

Improving the Performance of Nuclear Quadrupole Resonance Sensing Technologies for *in-situ* Detection of Narcotics and Explosives

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What I shall be talking about today

- Why this project is being undertaken
- RFI Characterisation
- Testbed Development
- Suppression Technique
- Human Validation
- Remaining Work
- Conclusion

Traditional NMR Applications



High Field NMR System in an NMR Laboratory (1)



MRI Medical Scanner (2)

[1] = "700 MHz 52mm NMR Magnet", National High Magnetic Field Laboratory, 03 August 2015, <https://nationalmaglab.org/user-facilities/nmr-mri/nmr-instruments/700-mhz>

[2] = Commons.wikimedia.org. (2015). File:MRI Scanner at Narayana Multispeciality Hospital, Jaipur.jpg - Wikimedia Commons. [online] Available at: https://commons.wikimedia.org/wiki/File:MRI_Scanner_at_Narayana_Multispeciality_Hospital,_Jaipur.jpg

In situ NMR/NQR Applications



MRI Tree Scanner [3]



NQR Contraband Luggage Scanner [4]



NQR Landmine Detector [5] 44

[3] = Nagata, A., Kose, K. and Terada, Y. (2016). Development of an outdoor MRI system for measuring flow in a living tree. *Journal of Magnetic Resonance*, 265, pp.129-138.

[4] = Institute, J., Technology, G., University, K. and London, K.

Institute, J., Technology, G., University, K. and London, K. (2019). *Magnetic Resonance Detection of Explosives and Illicit Materials* | SpringerLink. [online] Link.springer.com. Available at: <https://link.springer.com/book/10.1007%2F978-94-007-7265-6> [Accessed 21 Oct. 2019].

[5] = *Nuclear Quadrupole Resonance Detection of Explosives: An Overview*. Miller, J. B. 15, 2011, Proc. of SPIE, Vol. 8017.

Experimental Sequence

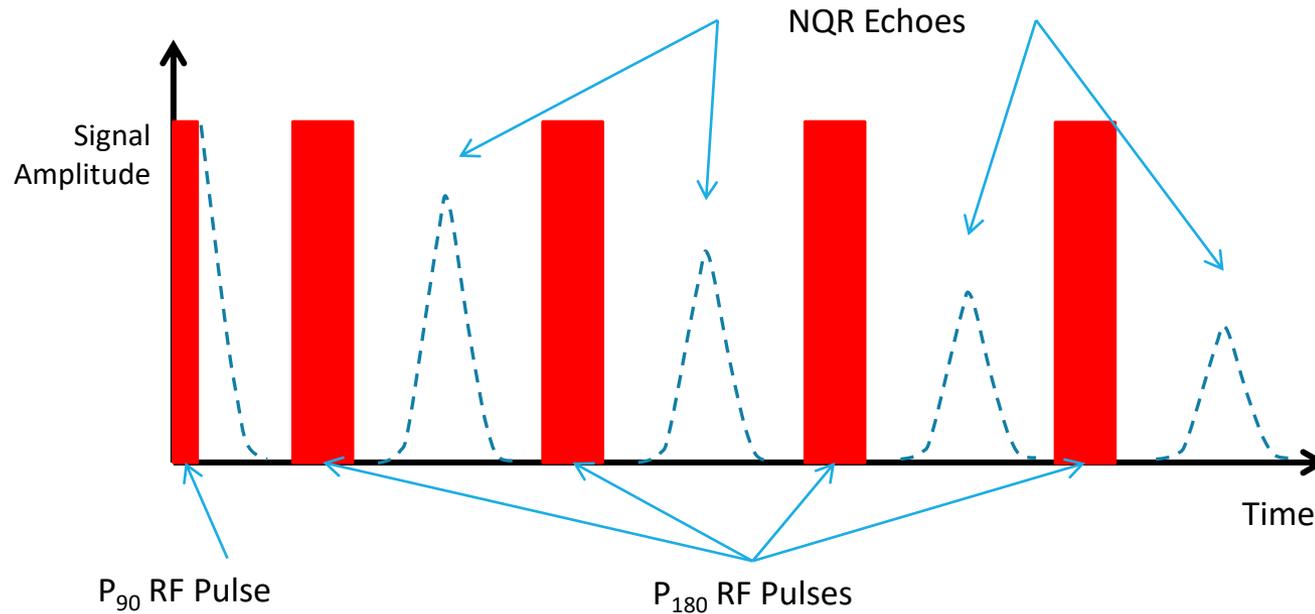
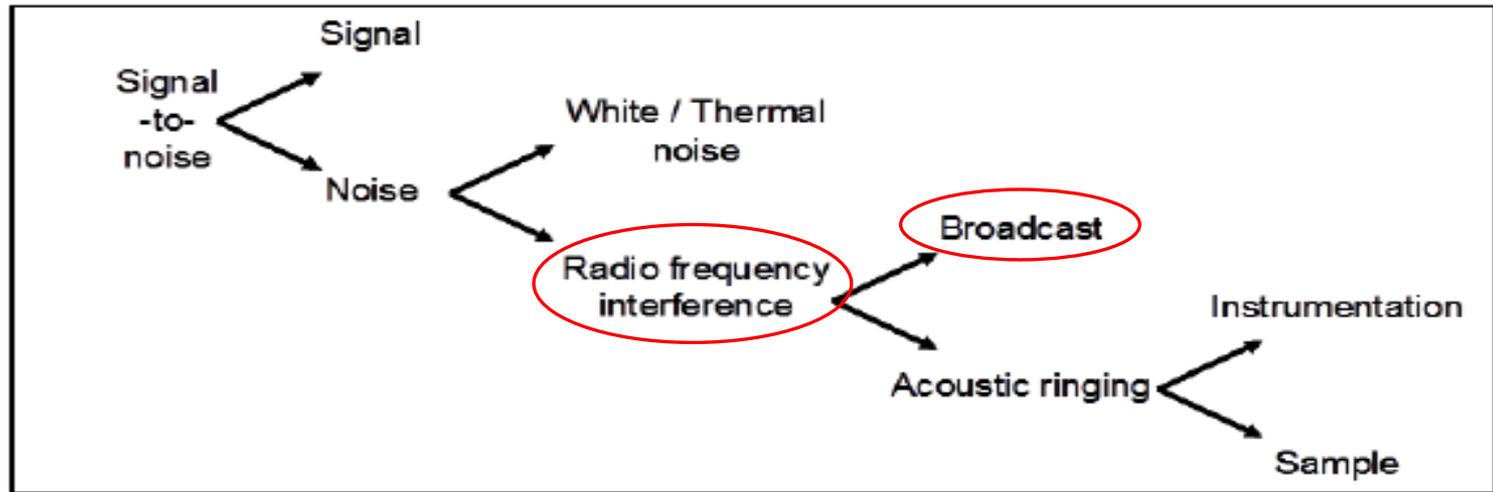


