Feasibility of SSTDR for Identifying Electrochemical Signatures of Degradation

PDRA Presentation

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WP:3

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WP3: Electrochemical Signatures of Degradation

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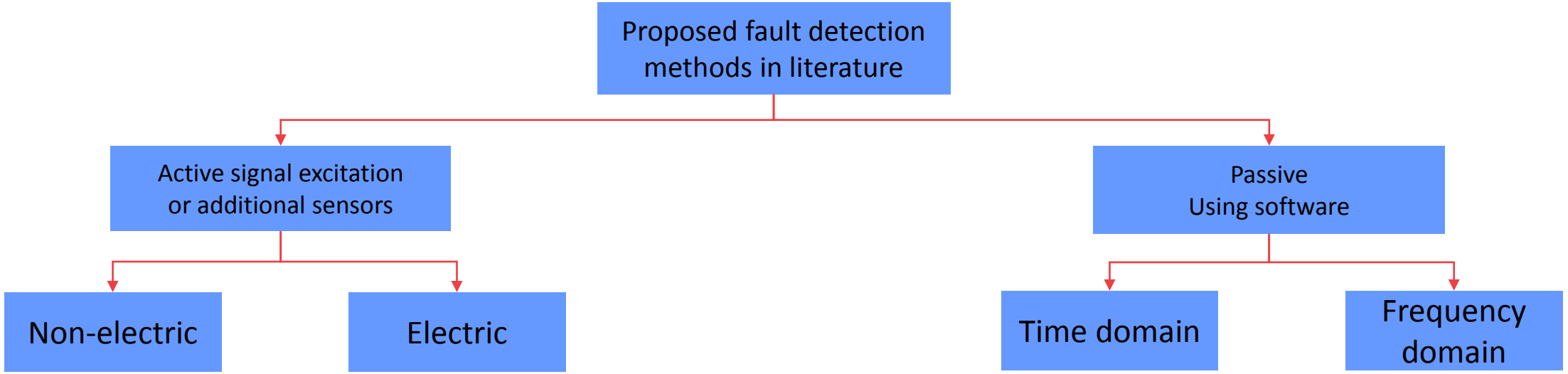
Outline

- Research background
- Reflectometry Sensors for Fault Location
- Future Milestone

Background

- Objectives
- Identify electrochemical signals related to degradation using microscopic techniques
- Identify various properties relating to SoH, SoC using electrical techniques and correlate with the other work packages
- Transfer this knowledge from the cell to module and the stack
- Develop tools for analysing and managing large data (degradation signatures)
- Develop a concept of novel BMS that identify signals indicating degradation

Battery Diagnostics Methods



Active ultrasound
Acoustic
Gas-detection
Pressure
Temp. Measurement

EIS
Pulse Excitation
(Time domain)

