

Initial findings using RUK AM assessment methodology

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Introduction

- Artificial test files
- Real data
- Issues with RUK AM method
- Comparison of results with other methods
- Potential improvements

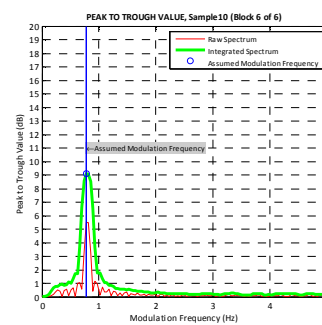
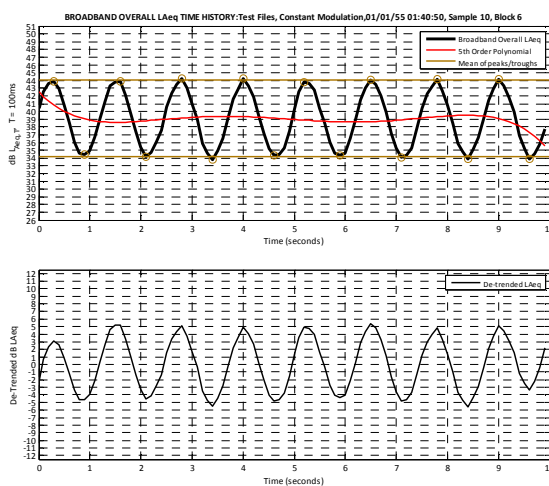


Artificial Test Files

- Synthesised test files with constant and known modulation
- Sensible results when compared with the mean Peak-to-Trough value?
- Seems to under-estimate by ~1dB, increasing with the modulation depth
- Room for improvement in;
 - Normalisation value
 - De-trending step



Artificial Test Files

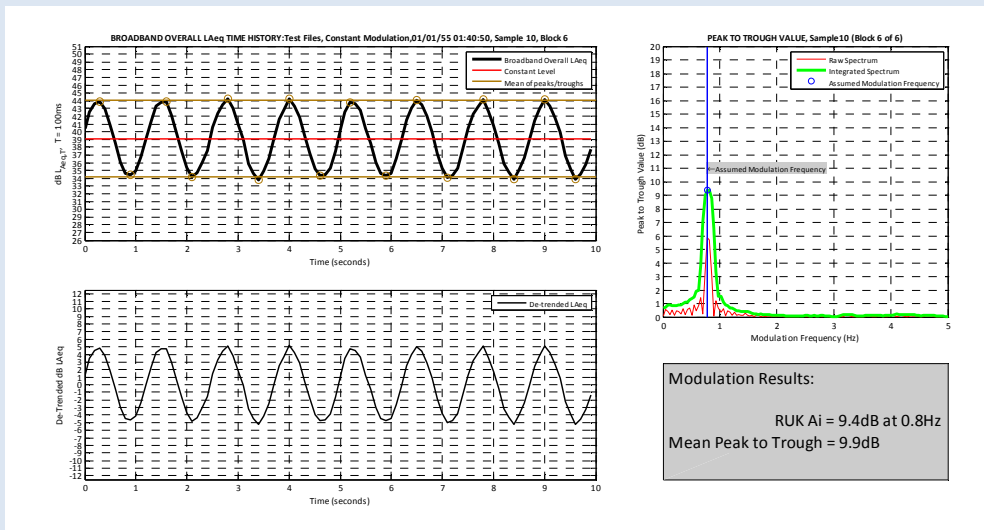


Modulation Results:

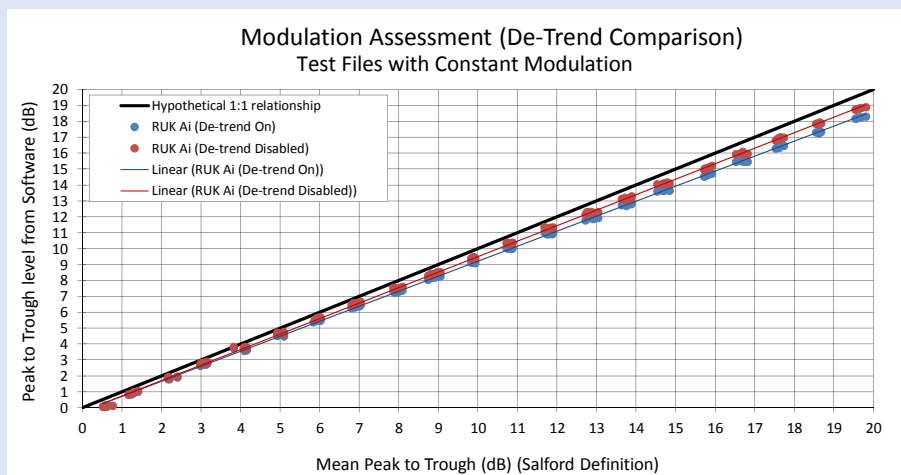
RUK Ai = 9.1dB at 0.8Hz
Mean Peak to Trough = 9.9dB



Artificial Test Files – De-trend Disabled



Artificial Test Files



- De-trending step may impart a bit of under-estimation, depending upon how the tails of the polynomial end up
- Define the polynomial outside the 10s block, e.g. across 12s?
- Refine the normalisation step? $A_i = 2 \cdot \sqrt{2 \cdot \Delta f \cdot E_c}$

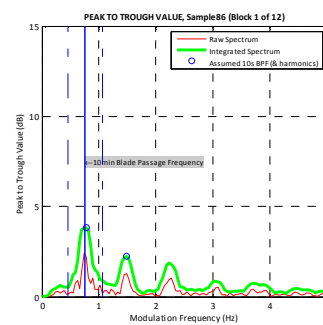
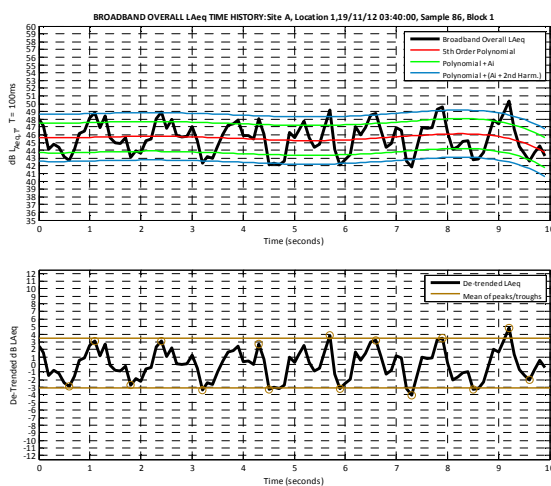


Real data

- More sensible results when looking at real data?
- Seems to under-estimate even more when compared to a mean Peak-to-Trough value
- Modulation rarely sinusoidal
- Modulation quite variable



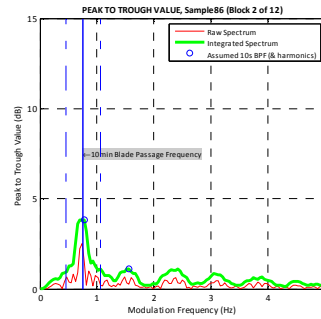
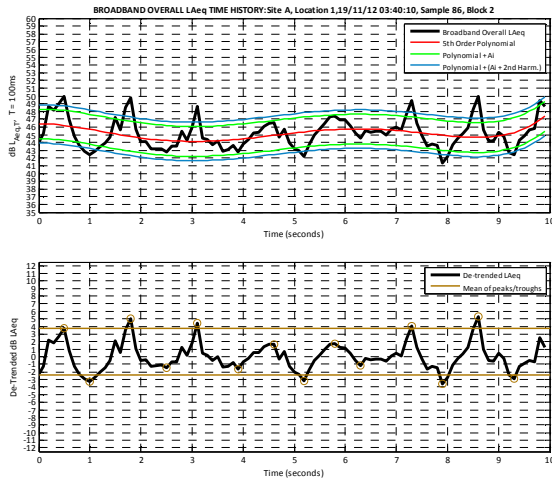
Real data – Site A



