	Most applicable to large operations with remote infrastructure.	Medium - Reduced requirement for personnel and vehicles required to visually monitor water, fences and livestock.	High - Improved pasture management, visual checking of watering infrastructure,	More regular visual checks of water, fences and livestock without the requirement for personnel and vehicles. Improved knowledge of problems, breakdowns and damage prior to maintenance visits. Increased understanding and improved management of pasture management	Improved quality assurance reduced overhead costs.	Cost and reliability of the aircraft system	QDPI, Peter Corke (CSIRO), Micropilot, UAV Vision, Boeing, Aerosonde, HELImetrex, V-TOL Aerospace
Satellite imagery and pasture modelling software	Already established	Dependent on number of livestock	Satellite imagery, Geographic information systems, biomass and feed on offer software	Commercially available - already used in some operations	Medium to Large - Particulalry applicable to larger operations where there are extensive seasonal pastures and large holding of livestock.	Medium to High - Improved understanding of pasture management requirements and feed-on-offer permits precision grazing if employed with virtual fencing technology	High - Increased efficiency and management of pasture. Improved knowledge of feed on offer leading to better livestock management and planned sales	Understanding of pasture growth modelling ability when combined with rainfall data and predictive growth models.	Improved understanding and utilisation of pastures. Increased uniformity of stock delivered.	Understanding of the application of data and images. Irregularity of satellite passes and cloud cover in some northern areas during wet season	Steve Petty (Heytesbury), Greg McKeon & Tracy Van Bruggen (QCCA), Dr Beverley Henry (QDNR),
Animal health maintenance	Not known - blue sky application	N/A	RFID, Health sensor tags/bolus, gas-powered application guns, attachment methods	Health tags under experimental trial in UK, gas-powered application guns under commercial trial	Small - Large - precision livestock management, dependent on cost of system	Medium - Improved herd health, early detection and minimisation of disease spread when combined with auto-drafting technologies	Medium - Improved knowledge and management of animal health when combined with sensor network and data transfer systems	Medium	Improved herd disease minimisation and management - potentially providing the industry with a reduced animal health overhead	Still in conceptual development	Dr Toby Mottram (ITI techmedia UK), Mr Mark Nicmanis (TTP UK), Grant Weyer (Vetcap)

8.3 Appendix 3 RFID options

Lessons learnt show there are options for sheep RFID

With the sheep industry looking for a system to use for its national livestock identification scheme, this article on how the packaging industry keeps track of its goods provides food for thought for sheep producers and highlights the alternatives to choose from.

by Gerry Wind,
KONDININ GROUP

Technology that keeps track of goods, be it boxes, sheep in a paddock or a bale of wool, will mean significant savings in the supply chain and productivity gains for producers.

Businesses today have millions of transactions per day which are impossible to keep track of manually.

Experiences from the packaging industry show technologies such as radio frequency identification (RFID) not only keep track of products but also improve efficiency as well as providing valuable information on production and manufacture.

One company using RFID reduced stocktake costs by 97 per cent and slashed labour costs when efficiencies meant only half the number of despatch staff were required.

This space is deliberately blank

A case study

Packaging company Amcor realised it needed to keep better track of where its goods were.

Visualise a pallet of goods arriving from the production floor on a conveyor into the warehouse.

There are 10 machines making cardboard boxes, all different. Due to space constraints the pallets cannot be kept together near the machine, so each pallet is placed on the conveyor on completion. This means that when it arrives in the warehouse, there can be 10 pallets belonging to other clients arriving before the second pallet for one specific client. Each pallet can be deposited in the warehouse by a different forklift operator. As a result, various pallets for one client could be located in different sections of the warehouse, making if difficult to find all the pallets for despatch.

The loss of efficiency and cost can be significant (see box opposite).

Amcor looked to RFID technology as a way of capturing information on the location of each pallet.

At a glance

- The experience of the packaging industry shows radio frequency identification (RFID) can help save time and money in locating goods quickly and efficiently.
- RFID has cut the waiting time for truck drivers, reduced stocktake costs and minimised the amount of stock stored in the warehouse at any one time.
- The sheep industry could be losing millions of dollars because of the lack of information on individual sheep.
- RFID could be a way the sheep industry obtains quality information on which to base decisions.