Correlation based methods

Passive EIS

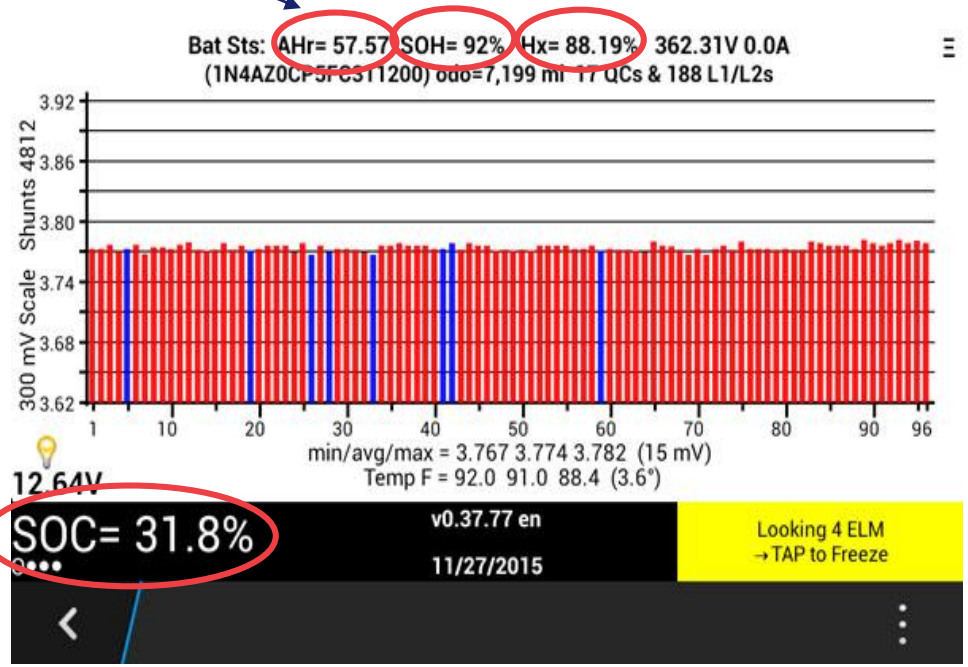
Model based methods

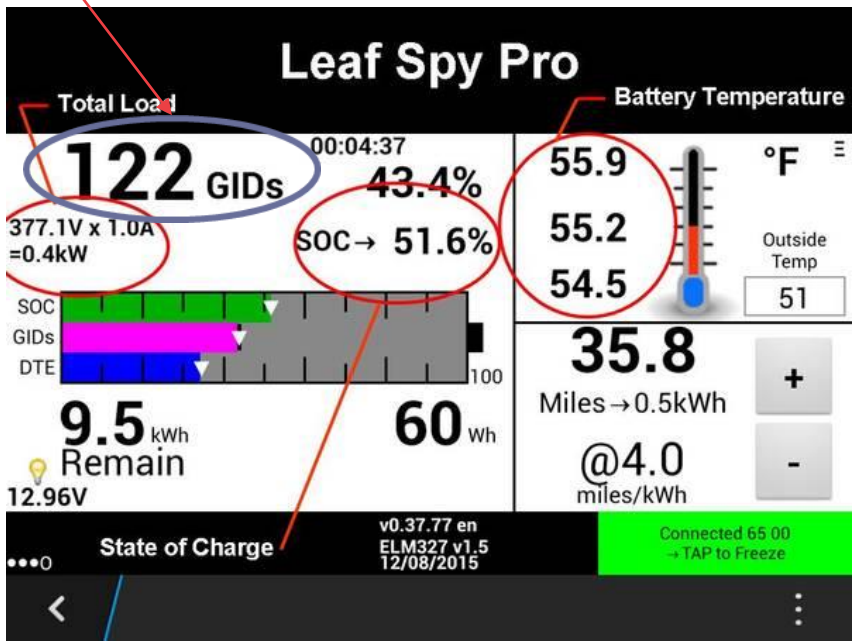
OEM Diagnostics Methods :Nissan Leaf

SoH Metrics

Battery capacity

Battery conductance





Remaining SoC

Fig.1 Leaf spy data

GIDs named after Garry Giddings
281 GIDs for New battery pack

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SoH Monitoring Using Reflectometry

- Time Domain Reflectometry TDR
- Frequency Domain Reflectometry FTDR
- Standing Wave Reflectometry SWR
- Mixed Signal Reflectometry MSR
- Coherent Optical Time Domain Reflectometry COTDR
- Sequence Time Domain Reflectometry STDR
- Spread Spectrum Time Domain Reflectometry SSTDR

SoH monitoring using TDR

TDR Basics – signal propagation

- Impedance discontinuity leads to reflection of travelling signal
- Pulse signal is driven into utilised cable, then travels down the line
- At impedance disruption $Z_L > Z_O$ a signal portion is reflected back
- Transmitted signal travels further, get reflected at the event exit $Z_F > Z_L$ and travels to the source
- At the cable end, the remaining signal is reflected back
- Cable properties and fault location easy to determine