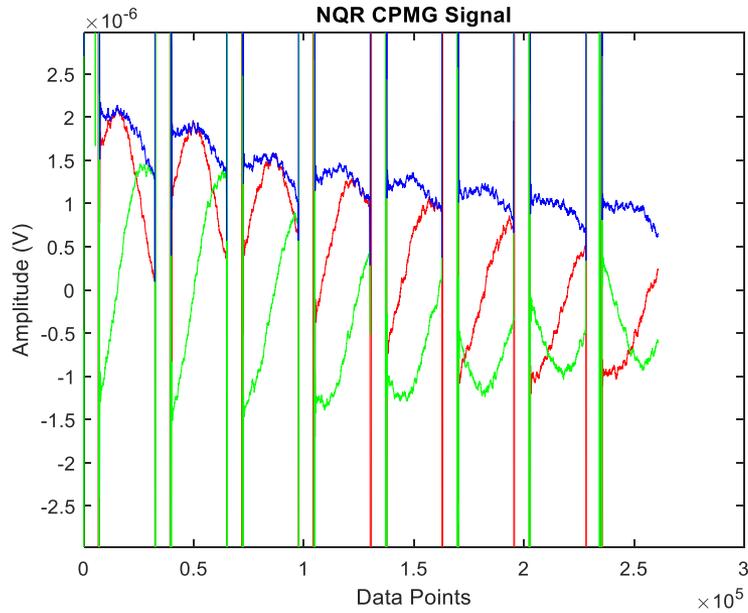
Illustration of a multiple pulse experiment

What is Noise?

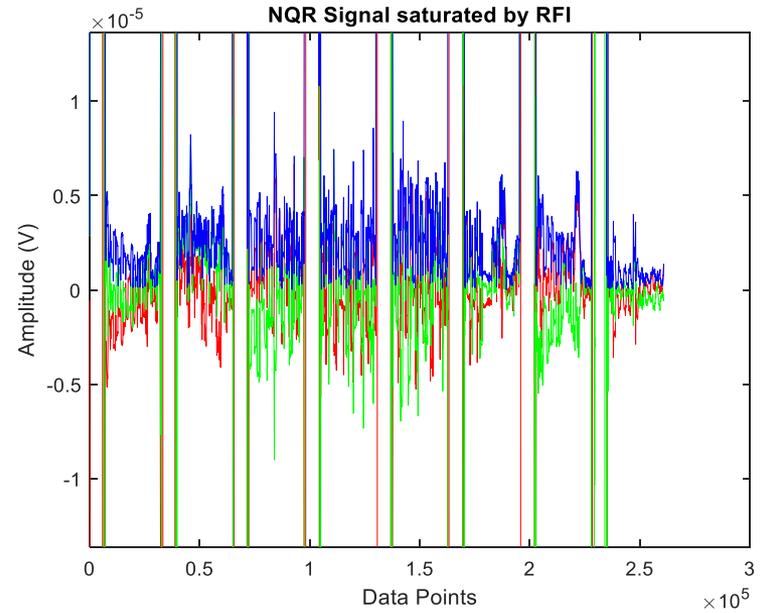


Types of Noise [6]

Why is it a problem?