Modulation Results:
RUK Ai = 3.8dB at 0.8Hz
Mean Peak to Trough = 6.6dB
RUK Ai + 2nd Harm. = 6.1dB



Real data – Site A

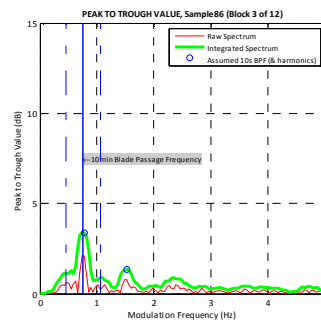
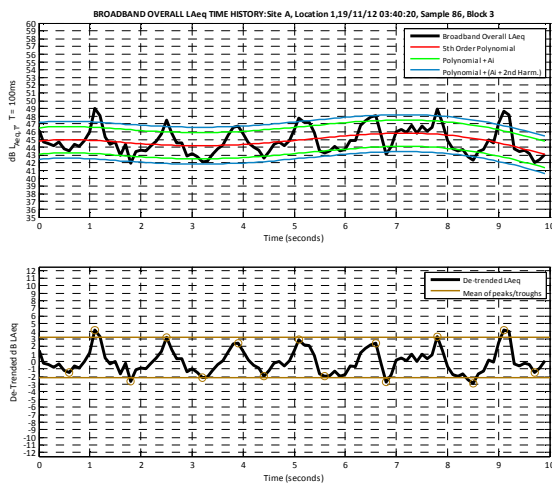


Modulation Results:

RUK Ai = 3.8dB at 0.8Hz
 Mean Peak to Trough = 6.2dB
 RUK Ai + 2nd Harm. = 5.0dB



Real data – Site A

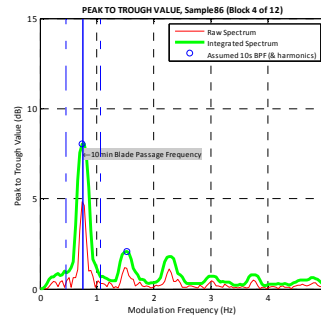
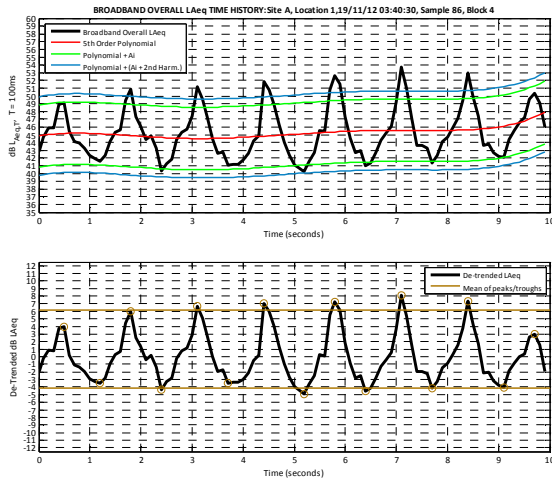


Modulation Results:

RUK Ai = 3.4dB at 0.8Hz
 Mean Peak to Trough = 5.3dB
 RUK Ai + 2nd Harm. = 4.8dB



Real data – Site A

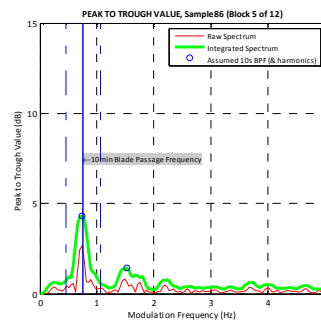
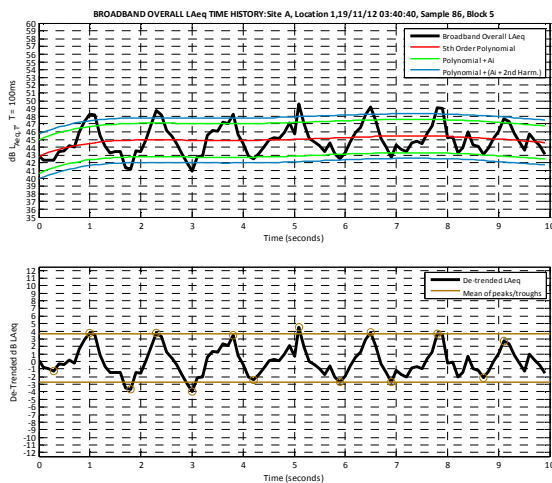


