Microwave System for Non–destructive Measurement on Carcass Fat Depth in Abattoirs

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MEAT & LIVESTOCK AUSTRALIA

RESEARCH FOR A GOLD STANDARD OUTCOME

ALMTech

Advanced Livestock Measurement Technologies

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Outline

- Background of microwave technology for fat measurement
- Lamb back fat depth experiment using microwave technology
- Microwave predicts fat depth
- Future development of test unit and array design

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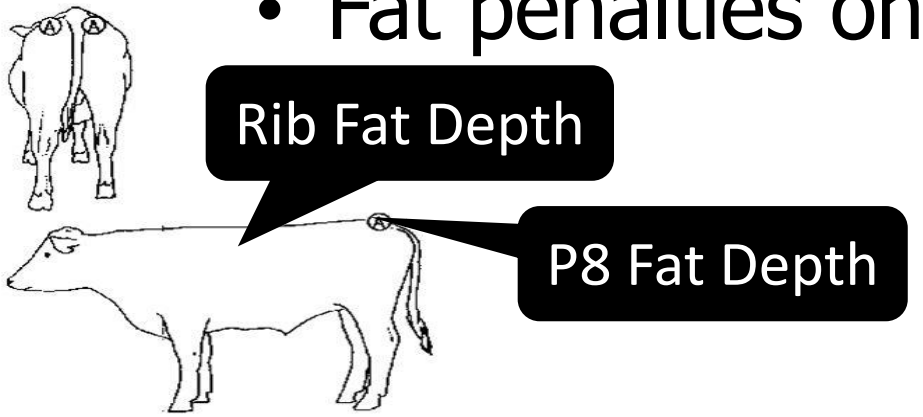
Trading beef and lamb

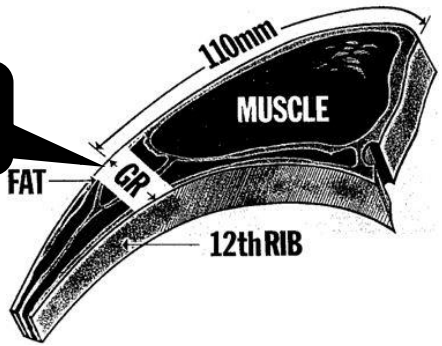
- Traded largely

on carcase weight

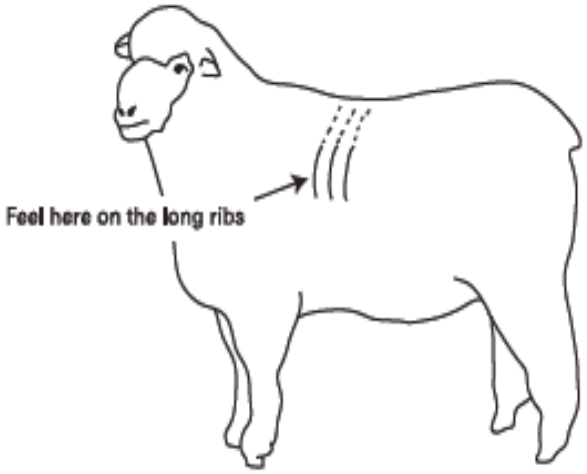
- Fat penalties only at the extremes

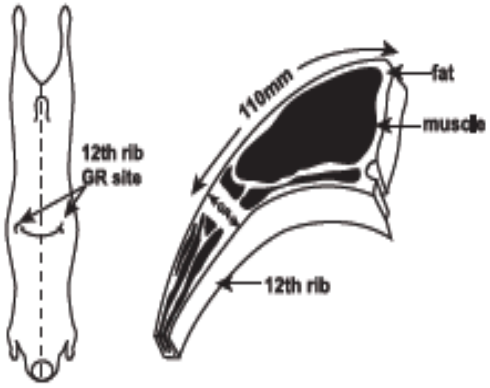


GR tissue depth



Are there solutions for non-invasive measurement?





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Microwave Definition

- You can’t cook with it!

- Frequency similar, but…
- Power much higher!

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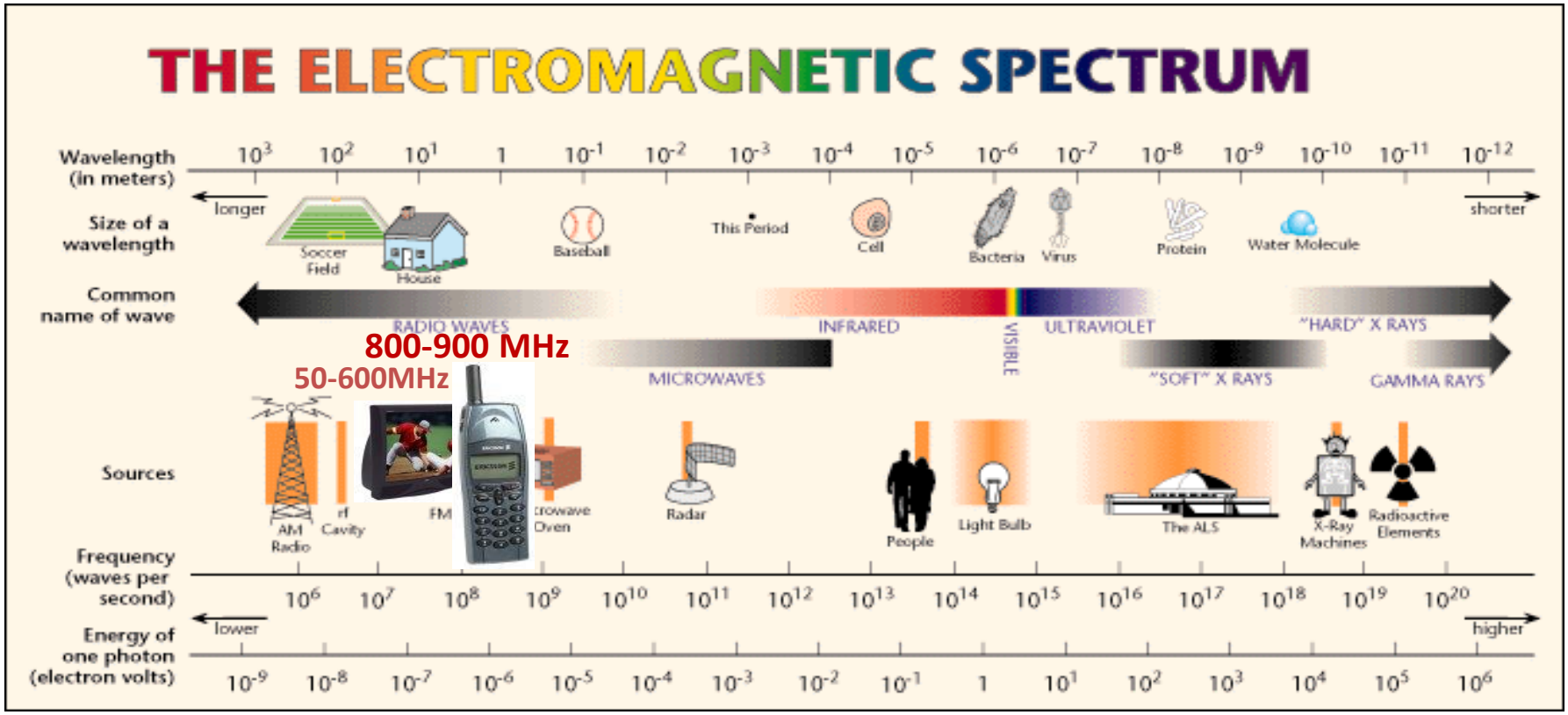
Microwave Definition



