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# Technical Report

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**Report Title:** On farm and abattoir suitability of microwave scanner system design

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## Abstract

This report details the development of a low cost, portable hand-held Microwave System as an objective measurement technology for measuring various traits in cattle and sheep, live animal and carcass.

## Executive summary

- The first experimental work of microwave system used the commercial Keysight FieldFox Vector Network Analyser (VNA) with frequency range 30kHz – 6.5GHz. However the system was not user friendly due to its size, weight and technical issues including a short battery life and temperature instability in the chiller. Furthermore the cost of the system was expensive thus with all factors considered this system was deemed not suitable for the abattoir environment
- The ALMTech Murdoch University Meat Science Engineering department designed and fabricated a portable hand-held microwave system from readily available, off the shelf components. The system operates at 80MHz – 5.4GHz with a Dynamic Range of 97dB. The system has gone through 4 generations of testing to create a portable, robust and light weight prototype ready for widespread commercial testing

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# 1 Milestone description

Design and development of low cost portable handheld Microwave System for feedlots/farms and abattoirs in Australia meat industry.

# 2 Project objectives

The overall objective of this work is the design and development of a low cost, portable, microwave scanning device. To ensure successful industry adoption and commercialisation of the device the proposed system must accommodate chain speed, chiller temperature, food and operator safety. The system will be used on cattle/sheep at feedlots/farms and on beef/lamb at abattoirs for the various traits measurements.

# 3 Methodology

## 3.1 Initial Microwave System (06/10/2017 - 04/05/2018)

The initial system was developed using a commercial vector network analyser (VNA) called “FieldFox” from Keysight Technologies (Figure 1). This is technology was designed for general application use in telecommunication industries, including in AM/FM tune and listen, cable and antenna analysis, field strength measurement, SCPI code compatibility, Spectrogram and stimulus response.

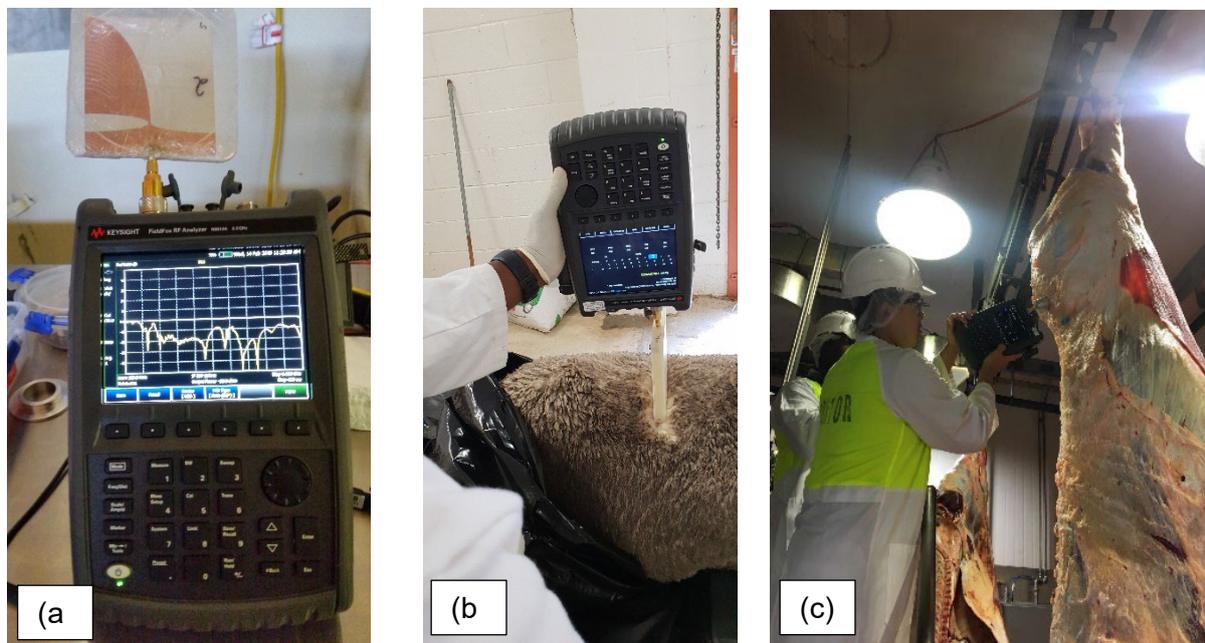


Figure 2 The initial Microwave system Using (a) Keysight FieldFox with Vivaldi Patch Antenna (b) Scanning live sheep (c) Scanning beef carcass.