NQR Signal without RFI



NQR Signal with RFI

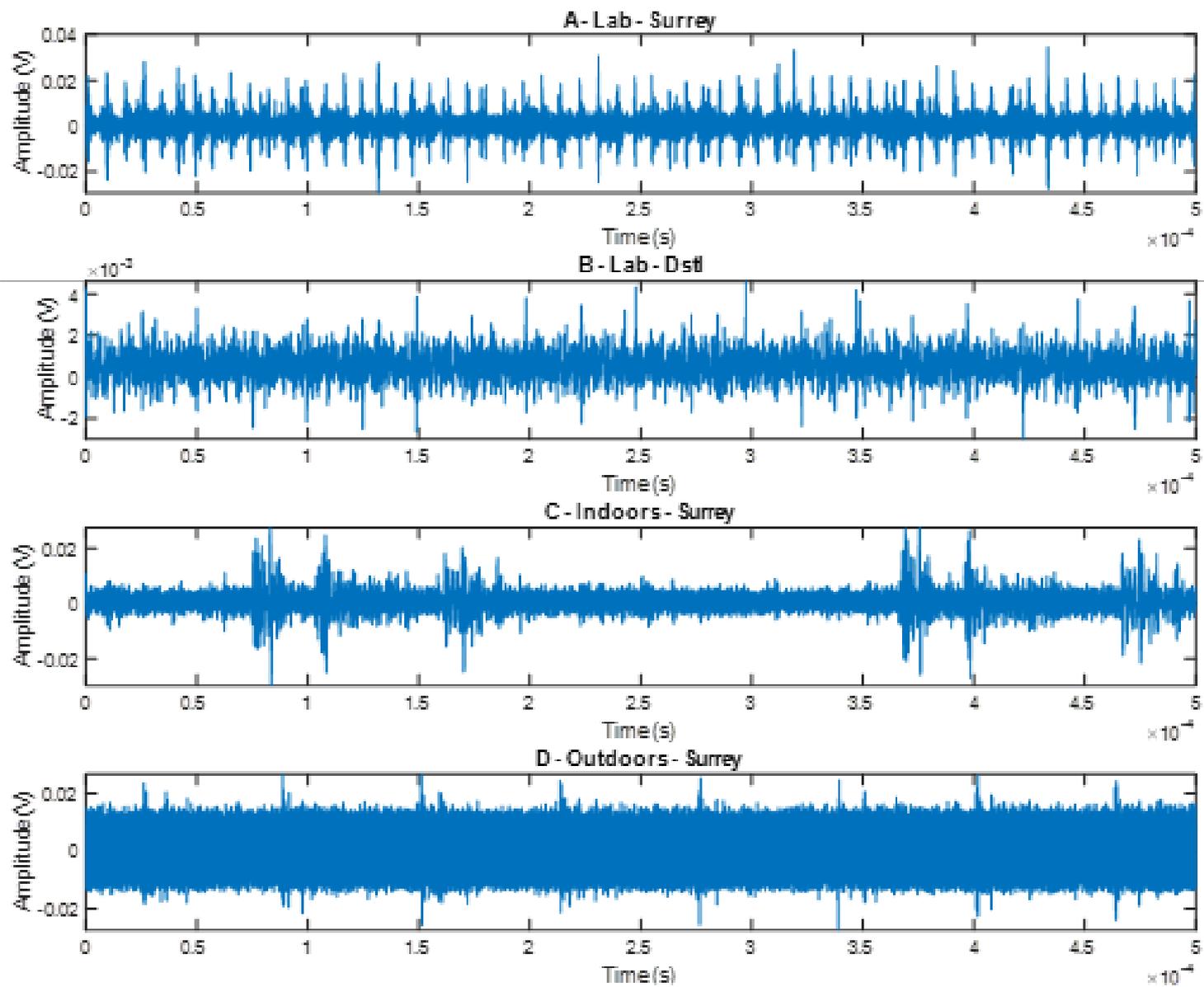
Aims of this project

To utilize the adaptability of Machine Learning to identify and suppress digital 'burst mode' RFI to be able use NMR/NQR equipment *in-situ*