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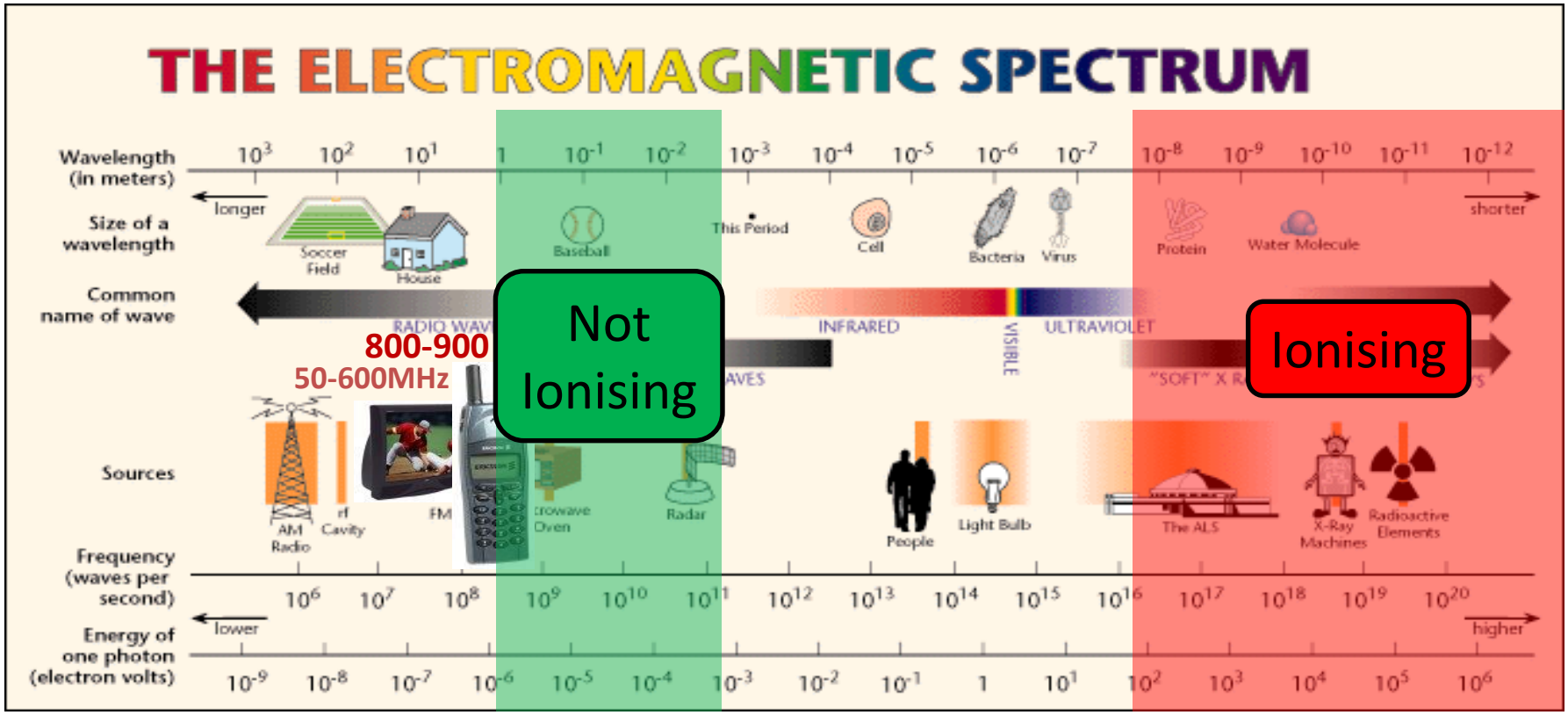
Microwave Definition



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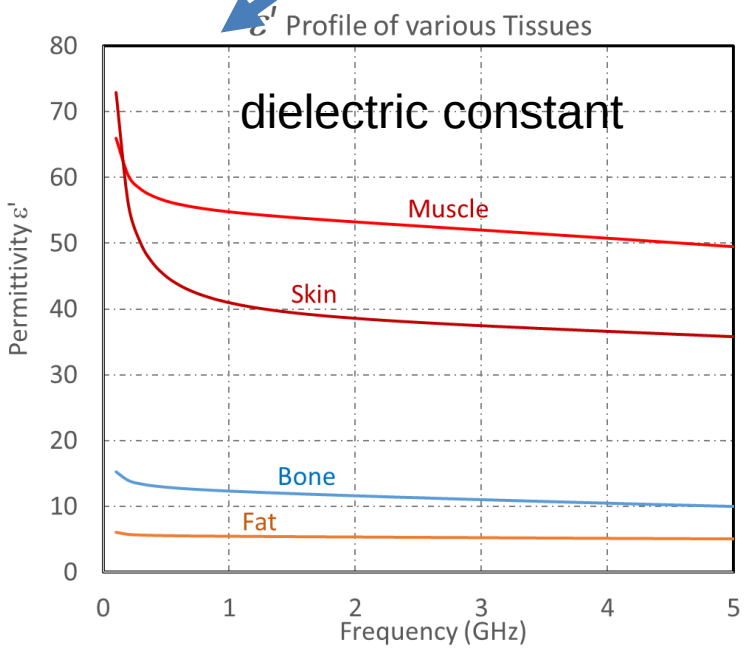
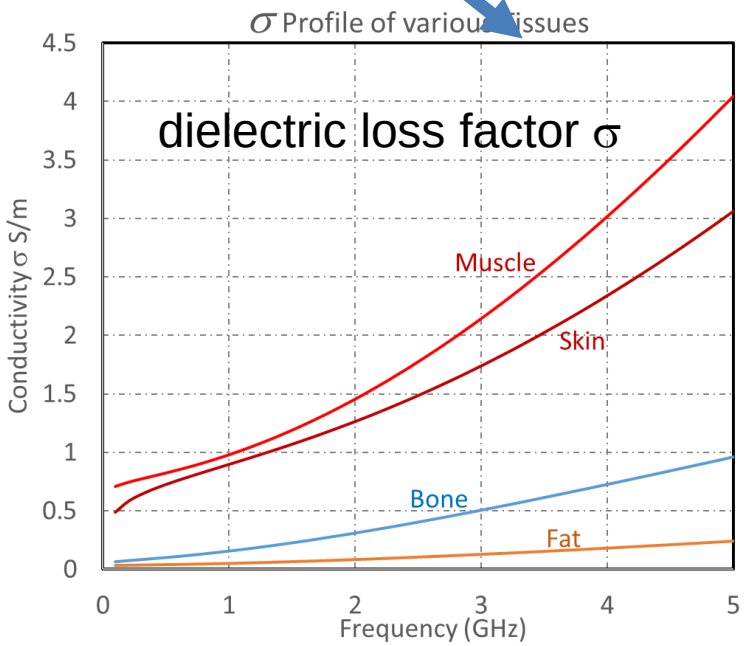
Microwave and Biological Tissues