Testing commenced on 6<sup>th</sup> October 2017 at JBS Australia, Bordertown, South Australia. The initial microwave system was tested at the following sites:

- Lamb carcase
  - a) JBS, Bordertown, South Australia
  - b) WAMMCO, Katanning, Western Australia
  - c) Murdoch University Animal House, Western Australia
- Beef carcase
  - d) JBS, Longford, Tasmania

Following the initial measurements further assessments were made;

Advantage:

1. Wide range of frequency selection from 30kHz – 6.5GHz
2. Full 4 port measurement by using two antennas (S11, S12, S21, S22)
3. Frequency and time domain analysis
4. Dynamic Range 100dB
5. Excellent safety packaging and mechanical stability
6. Self-life batteries

Disadvantage:

1. Heavy (3 kg) with dimension 300 mm x 200 mm (without antenna) not suitable for abattoirs and chillers
2. The operating system not suitable for untrained operators. This system would require extensive knowledge and training for operation
3. Sensitive to ambient temperature not able to use longer than 1hour in the chiller temperature below 5°C. System unstable.
4. Expensive. The system alone retails at approximately \$45,000 (not including antennae)
5. Heavy battery consumption, not suitable for long hour usage.
6. Not able to change the firmware. Fixed firmware and required support from Keysight
7. High maintenance cost.
8. Issue with online calibration.

Previous submitted reports have discussed the ability of the initial microwave system, for reference please refer to;

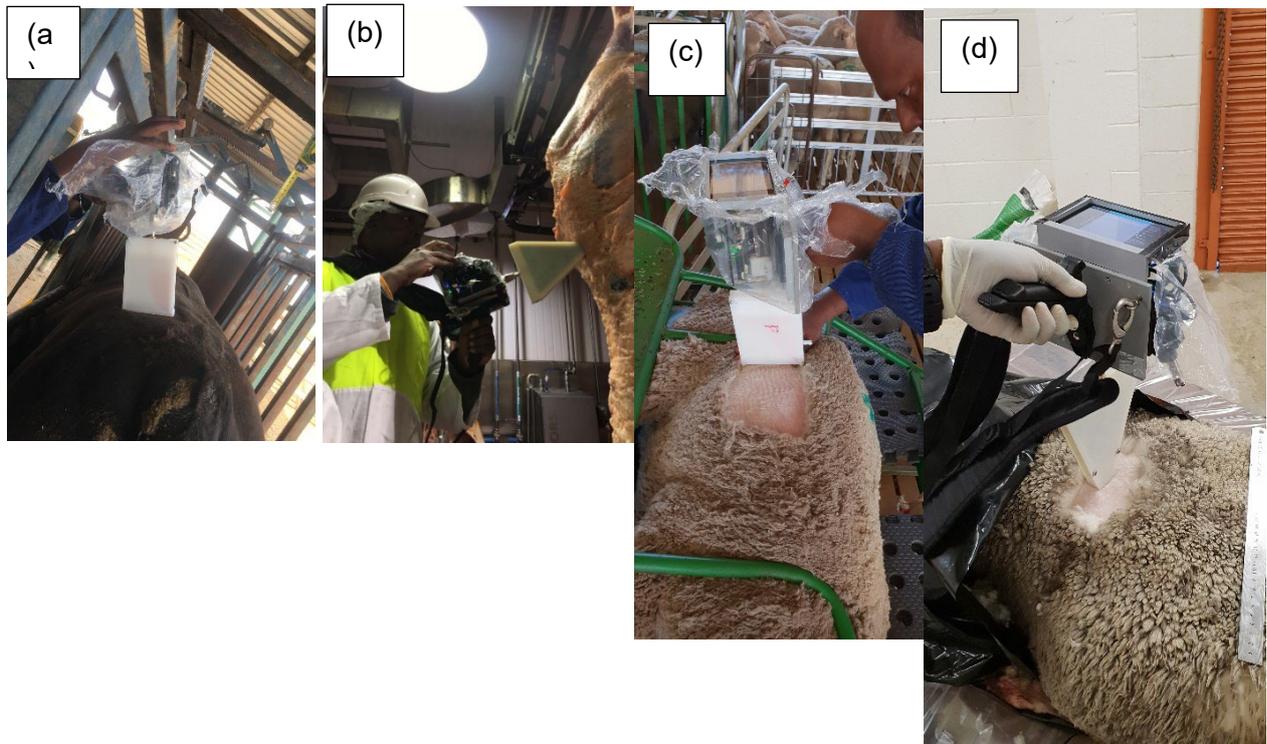
- Report KPI 4.4 “Non-invasive Technology using Low Cost Portable Microwave System on Carcass for Fat Depth Measurement”
- Report KPI 6.6.3a “Validation testing of microwave technology across separate devices to detect beef carcass fatness at the ribbing site and the P8 site in abattoirs”