Reflection coefficient $\rho = V_{reflected}/V_{incident}$

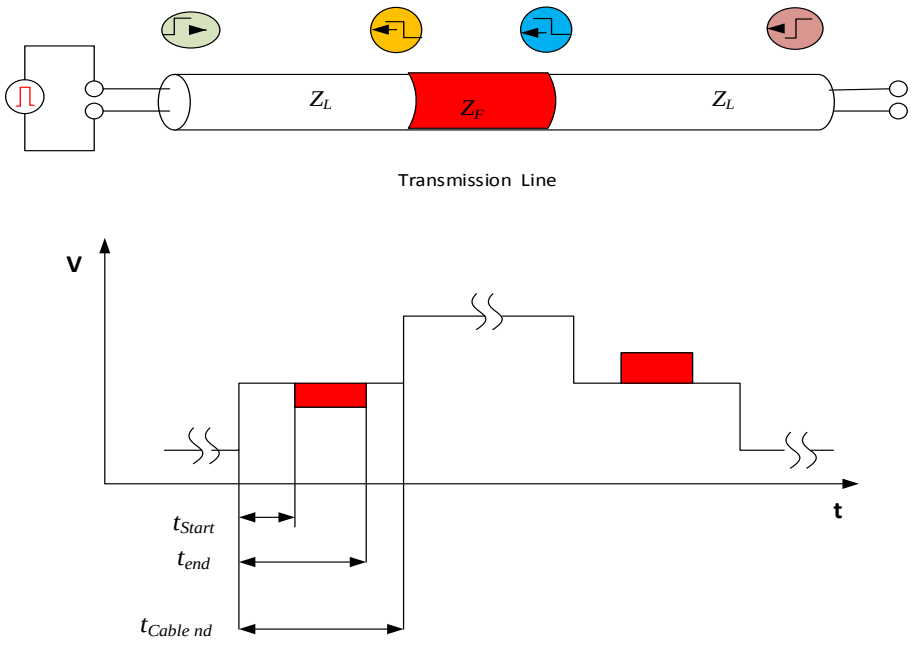

Fig.2 Time domain reflectometry

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TDR on Coaxial Cable

- Various length of coaxial cable tested under open, splice and short circuit conditions
- Characteristic impedance of the cable easily determined
- The location of the fault or impedance discontinuity can be determined using propagation delay