Permittivity

$$\varepsilon^* = \varepsilon' - j\varepsilon''$$





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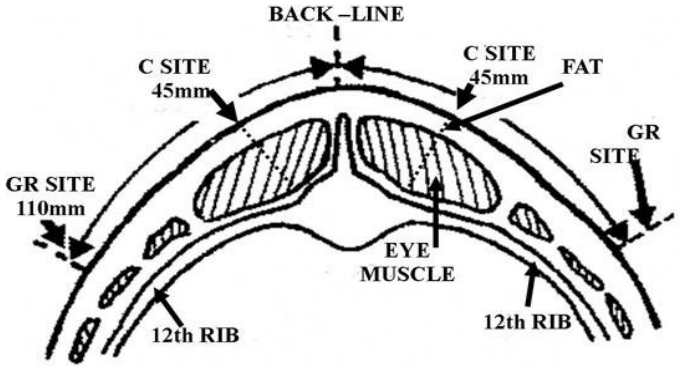
Microwave & Biological Tissues

Permittivity ε ⟹ **Impedance** Z ⟹ **Reflection Coefficient** Γ

Impedance Z ⟹ **Transmission Coefficient** T



Skin	Fat	Muscle
ε = 38	ε = 5.27	ε = 52.7
Incident wave (1.0)	Transmitted wave (0.54)	Transmitted wave (0.26)
Reflected wave (0.46)	Reflected wave (0.28)	

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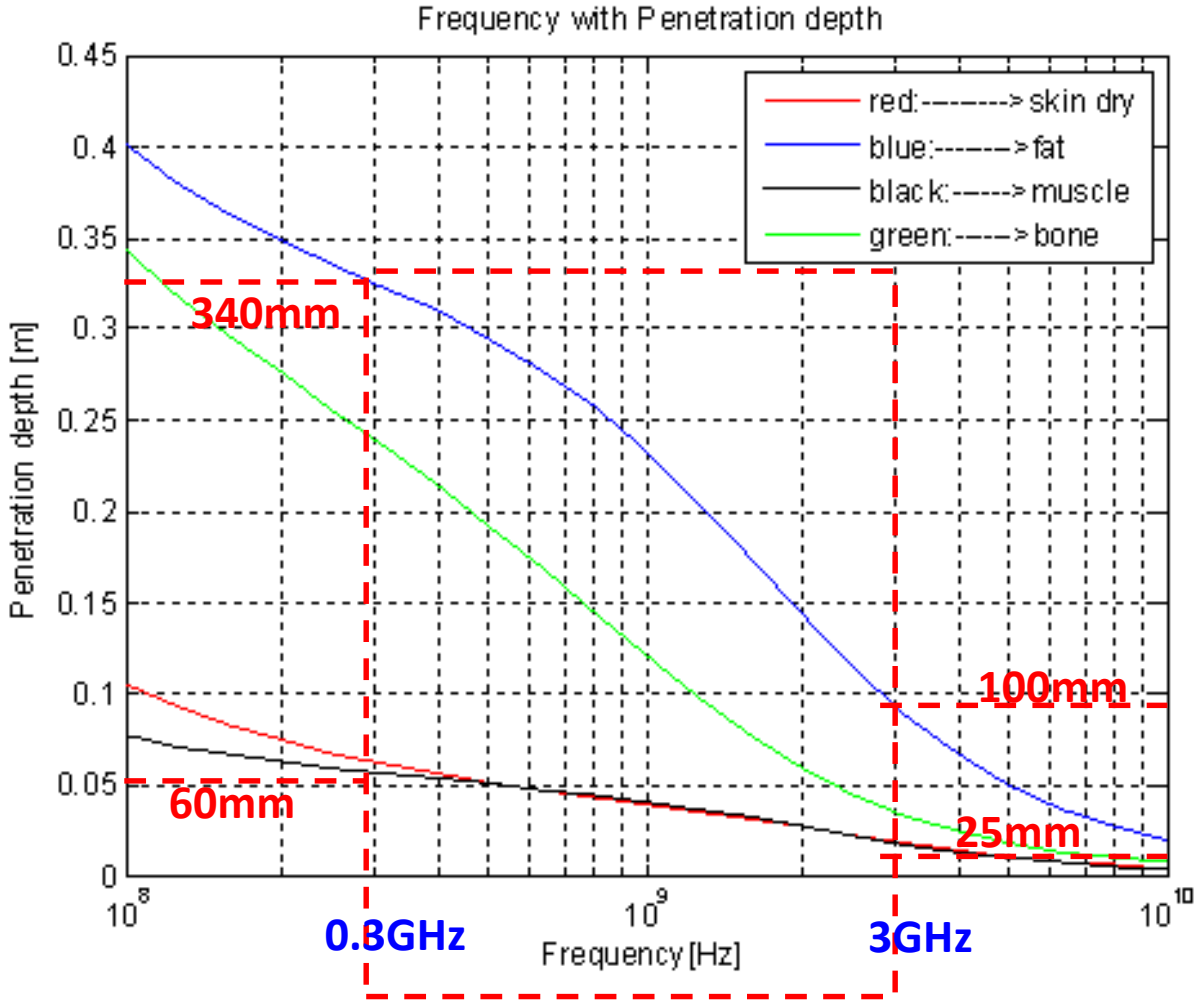
Penetration Depth for Biological Tissues



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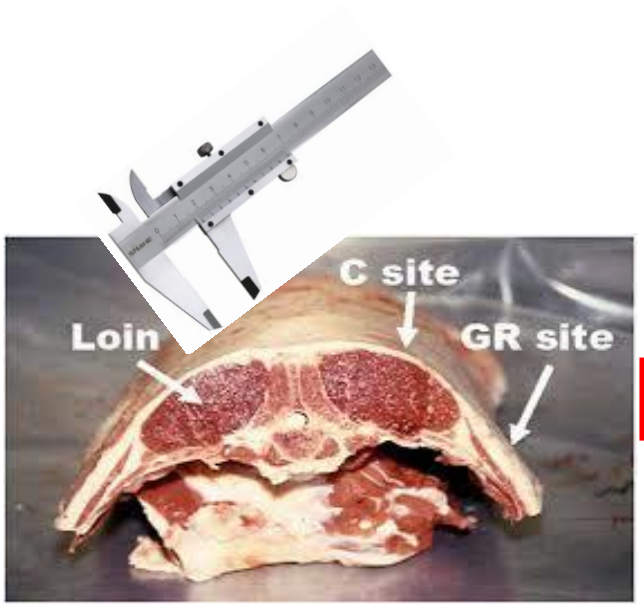
Hypothesis