### 3.2 1<sup>st</sup> Generation Microwave System (04/05/2018 – 26/03/2019)

Based on issues listed above, ALMTech team developed and designed own Microwave System as shown in Figure 2 for meat industries. Two units of this system designed and build by ALMTech crew members using various components from the shelf (readily available components). The system small, light and portable and used widely in the abattoirs and feedlots for the microwave scanning and measurements as shown in Figure 3.



*Figure 3 The Murdoch University (ALMTech) prototype Microwave System (1st Generation) design and build by ALMTech crew members.*



*Figure 4 The 1st Generation Microwave System in commercial feedlots and abattoirs (a) Cattle feedlots in Tamworth NSW (b) JBS Australia Longford Tasmania Beef Abattoir (c) Katanning Research Facilities, Katanning, WA (d) Murdoch Animal House, WA*

Initially the system tested in various abattoirs across Australia as stated below:

- a) JBS Australia Bordertown Lamb Abattoir, South Australia
- b) WAMMCO Katanning Western Australia Lamb Abattoir
- c) Farm Murdoch Animal House, Western Australia
- d) JBS Australia Longford Tasmania Beef Abattoir
- e) Katanning Research Facility Sheep Feedlots
- f) NH Beef Abattoir, Wingham NSW
- g) John Dee Beef Abattoir, Warwick QLD
- h) Australian Country Choice (ACC) Abattoir, Canon Hill QLD
- i) Cattle Feedlots in Tamworth, NSW
- j) Tullimba Cattle Smart Farm, Tullimba NSW
- k) ACC Cattle Feedlots, Brisbane Valley QLD

Based on measurements listed above on live animal and carcasses in farms, feedlots and abattoirs, we picked up various issues pertaining the usability of the proposed microwave system as sated below:

Advantage:

1. Wide range of frequency selection from 80MHz – 5.4GHz, good for biological tissue
2. Light weight less than 1.5kg, overall dimension 150mm x 150mm (without antenna)
3. Battery operatable using mobile power bank, dismountable and chargeable
4. One port measurement by using one antennas (S11)
5. Frequency and time domain analysis
6. Dynamic Range 97dB
7. Simple system with manageable firmware, software and hardware
8. Low cost, handheld and portable system

Disadvantage:

1. Poor packaging, not suitable for abattoirs and feedlots, the hardware covered with plastic sheet only
2. Sensitive to ambient temperature not able to use longer than 1hour in the chiller temperature below 5°C. System unstable and touch screen fail.
3. Touch screen monitor not suitable for the chiller at freezing temperature
4. Cable and other parts are very fragile

Previous submitted reports have discussed the ability of the 1<sup>st</sup> generation microwave system, for reference please refer to;

- Report KPI 6.6.3a “Validation testing of microwave technology across separate devices to detect beef carcase fatness at the ribbing site and the P8 site in abattoirs”
- Report KPI 6.6.3b “Development and validation of microwave system at ACC”

### 3.3 2<sup>nd</sup> Generation Microwave System (04/05/2018 – 26/09/2019)

Six units of this system developed and used widely in the abattoirs and feedlots for the microwave scanning and measurements. System was designed and build by ALMTEch – ED2 crew members.