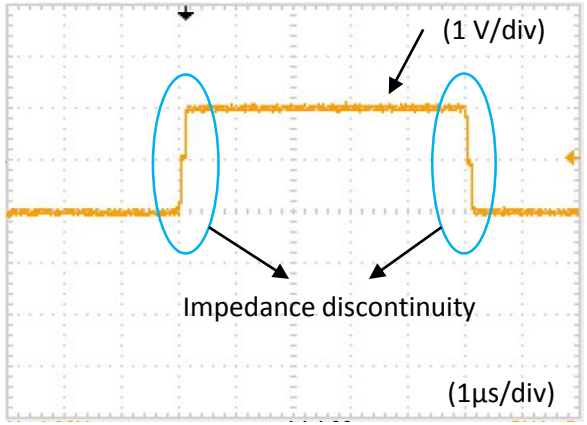

Fig. 3a Pulse signal transmitted

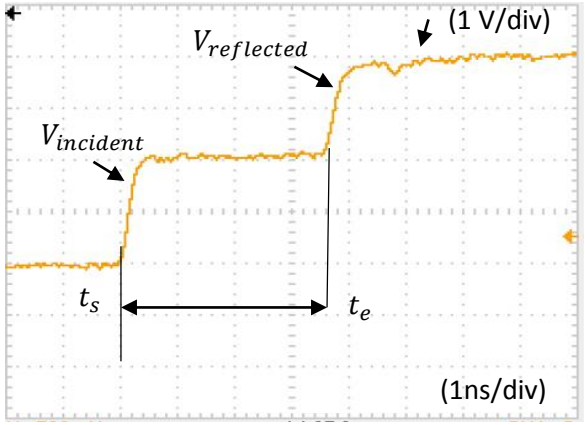

Fig. 3b Closed up of transmitted signal

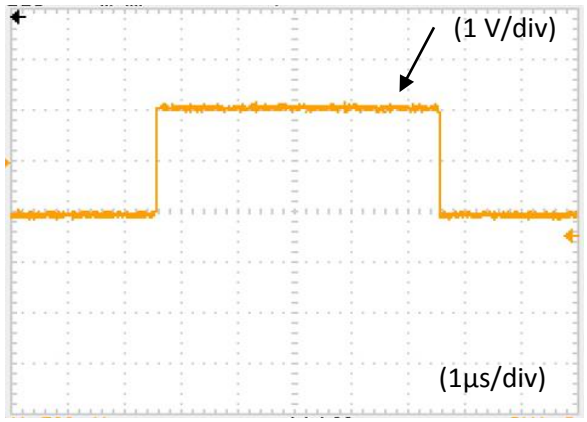

Fig. 3 c $Z_F = Z_L$

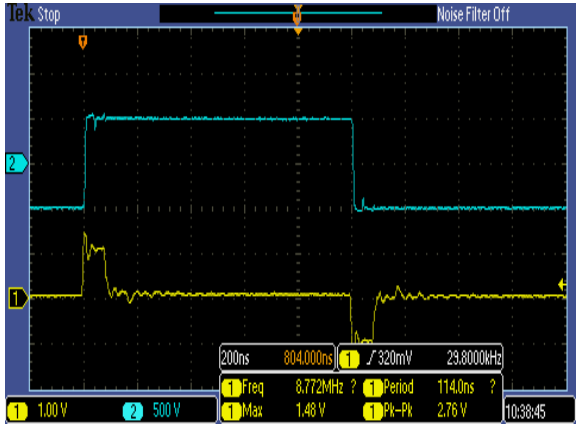

Fig. 3d Short circuited

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TDR on coin cells

Damaged cell
OCV: 1.000 V
Scratched cell
OCV: 2.874 V
Overcharged cell
OCV: 3.015 V
Pristine cell
OCV: 3.141 V