Microwave Technology can estimate **fat depth in lamb carcases**



Non-Invasive

Non-Destructive

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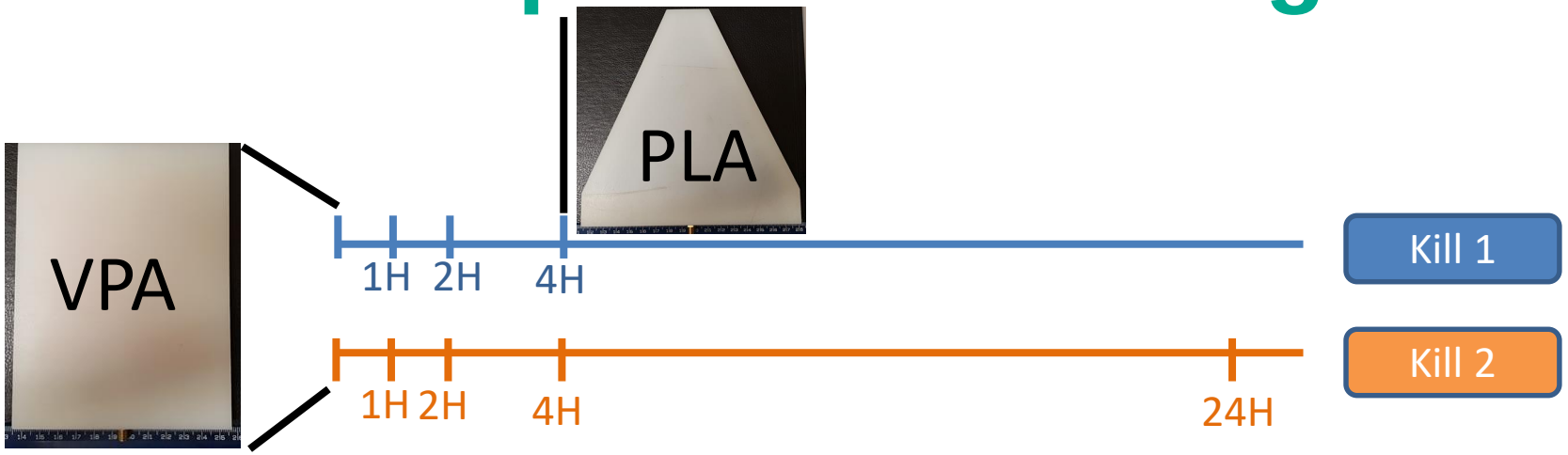
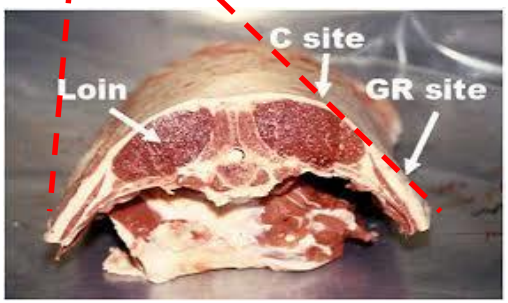
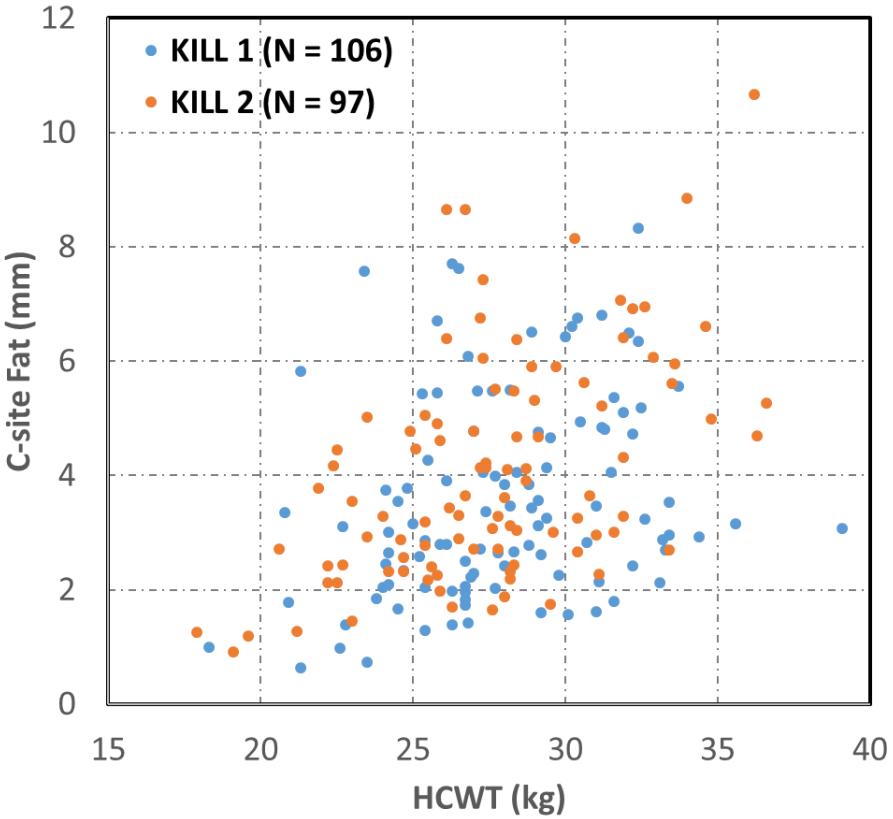
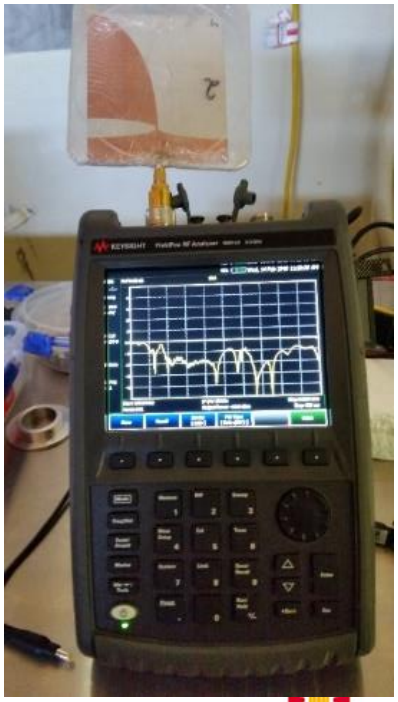
Methods