RFI Characterisation

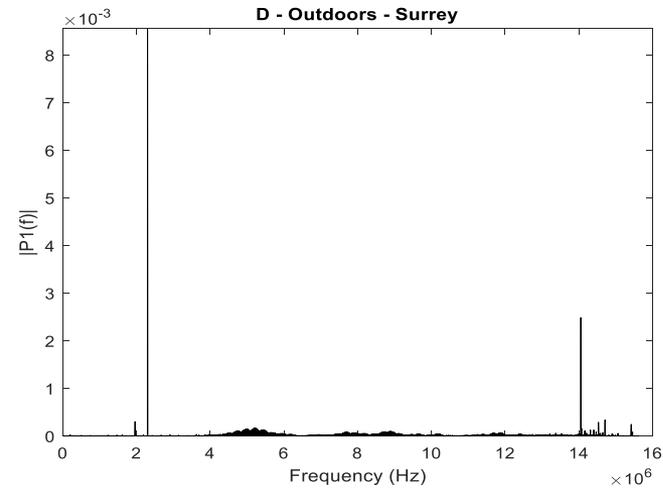
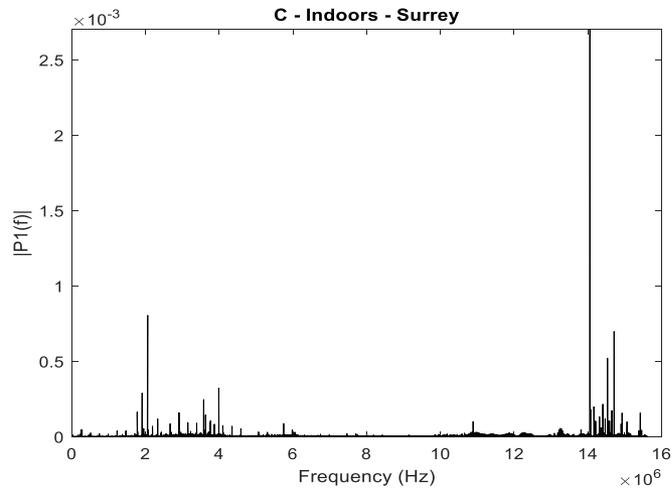
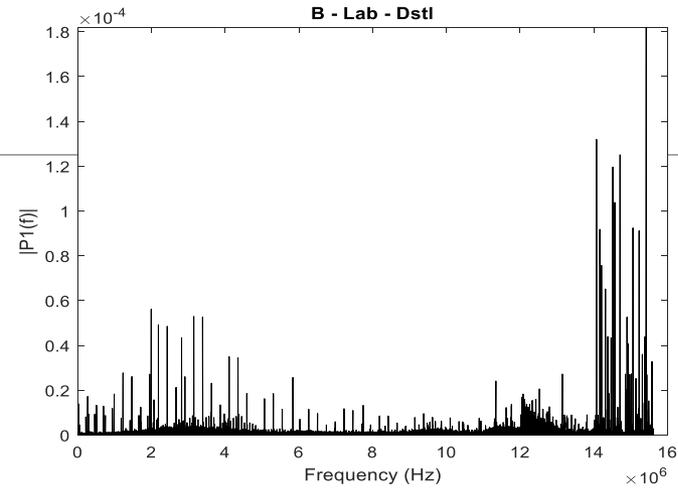
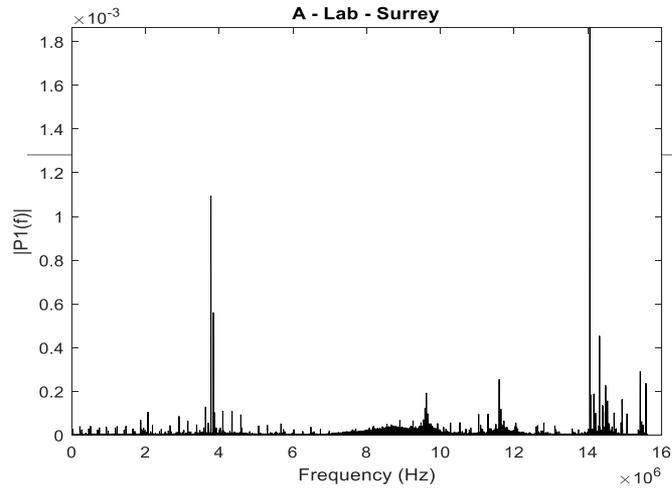
RFI can vary greatly from location to location

In order to determine the variability, a range of parameters were calculated to allow comparisons between locations



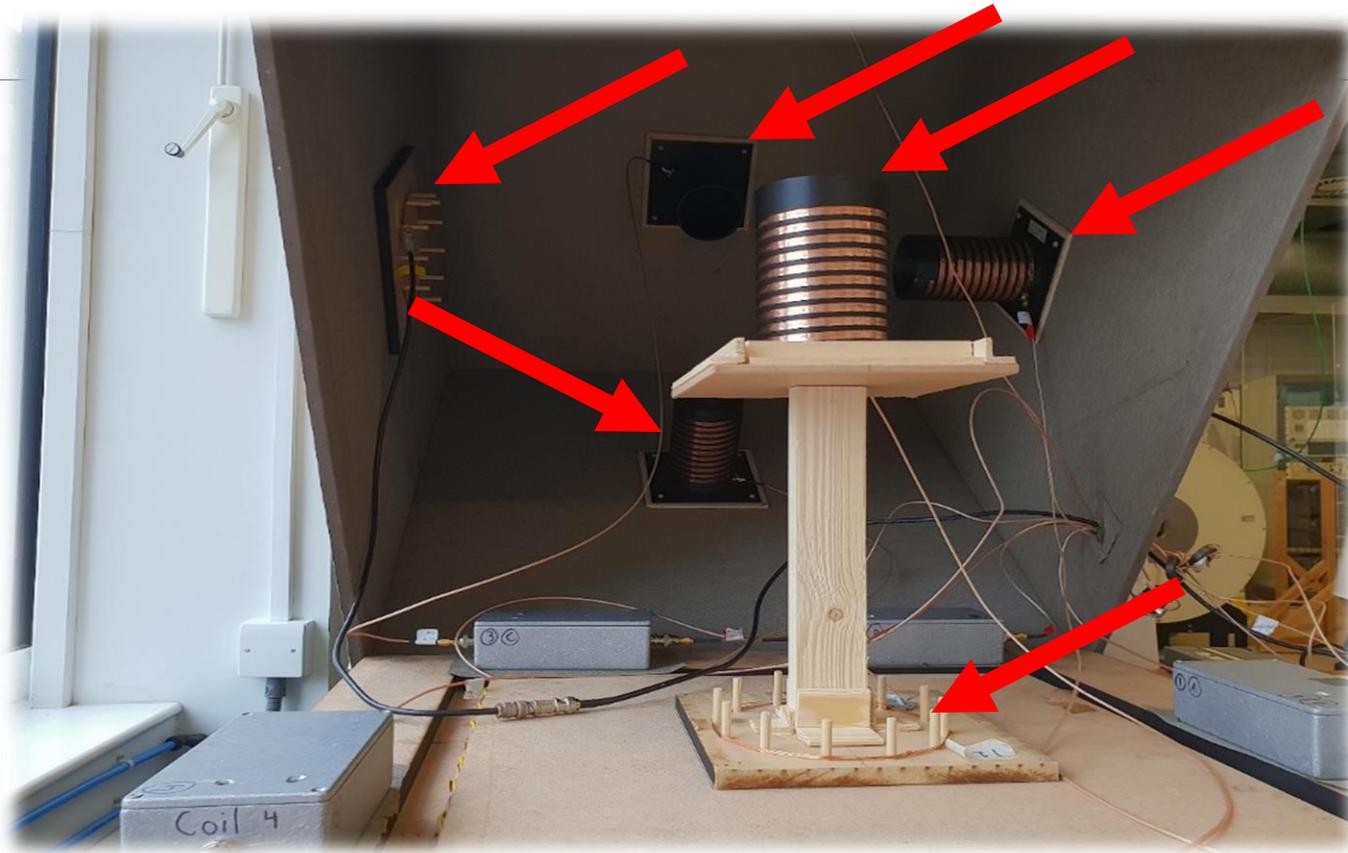
Plot showing 500us of raw RFI measured at: A = NMR lab at Surrey, B = NQR lab at Dstl, C = Indoor Location at Surrey, D = Outdoor Location at Surrey