The newly developed system is shown in the Figure 5. The new design comes with build in battery and touch screen also it is now suitable to take the system into abattoir and farm for measurements. Figure 6 shows the measurements done in different locations.



Figure 5 ALMTEch Microwave system, based on the Second-Generation system.



Figure 6 The proposed Microwave System used for various measurement (a) Live sheep measurement at feedlots (b) Lamb carcass measurement at abattoir (c) Beef carcass P8 fat depth measurement at abattoir (d) Beef carcass Rib fat depth measurement at abattoir

Initially the system tested in various abattoirs across Australia as stated below:

- a) JBS Australia Bordertown Lamb Abattoir, South Australia
- b) WAMMCO Katanning Western Australia Lamb Abattoir
- c) Farm Murdoch Animal House, Western Australia
- d) JBS Australia Longford Tasmania Beef Abattoir
- e) Katanning Research Facility Sheep Feedlots

- f) NH Beef Abattoir, Wingham NSW
- g) John Dee Beef Abattoir, Warwick QLD
- h) Australian Country Choice (ACC) Abattoir, Canon Hill QLD
- i) ACC Cattle Feedlots, Brisbane Valley QLD

Based on measurements listed above on live animal and carcasses in farms, feedlots and abattoirs, we picked up various issues pertaining the usability of the proposed microwave system as sated below:

Advantage:

1. Wide range of frequency selection from 80MHz – 5.4GHz, good for biological tissue
2. Light weight less than 1 kg, overall dimension 120mm x 120mm (without antenna)
3. The system has built in battery.
4. One port measurement by using one antennas (S11)
5. Frequency and time domain analysis
6. Dynamic Range 97dB
7. Simple system with manageable firmware, software and hardware
8. Low cost, handheld, friendly usable and portable system.

Disadvantage:

1. Touch screen monitor not suitable for the chiller at freezing temperature
2. Not strong body, very soft and fragile cover
3. Issue with in-house developed Python programming for data acquisition.
4. Need to open the system to charge the battery and system not showing the life of the battery

### 3.4 3<sup>rd</sup> Generation Microwave System (26/09/2019- 25/06/2021)

All the previous 2<sup>nd</sup> generation system were updated to 3<sup>rd</sup> generation by adding new features. The updated version of the 2<sup>nd</sup> generation Microwave handheld device will have a trigger button to take measurements and a small cooling fan on the side to cool down the device in summer. Figure 6 shows the updated Handheld microwave units.

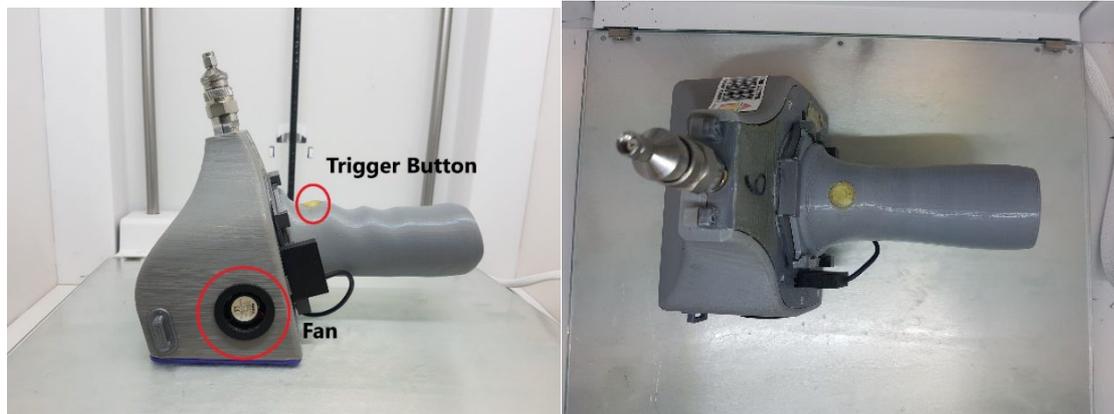


Figure 9 Updated Microwave handheld device



Figure 10 Live cattle measurement at feedlots using Horn Antenna with new antenna holder.