Experimental Design









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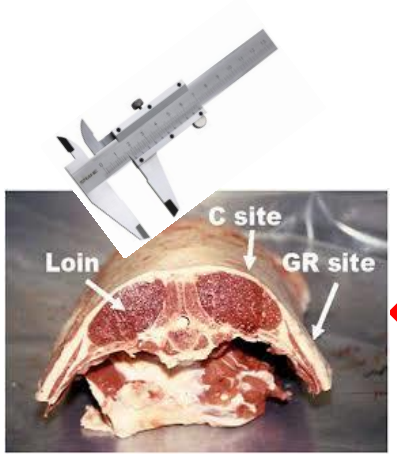
Data Analysis

Device Calibration

Microwave Measurement
$f_n(\Gamma_{mn}, \Gamma_{\varphi n})$ n = 1 to 311

Data Calibration
$f_n(\Gamma'_{mn}, \Gamma'_{\varphi n})$

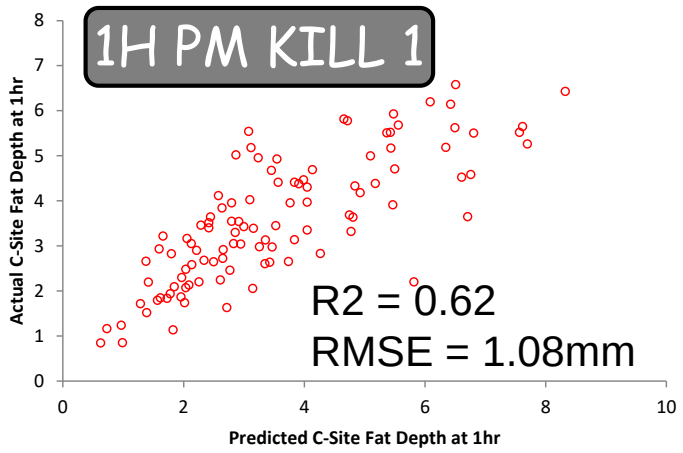


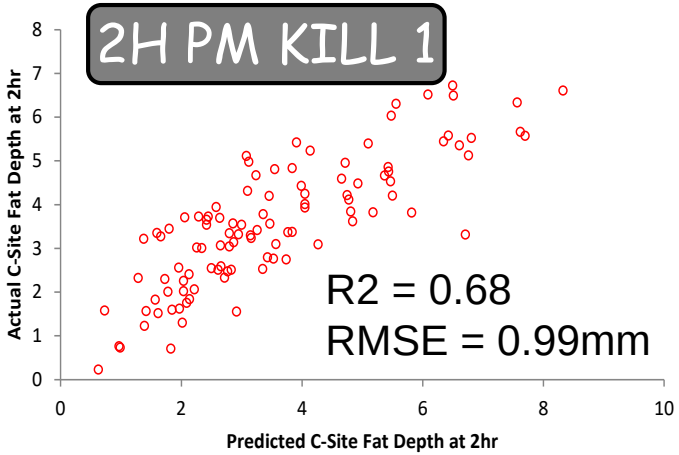
Partial Least Squares (PLS) Regression using leave-one-out cross validation

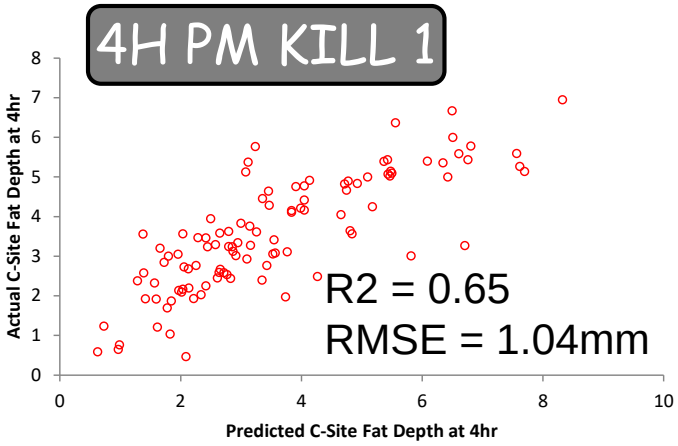
Results

Performance in training data

Microwave Prediction of Fat Depth

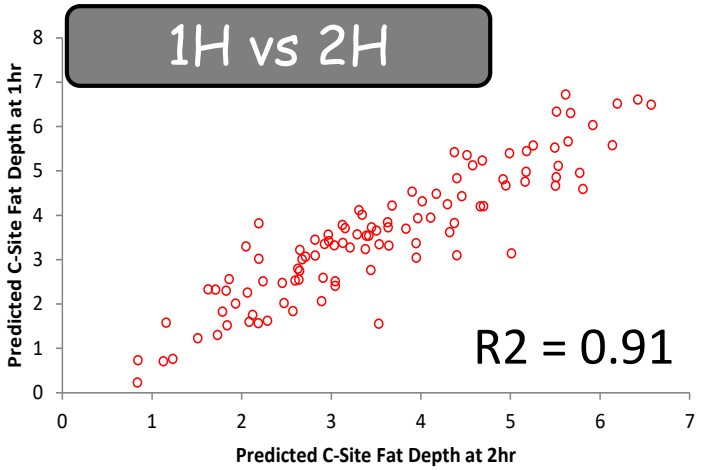


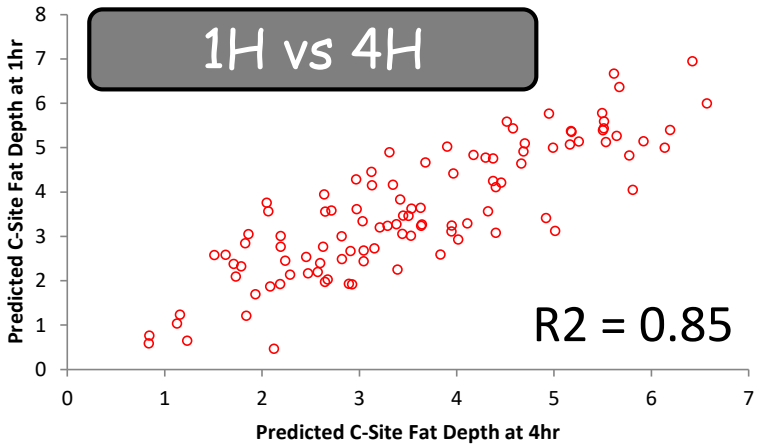


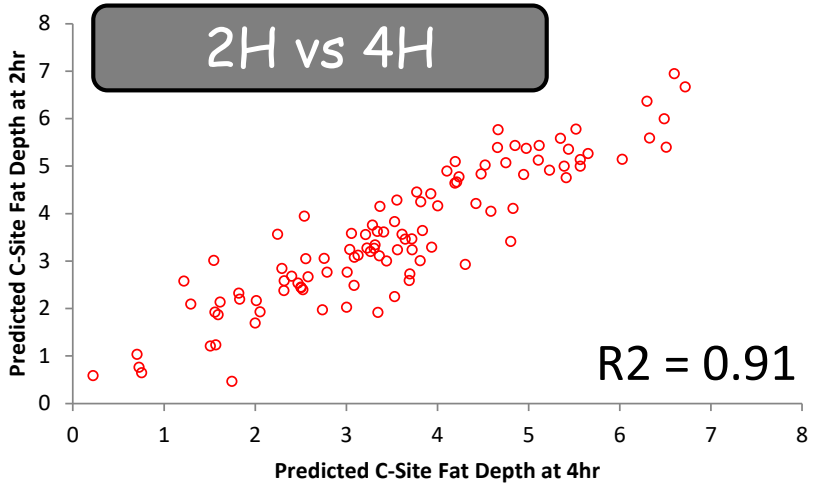


	Kill 2			
	N = 97			
	1h	2h	4h	24h
R^2	0.62	0.58	0.64	0.63
RMSE (mm)	1.22	1.34	1.18	1.19