TDR Pulse width: 0.1 ms
Frequency: 1 KHz
Magnitude: 500 mV

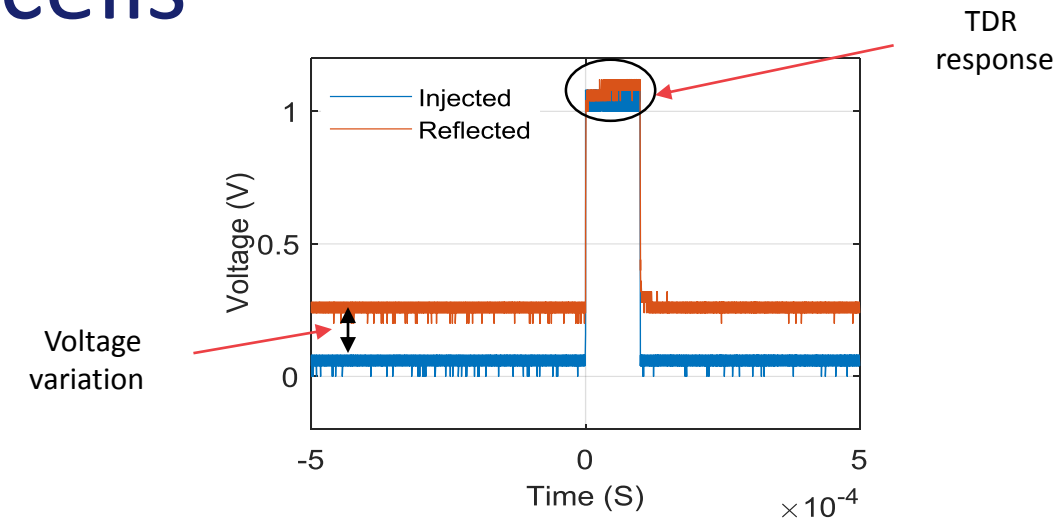

Fig 4a. Damaged cell

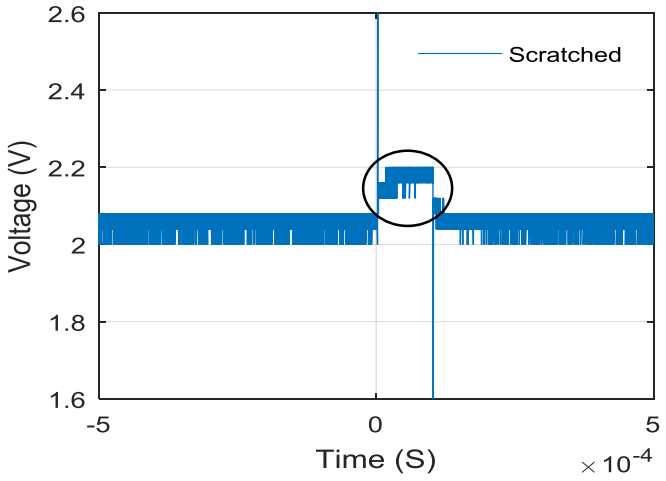

Fig 4b. Scratched cell

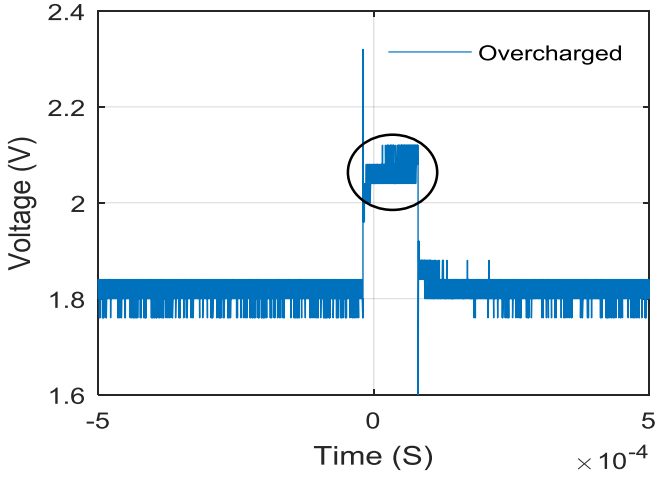

Fig 4c. Overcharged cell

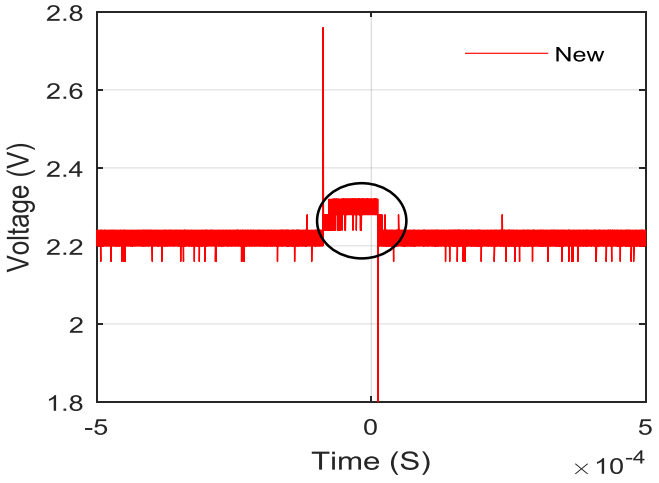

Fig 4d. New cell

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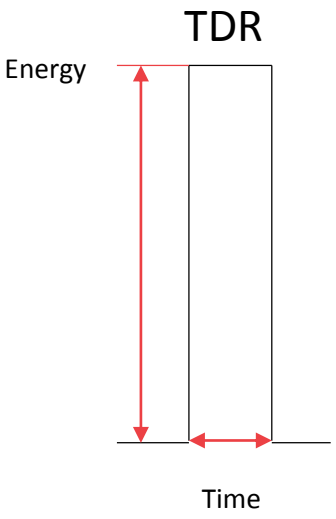
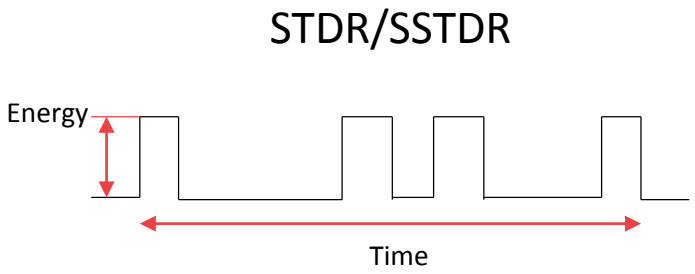
Conclusion on TDR