What is RFID?

RFID has been around since World War II, when it was used to identify 'friend or foe' but is now has come of age where several frequencies can be used for different tasks.

The technology is a tiny piece of silicon (a microchip averaging 0.4 square millimetres in size) which can hold a small amount of information. The more information required, the larger the silicon needs to be and subsequently the higher the cost. The microchip is then attached to an antennae (either wire or conductive ink).

When energy (electricity) is pushed toward the antennae by a 'reader', the microchip is activated and releases its contents of information.

If the microchip has a battery attached, the signal can be 20,000 times stronger and the information (signal) can be picked up from a longer distance (10–30 metres).

64 FARMING AHEAD | No. 162 | July 2005

A passive tag (without a battery) can only use the energy it receives from the reader. As a result, the read range is significantly shorter.

The read range varies according to the frequency used (see Figure 1).

Microwave frequency at 2.45 gigahertz (Ghz) — This has a very short wavelength and without a battery it has a short read range, about 100mm but it transmits and responds quickly.

This frequency is commonly used for E-toll on freeways but it has a battery to extend its range (an aeroplane could fly past and the tag still would be read).

Very high frequency (VHF) or 900 megahertz (Mhz) frequency — This is the most common RFID tag, as it has the longest read range, with the simplest design, making it the cheapest to produce.

Typically, the tag is used for supply chain applications of dry non-metal goods (such as clothes and pallets).

A major drawback is that water or moisture absorbs the signal completely (for example, a human or animal body stops the signal if it is between the reader and tag). Metal scatters this signal, so it cannot be read.

High frequency (HF) or 13.56Mhz — This frequency has a short read range of 300–700mm, depending on the complexity of the tag and reader.

Although it is used for some cattle tagging in Australia and overseas, water and metal still limit the signal but not to the same degree as for VHF.

The packing industry has used the short read range to its advantage. For example, VHF frequency tags can be placed in the floor of a warehouse. As a forklift drives over them, a reader beneath the machine picks up the location as it is programmed into the tag. This enables operators to pinpoint where they are (requiring only a 300mm read range), not the locations to either side.

Then and now: a warehouse experience

Keeping track of products using radio frequency identification (RFID) has not only allowed packing company Amcor to find goods and deliver on time but there have been benefits in warehouse efficiency.

Before RFID

- At least one person per shift had to look for the correct goods to despatch.
- Multiple forklifts placed goods in the warehouse, so the previous pallet location of a job was not known to other drivers.
- At shift change meant a whole new pattern would be started.
- The 2000-pallet capacity warehouse regularly stored more than 3500 pallets.
- The factory would have to stop production while waiting for the warehouse to clear finished goods.
- Loads needed to be staged on the loading dock (creating double-handling and increased damage).
- An average of 12–20 trucks would wait 6–9 hours to be loaded.
- Remake of 'lost' pallet of cartons and waste of original product when 'found'.
- Below economic order quantity in remake.

After RFID

- The factory does not stop due to an inability to move out finished goods.
- Trucks only wait for 20–40 minutes.
- The warehouse seldom has more than 800–1000 pallets in storage (a reduction of 60 per cent or more).
- Reduced stocktake costs from 25 people for nine hours a month to six people for six hours twice a year (a 97% reduction).
- Reduced despatch staff by 45% and the remaining staff have considerable spare time.
- Loads are direct from the warehouse into trucks.
- All forklifts can load one truck together.
- Delivery dockets are printed by the time the driver arrives.

Low frequency (LF) at 125Khz and 134Khz — Commonly used to tag most cattle and pets, this frequency can have a slightly longer read range than the 13.56 kilohertz and has little problem with metal and moisture.

There are two major drawbacks with this frequency: the data speed is very slow, making it unsuitable for most applications where tags are moving (for example, an animal walking will be 'read' but not if it is running); and the tags do not have anti-collision capability. This means multiple tags in a reader field will respond at the same time and these signals will 'collide' and cancel each other out. In all other frequencies, signal collision has been overcome by 'smart' tags that wait for each other to 'talk' but it requires a high operating speed.