Microwave Repeatability KILL 1







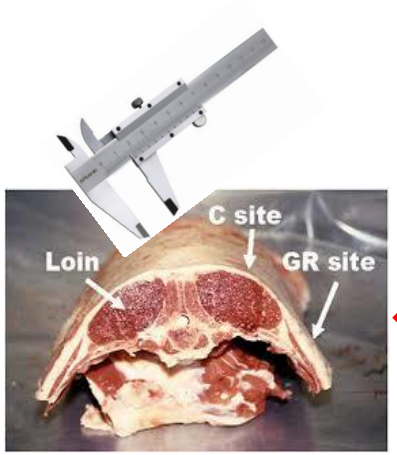
But does it transport?

Transportability & Validation

Device Calibration

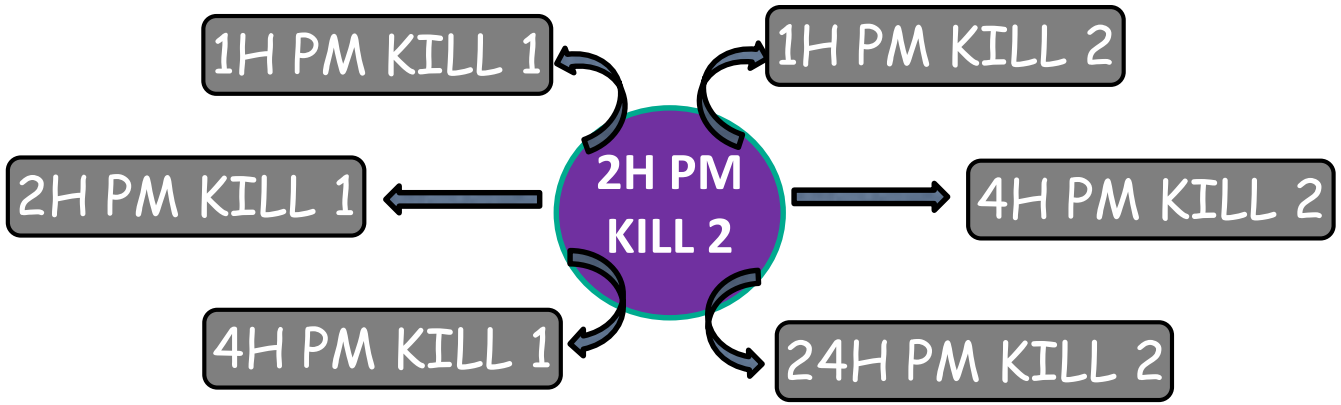
Microwave Measurement
$f_n(\Gamma_{mn}, \Gamma_{\varphi n})$ n = 1 to 311

Data Calibration
$f_n(\Gamma'_{mn}, \Gamma'_{\varphi n})$



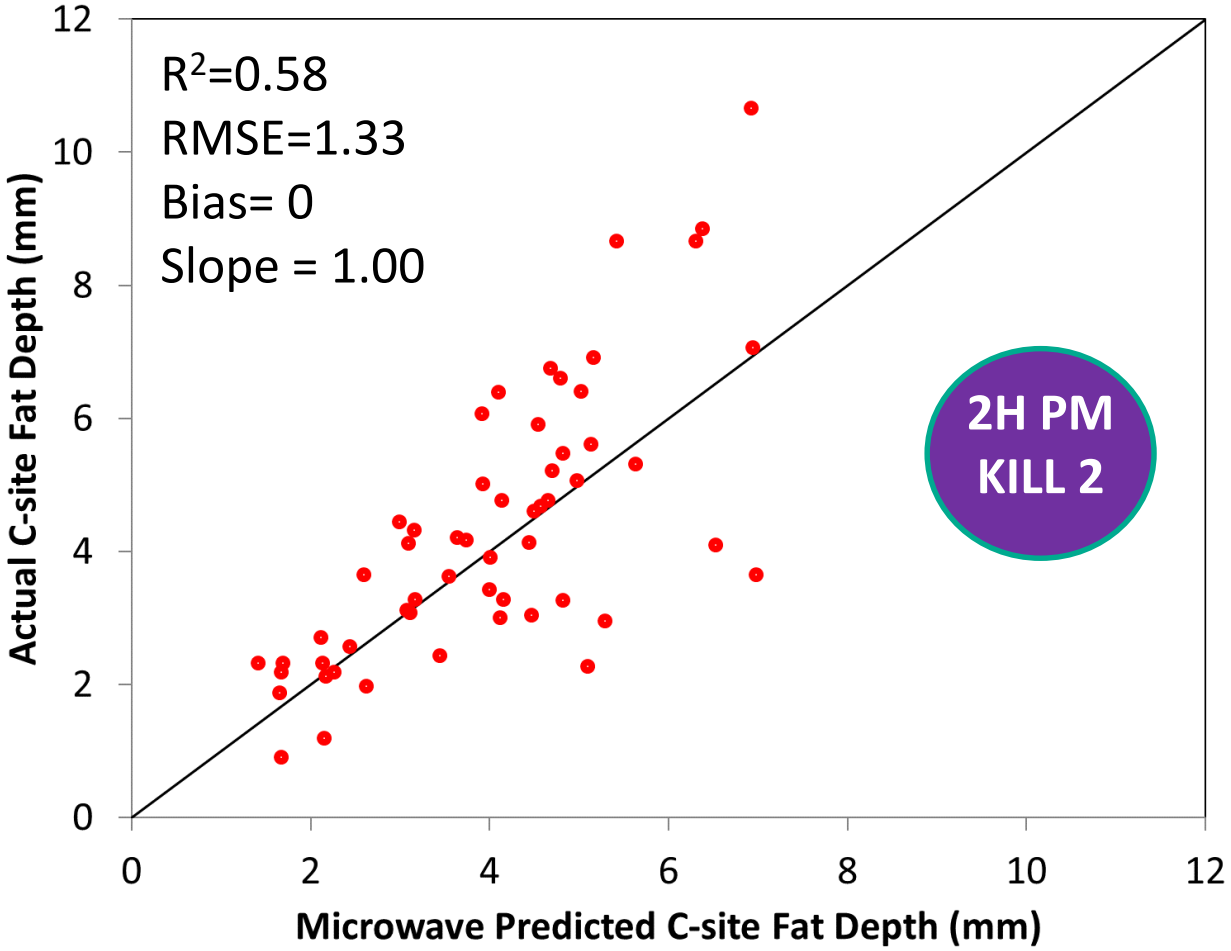
Partial Least Squares (PLS) Regression using leave-one-out cross validation