- Higher energy in the signal
- Interference with other/ by other signals
- Narrow time
- Susceptible to noise

- Low energy in the signal time (PN code)
- Minimal or “NO” interference
- Broad Features allows it to be used in live aircraft wires
- Noise immunity

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STDR/SSTDR

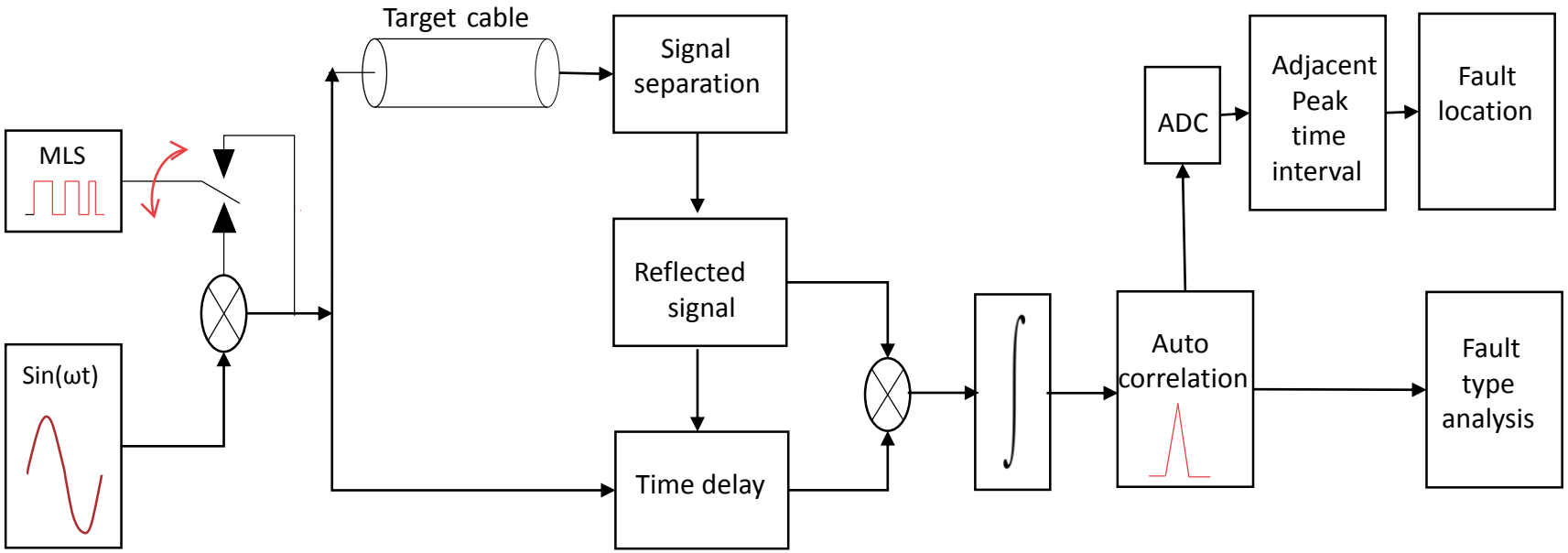
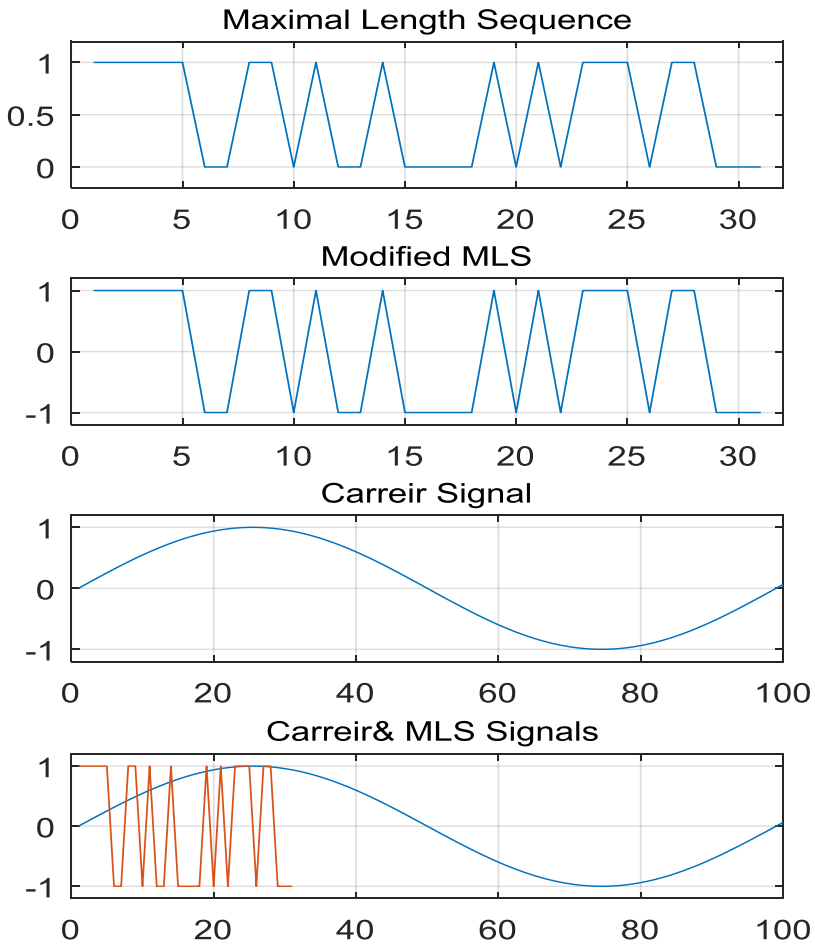