Frequency Spectrum



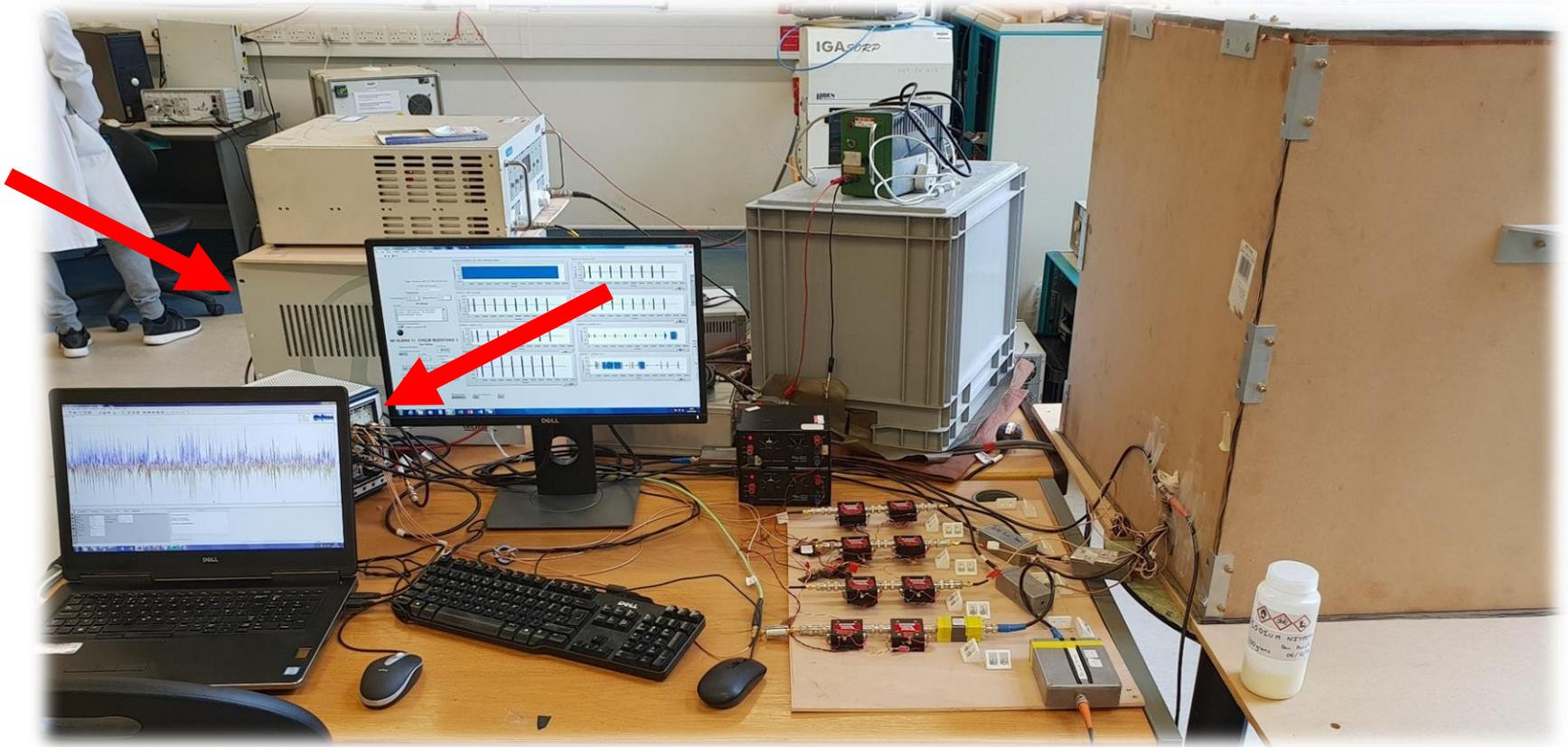
Fourier Transform Plots of RFI measured at: A = NMR lab at Surrey, B = NQR lab at Dstl, C = Indoor Location at Surrey, D = Outdoors Location at Surrey