Validation



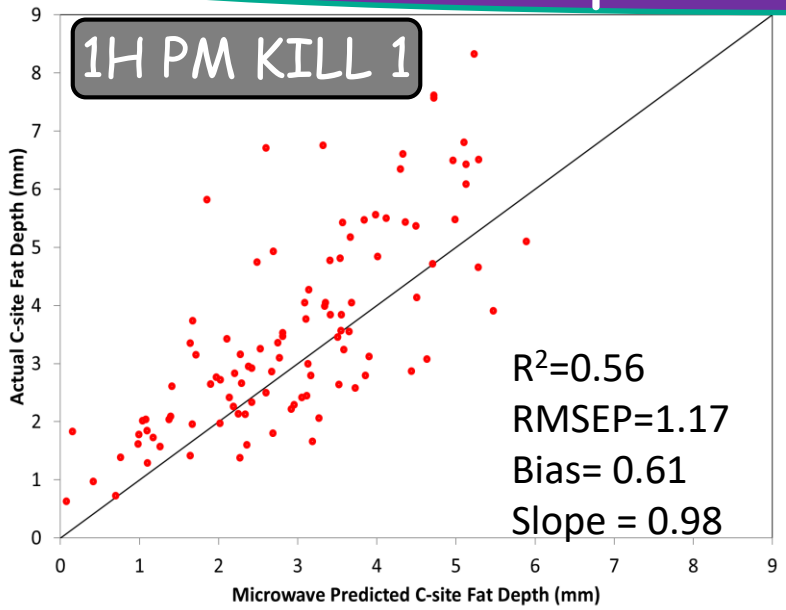
Does Microwave Transport?

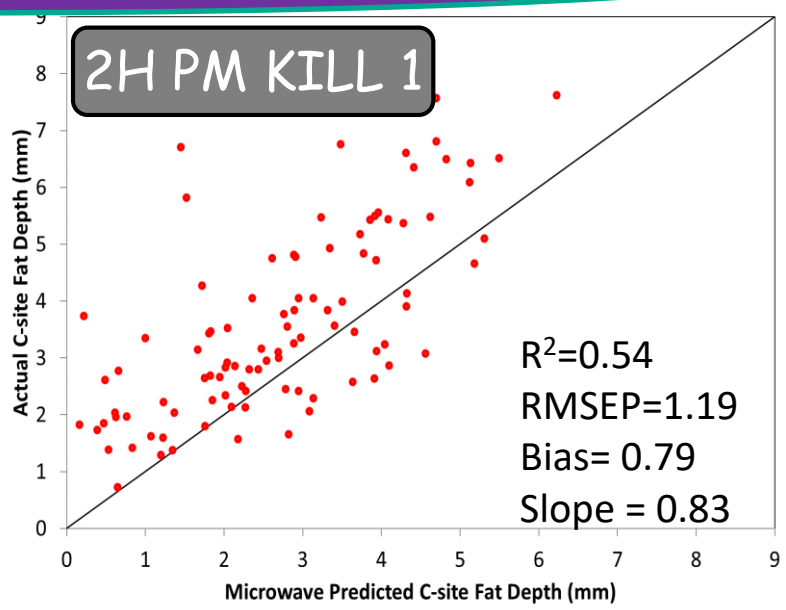
Lets transport this one!

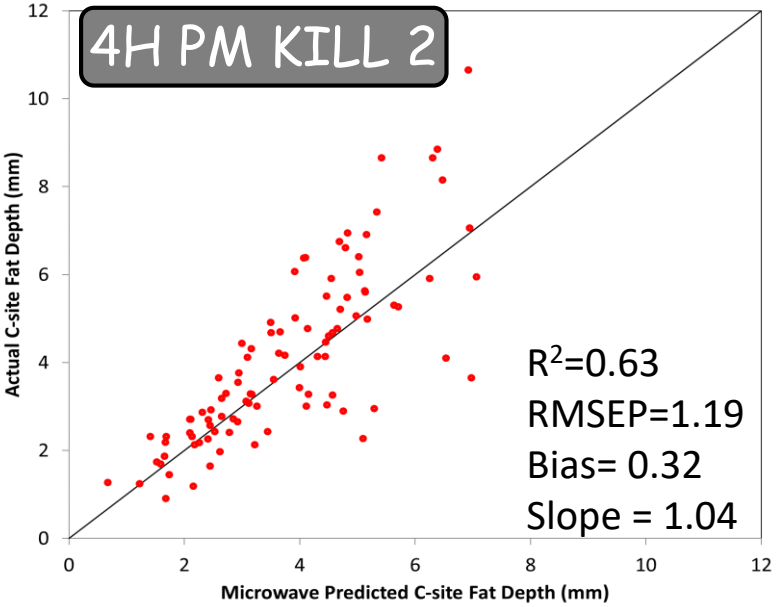


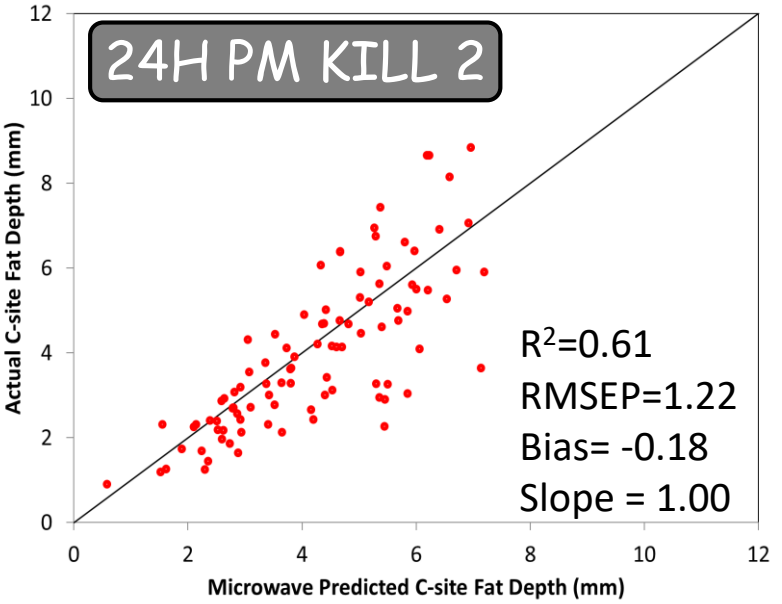
Does Microwave Transport?