Figure 7 Beef carcass hot P8 and Rib fat depth measurement at abattoir kill floor using a spring balancer.



Figure 8 Live cattle measurement at feedlots using VPA Antenna with new antenna case.

Figure 9 shows how we used the microwave handheld unit with a spring balancer for hot carcass measurements at kill floor with continuous power supply. The advantages of the using microwave handheld unit with a spring balancer are stated below:

- The system available for the hot carcass measurement at any time during the abattoir operating hours.
- The system also can be used for cold carcass measurements in the chiller. The system can be hanged with spring balancer and continuous power supply at available rail outside the chiller and measurements can be taken while the cold carcass moves.
- The system in spring loader (with power continuously charging) will make possible measurements of hot/cold P8 and Rib fat at one go.

- By connecting the device to a power supply, we can use the device 24 X 7.
- With inbuilt battery in the system we can disconnect the device and take out from the spring balancer if the area of measurement is difficult to take measurement. Once finish we can easily put the system back to spring balancer.
- The abattoir operators can handle the system with minimum supervision.
- Easy to maintain and clean.

We tested the updated Microwave handheld units in

- a) WAMMCO Katanning Western Australia Lamb Abattoir
- b) Farm Murdoch Animal House, Western Australia
- c) Katanning Research Facility Sheep Feedlots
- d) Australian Country Choice (ACC) Abattoir, Canon Hill QLD
- e) Tullimba Cattle Smart Farm, Tullimba NSW

Based on measurements listed above on live animal and carcasses in farms, feedlots and abattoirs, we picked up various issues pertaining the usability of the proposed microwave system as sated below

#### Advantages

- The trigger button helps to take the measurements easily.
- Fan helps to cool down the system to certain level.
- New casing for antenna makes it stable and strong.
- The device is only 0.8 kg without antenna.

#### Disadvantages

- Battery drains quickly.
- Trigger button connection going through outside makes it uncomfortable to take measurements.
- Device casing to not strong.
- Need a barcode reader for accurate data collection.



*Figure 11 Portable cooling system made for Live sheep measurement at Katanning Research Facilities.*

Figure 11 shows the portable cooling system designed and developed by ALMTech team at Murdoch University for live sheep measurements at Katanning Research Facilities. The portable air condition unit and with polystyrene box as shown in Figure 11, connected to a flexible ventilation duct exhaust hose. In future this can be replaced with spring balance for the long hour measurements without power disturbance.

### Advantages

- The cooling system helped us to cool down the handheld unit from 40° Celsius to 18° Celsius during the whole day measurements.
- Its portable and can be used to long-hour measurements.
- Specially in farm measurements it helps for whole day data collection.
- Helps to cool down multiple devices for measurements.

From all the data collection in farm, feedlots and kill floor we picked up some issues that we faced while using the device. All these issues are noted and solved for the next version of Microwave handheld system.

### 3.5 4<sup>th</sup> Generation Microwave System (1/08/2020)

Eight units of this system is going to be developed used widely in the abattoirs and feedlots for the microwave scanning and measurements. System was designed and build by ALMTech

The newly developed system shows in the figure 6 will be developed soon. The new system will have 4.7Ah battery which will allow us to use the device for 4 hours continually. The device will be weight balanced so that we can attach the device to a spring balancer for abattoir use.