Dual-frequency (DF) tag — By operating on two frequencies manufacturers can take advantage of the best feature of two types of tags.

A reader transmits the energy to the tag at 125Khz, which will pass through most objects to get maximum power to the tag. Each tag then responds at a significantly higher frequency of 7Mhz, taking advantage of faster data speeds as well as providing anti-collision capability.

This frequency is ideally suited to animal tagging.

Selecting a frequency

Amcor chose the 13.56Mhz frequency to tag the floor and the dual-frequency tag to identify paper reels due to the moisture content of paper (8%) which made VHF almost useless.

Trials using VHF showed signals were lost at 500mm of paper but Amcor required a range of at least 1200mm.

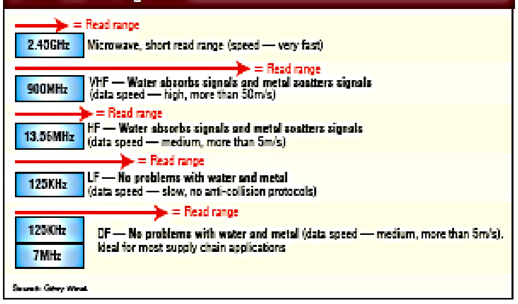
By using both 13.56Mhz and dual-frequency, the company could track paper reels from their manufacture until they were fully consumed in making cardboard for packaging.

The system works by the reader 'seeing' the dual-frequency tag as the forklift picks up the paper reel. The reader identifies the reel, linking it with computerised information from the paper mill. As the forklift drives to a storage location in the warehouse, the reader under the machine identifies the exact spot using the floor tags. The location is displayed on an on-board computer and the operator presses 'enter' on the keyboard to record the information.

This allows other operators to locate a specific reel quickly when required.

Paper reels in use are monitored by a reader located under the reel stand near cardboard manufacturing equipment, which confirms the correct paper is being used.

FIGURE 1 RFID tag choice



Source: Gerry Wind.

Combining technologies

Because RFID tags are still too expensive for single-use applications, a combination of RFID and bar codes also trace finished goods in storage.

The bar code system, which is similar to RFID, has a high-resolution scanner mounted on the mast of the forklift to scan the bar code when a pallet is picked up (the bar code is placed by machine in the same place each time).

With RFID tags in the floor, the goods were now linked to the location recorded in the computer.

For Amcor, all that was required was to know where the goods were, to find them easily and deliver on time. But when the system had been operational for a time, the company discovered considerably more benefits than anticipated such as faster despatch, less warehouse space being taken up in storage and considerable labour savings (see box, page 65).

Putting technology on farms

The experience of the packaging industry is food for thought for sheep producers deciding how best to introduce electronic identification technology on-farm.

The critical issue is to associate the product with a unique identification number, which can be captured, kept and read without human involvement.

The cost of labour and the inability of technology to meet needs in the past meant sheep were dealt with as flocks and not as individual animals.

RFID technology, for example, offers one possibility of separating individual animals. In farming, an added factor is that livestock moves itself — producers no longer have to be in the paddock to capture information about what each sheep is doing, instead, by placing readers in strategic places, animals can be monitored and drafted automatically (the Sheep Co-operative Research Centre has been working toward this).

Information is vital

What electronic identification technology means to the sheep industry is quality information on which to base decisions.

The sheep industry could be losing millions of dollars because of the lack of information on individual sheep.

Compare that with the wine industry, which sells wine on quality that leads to awards and hence higher prices. A quality wine can cost 5–10 times more than low-cost wines. If wine makers followed the sheep industry example they would sell all wines based on what the general trend was at the time.

Within 10 years, the sheep industry could look completely different. Companies would own large properties and manage sheep on an individual basis. Sheep and wool buyers would access databases of these companies and identify the qualities they want (weight, size, breed, fibre thickness, treatments) and deal with the producer directly to obtain larger quantities.

There will be significant savings in the supply chain and productivity gains for producers. Those business owners with foresight (as throughout history) will be the ones to grow large companies and make this happen.

About the author

Gerry Wind is a consultant based in Brisbane, Queensland.

Email: gerry.wind@optusnet.com.au
Phone: 0422 139 846.