Transported from 2H PM KILL 2



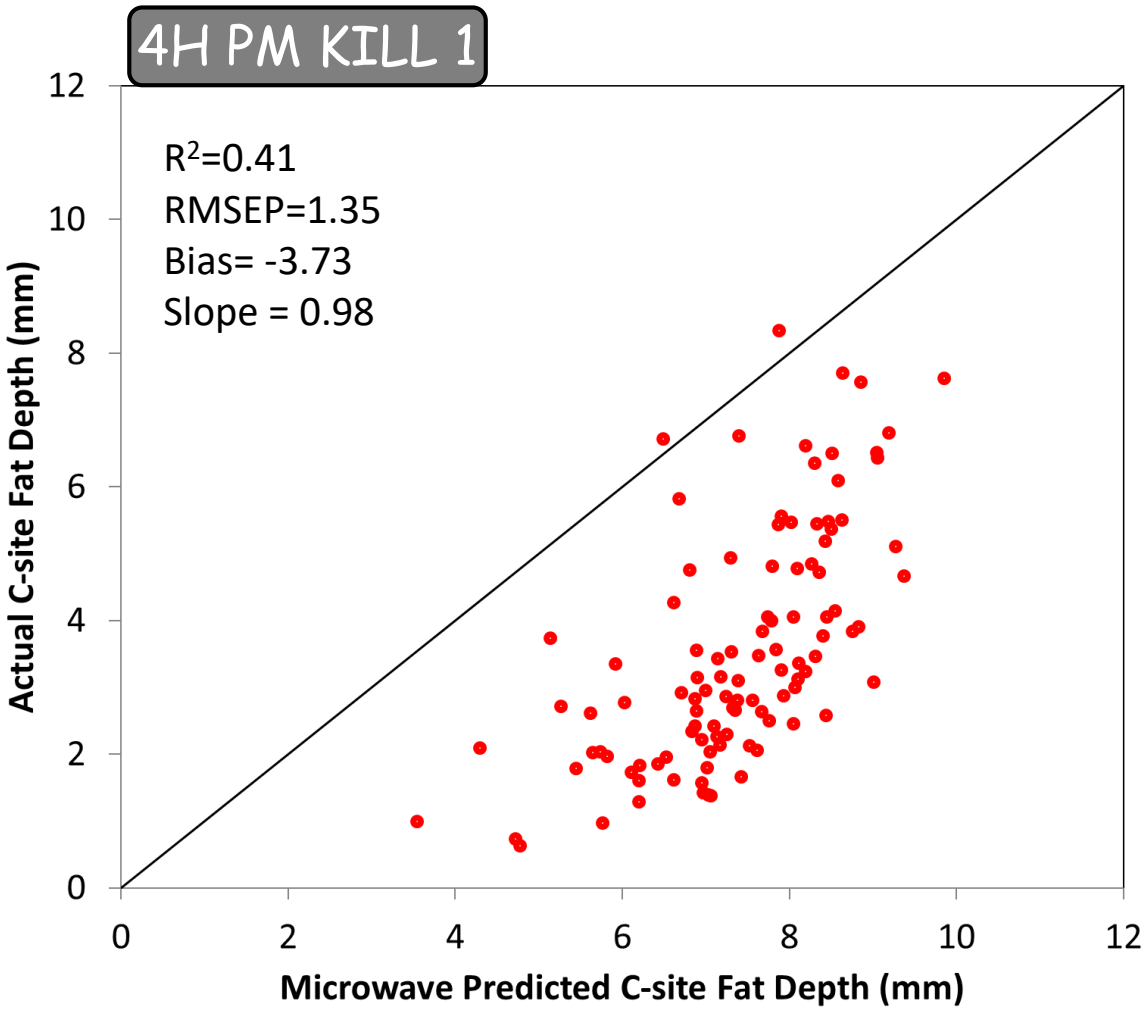






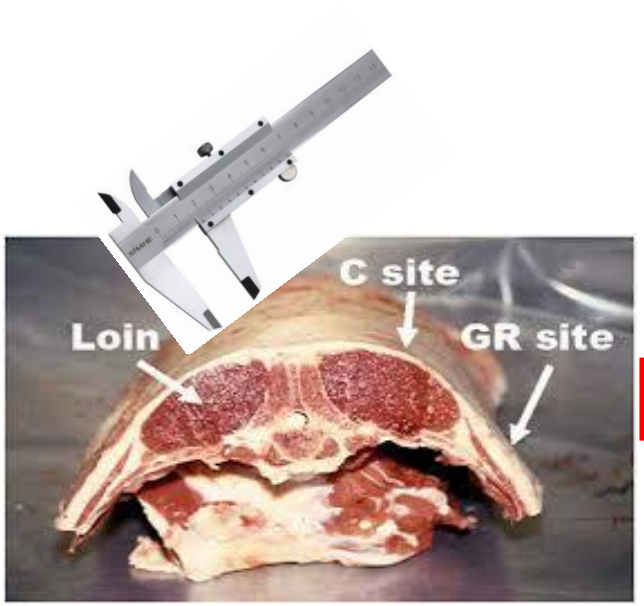
Does it transport for diff. antenna?

Transported from 2H PM KILL 2



Hypothesis

A prototype Microwave System can estimate fat depth at the *C*-site in lamb carcasses with good precision



Non-Invasive

Non-Destructive

Benefit of Microwave System

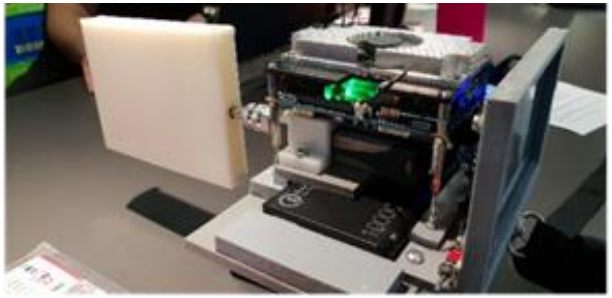
- Safe - low power, non-ionising
- Low cost
- handheld
- Applicable for carcase and live animals
- Fast (200µs measurement)
- Abattoir – 12 carcasses per minute

Future work

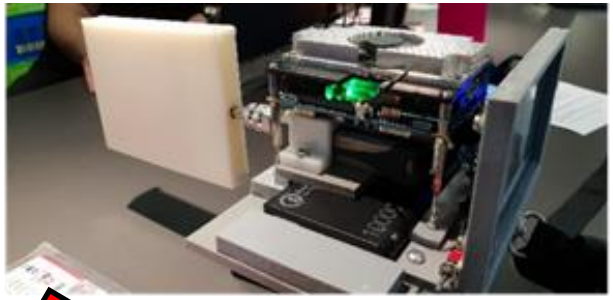
Engineering improvements

- Compact antenna
- Higher gain & better directivity
- Needs industry ready calibration system
- Explore time domain signal

Compact Design



Compact Design



Improved design!

Future Testing

- C-site fat depth (lamb) ✓
- P8 and 12/13th rib fat depth (cattle)
- Fat depth live (single site / array)
- Other structural traits (IMF/S.F.?)

Conclusion

- **Portable Microwave System to measure fat depth**
- **Measurement up to 24h post mortem**
- **Equations derived for one antenna (VPA) cannot be applied to another (PLA).**
- **Industry ready design!**

Thankyou!

Q & A