NQR Testbed System



Interior of the Shielded Faraday Enclosure

NQR Testbed System



Picture of the entire NQR testbed system

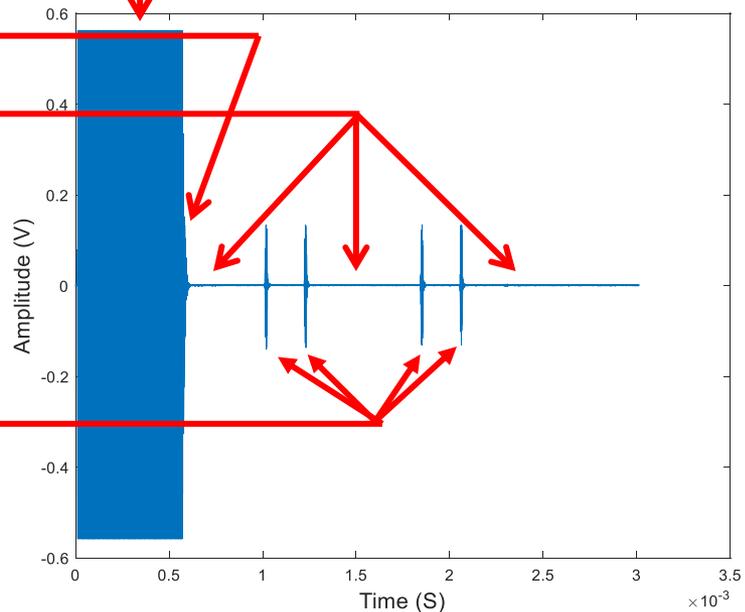
Decision Tree Model

Uses a decision tree machine learning model to identify the different components of a single 'unit' of data

Unit of data is a single NQR echo in its entirety, which includes;