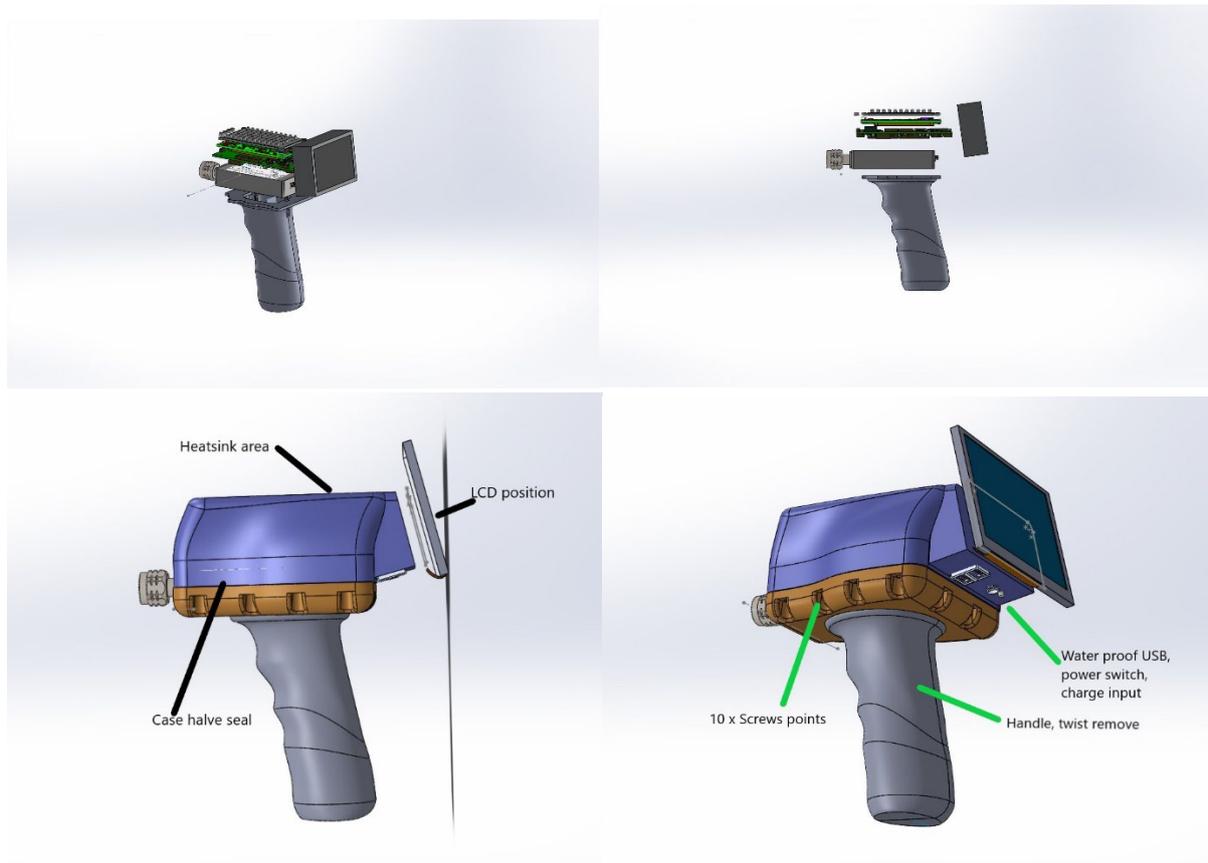


Figure 12 Proposed new design for Microwave handheld unit.

#### Advantage:

1. Modular design allows different LCD sizes while only changing the LCD housing - (not shown).
2. Twist and lock handle provide strong attachment.
3. Heatsink mounted topside prevent overheating.
4. IP67 USB/Power input/switch and LEDs.
5. Strong top and bottom sections could have added moisture ingress.
6. Better Trigger button.
7. Buzzer installed
8. Inbuild Wi-Fi and Bluetooth module.

9. Better battery.
10. Better touch screen display which can work in abattoir temperature.
11. Easily cleanable design.
12. Inbuild barcode reader.
13. Hardcase for all different types of antenna.
14. Weight balanced system so that we can hang in a spring loader for abattoir use.

## **4 Success in meeting the milestone**

A new microwave scanner is being developed at the moment. New better low battery consumable computer module will be installed with 4.0Ah battery pack. Which will allow us to use the device for at least 4 hours continually. The device is simple to use with no specific training required apart from correct placement of the antenna/probe. The device is portable, able to operate at industry speeds and poses no risk to operators or food safety. The spring balancer will be excellent solution for the abattoirs and farm measurements.