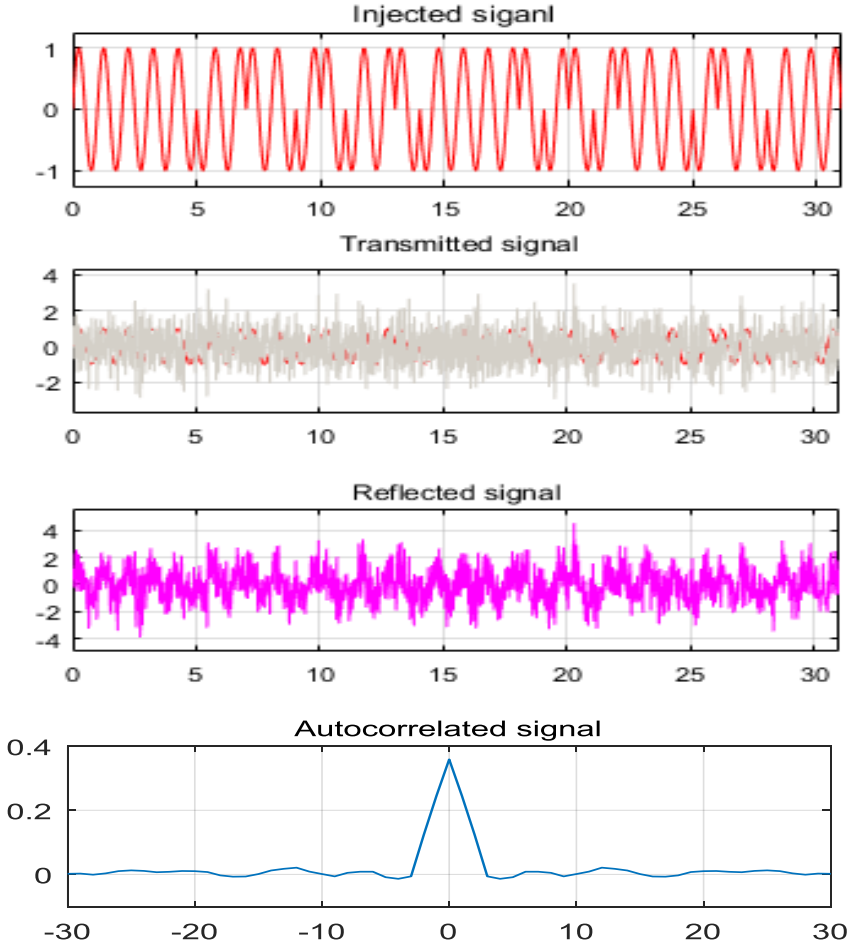
Fig. 5. STDR/SSTDR block diagram

- Correlation tells time shift between two signals*
- Signals are so small below the allowable noise margin of any signal