- RF Excitation Pulse
- Coil Ringdown
- NQR signal / white noise
- RFI

*Plot of a
single NQR
Unit*



Direct Removal RFI Suppression

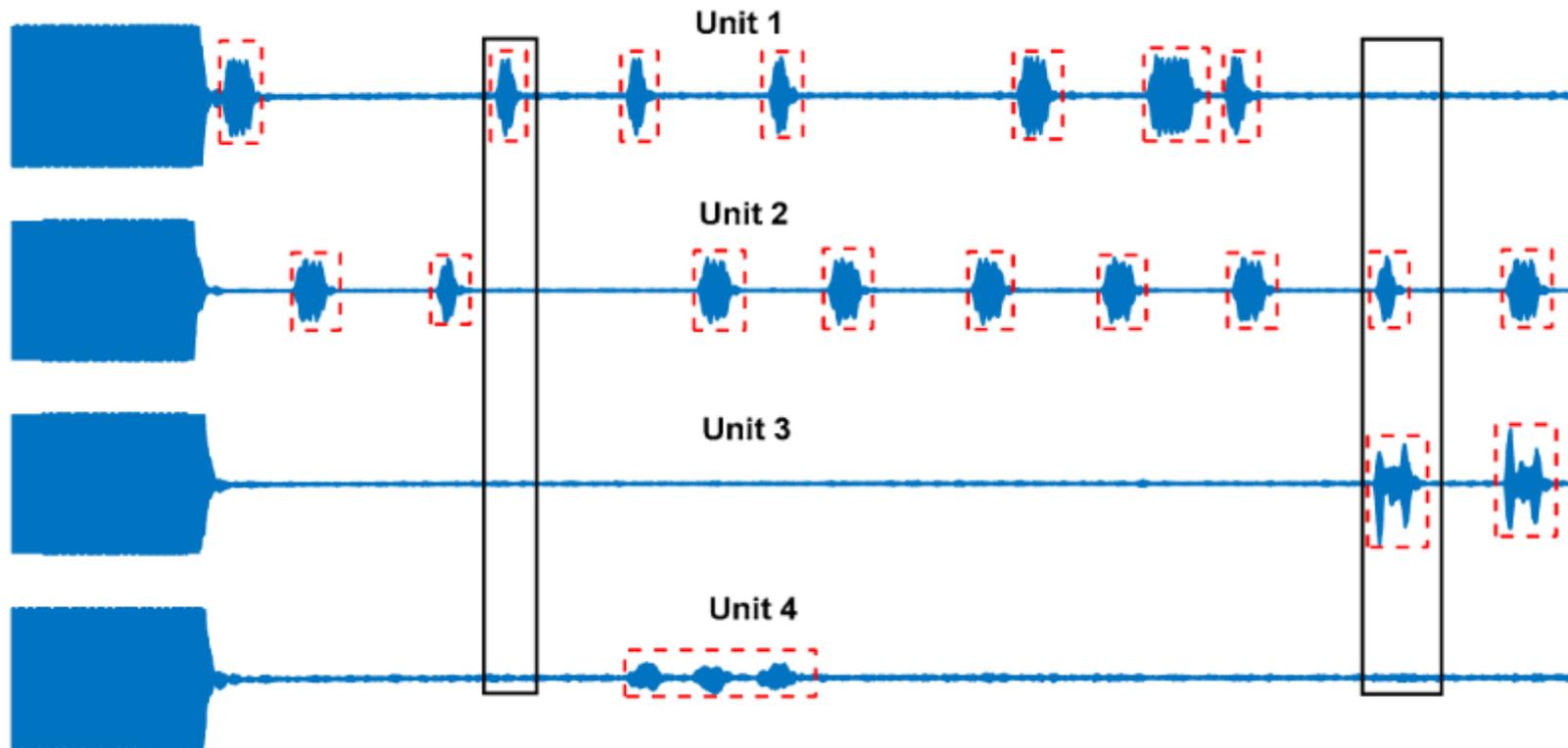
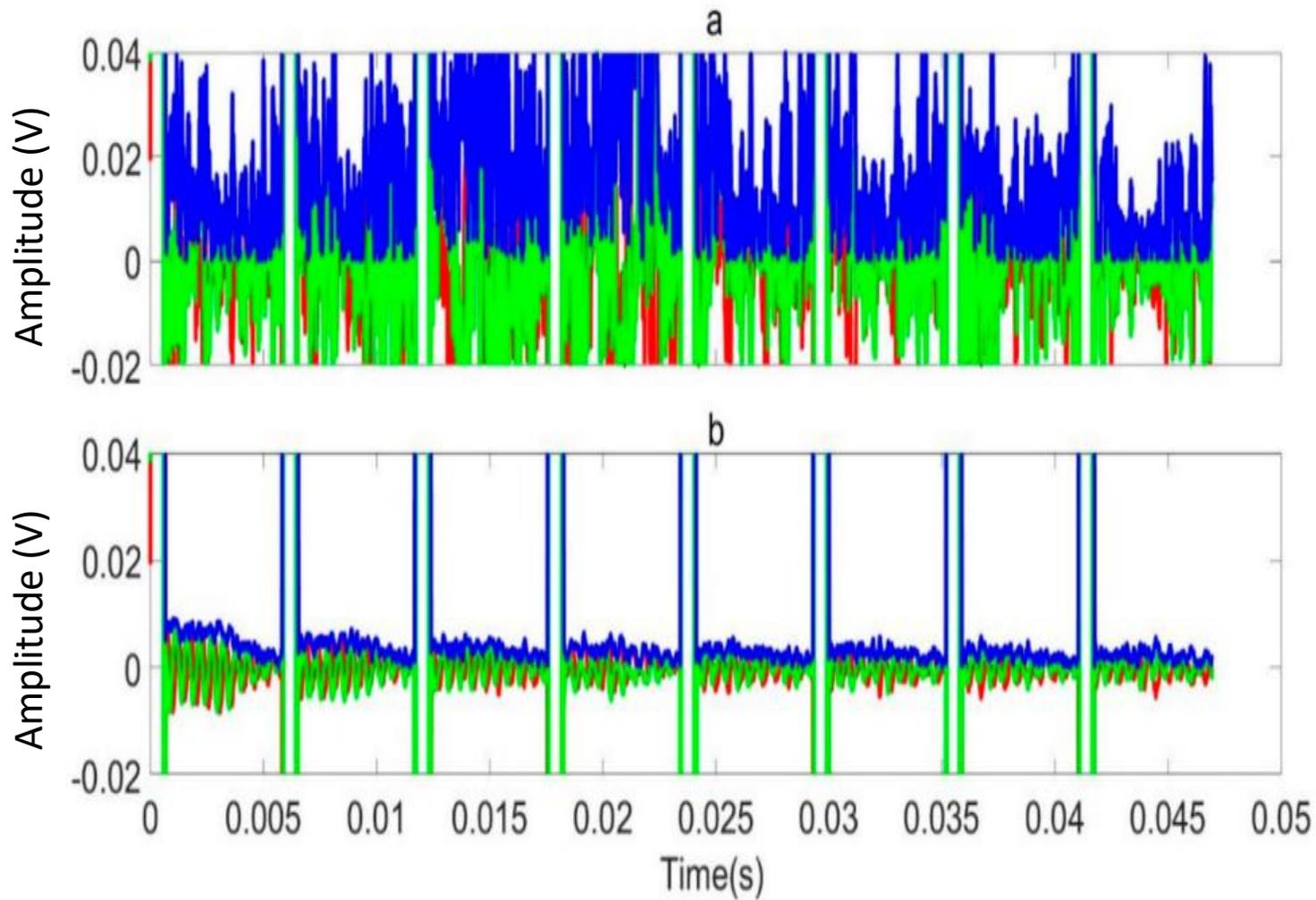


Illustration of the direct RFI removal method [7]



An averaged and demodulated signal. The red, green, and blue lines represent the real, imaginary, and magnitude of the data, respectively: (a) without and (b) with the application of the RFI decision tree identification model and removal algorithm [7]

[7] = *Decision tree pattern recognition model for radio frequency interference suppression in NQR experiments*. M. Ibrahim, D. Parrish, T. Brown, P.J. McDonald. 14, s.l. : Sensors (Switzerland), 2019, Vol. 19. 10.3390/s19143153.