*(shift signal in time, multiply them, integrate or add them)

Simulation





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S/SSTDR

Advantages

- Detect and locate faults on Dead or Live cables in “real time”

  60- 400 Hz Ac, 5-270 V DC

- Precise fault location of +/-2 % on cables up to 3650 metres
- Monitor system integrity without impact on system operation
- Suitable for intermittent condition when the fault is present
- Many signals peacefully co exist (frequency band sharing (CDM)
- Immune to noise
- Multiple channel/paths
- Loss/attenuation
- Low interference/Jamming potential

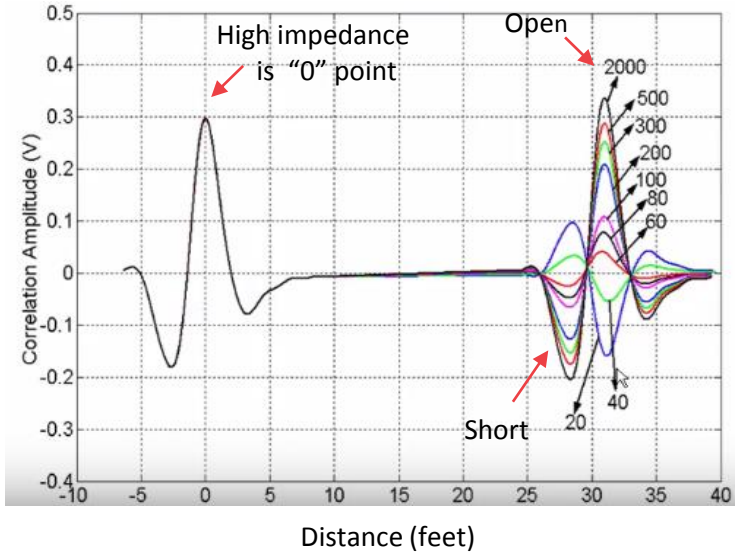

Fig. 6a Cable fault signatures [Furse et al]

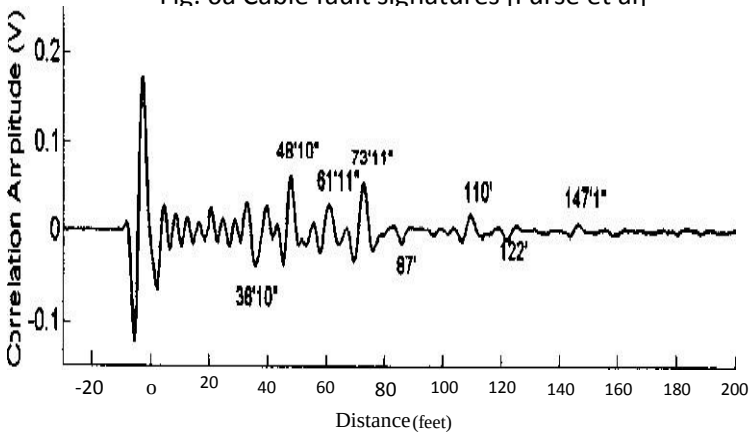

Fig. 6b Multiple junctions [Furse et al]

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Future Milestones

- Build a test rig to establish the suitability of S/SSTDR in identifying cell degradation signatures
- Correlate the findings with microscopic & spectroscopic techniques
- Correlate identified degradation signatures using SSTDR across work packages
- Transfer this knowledge from the cell to module and the stack
- Establish regular engagement with modelling fast-start to coordinate cell modelling and ReLIB for the development of non-invasive SoH techniques for re-use or recycling.
- IE:Spier New technologies on grading batteries and testing processes

Thanks for Listening

Q & A