Validation Process

Aim: To determine if the suppression technique works and provides improved results

Data Variables included;

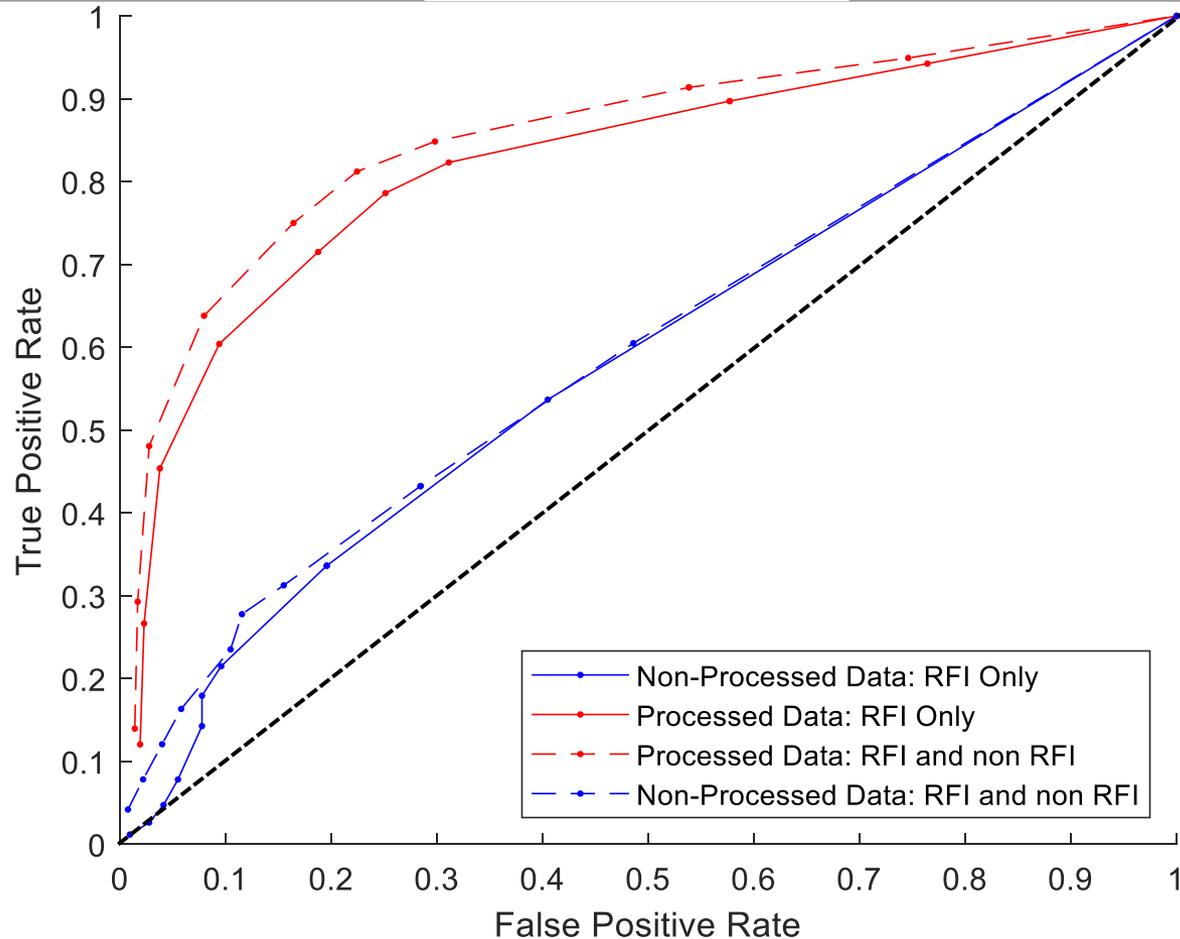
- RFI Suppression processed or non-processed
- Number of scans (repetitions) = 4, 8, 16, 32, 64
- Sample weights = 0, 50, 100, 150, 200g of Sodium Nitrite
- RFI / No RFI in the data

32 Volunteers were taught what a NQR signal looks like with and without RFI

Shown 100 datasets (90 random, 10 repeated)

Rated from 0 to 10 on confidence they see an NQR signal

Overall Receiver Operating Characteristic (ROC) Curve



Remaining Work

To adapt the process and technique to treat real RFI, not pseudo RFI

- Experiments will be done to record new training and testing data

Blind trials to be undertaken to prove if the real RFI method works in a realistic application

- Repeated over different periods of time to see how the performance of the model changes over time

Conclusion

A new and novel application of machine learning has been produced that identifies and suppresses digital burst mode pseudo-RFI in NQR data

Additional work is being undertaken to adapt the technique to work with real RFI, not pseudo RFI

It shows great promise to improve the performance of NMR/NQR technology in real world on site applications, such as detecting narcotic and explosive substances in security applications

Thank You for Listening

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