Modulation Results:

- RUK Ai = 8.1dB at 0.7Hz
- Mean Peak to Trough = 10.3dB
- RUK Ai + 2nd Harm. = 10.2dB



Real data – Site A

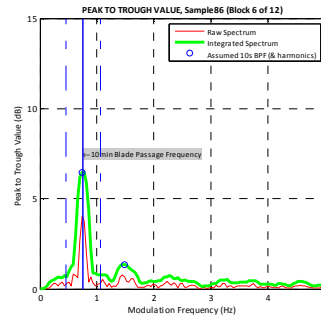
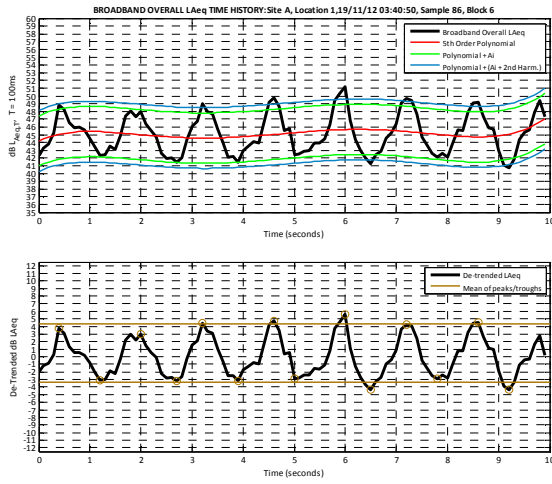


Modulation Results:

- RUK Ai = 4.3dB at 0.7Hz
- Mean Peak to Trough = 6.4dB
- RUK Ai + 2nd Harm. = 5.8dB



Real data – Site A

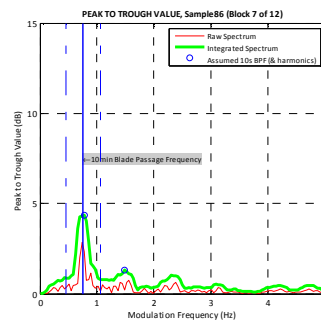
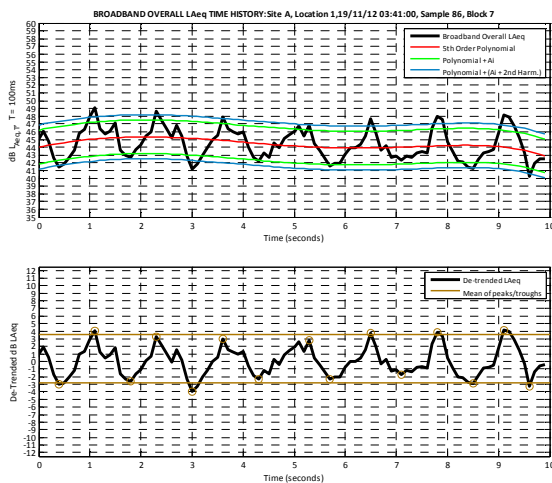


Modulation Results:

RUK Ai = 6.5dB at 0.7Hz
 Mean Peak to Trough = 7.8dB
 RUK Ai + 2nd Harm. = 7.8dB



Real data – Site A

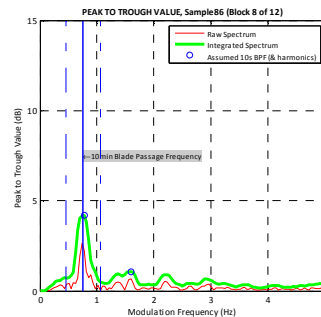
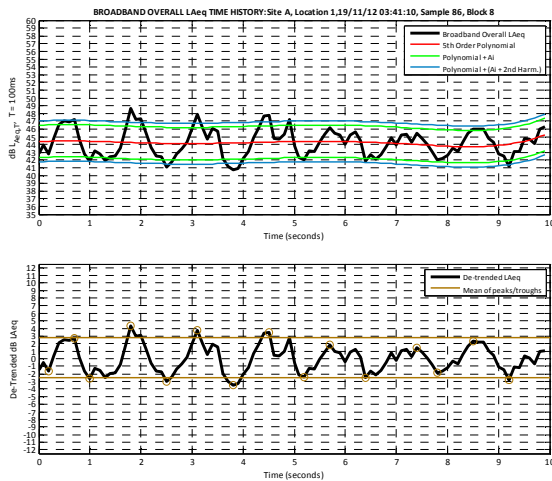


Modulation Results:

RUK Ai = 4.4dB at 0.8Hz
 Mean Peak to Trough = 6.3dB
 RUK Ai + 2nd Harm. = 5.7dB



Real data – Site A

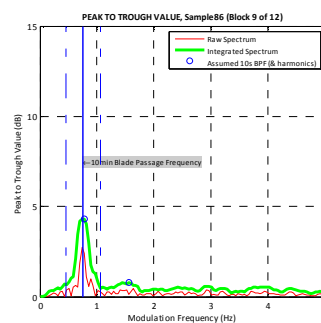
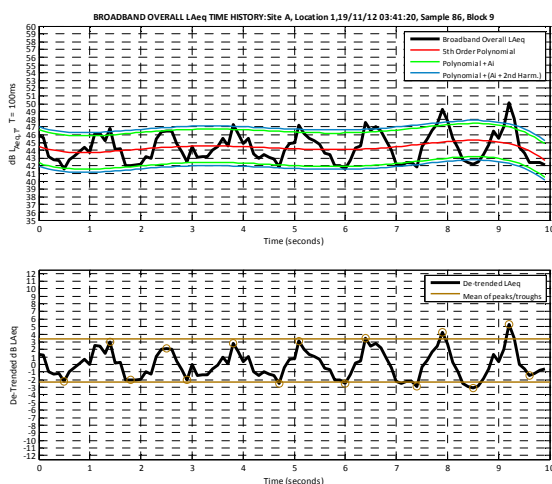


Modulation Results:

RUK Ai = 4.2dB at 0.8Hz
 Mean Peak to Trough = 5.4dB
 RUK Ai + 2nd Harm. = 5.3dB



Real data – Site A

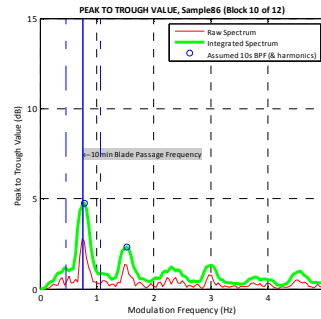
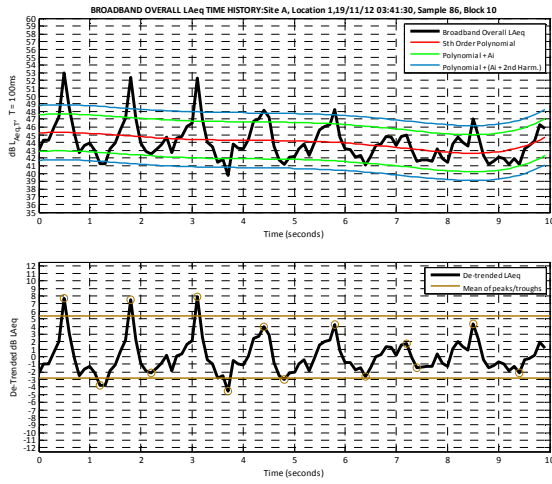


Modulation Results:

RUK Ai = 4.3dB at 0.8Hz
 Mean Peak to Trough = 5.7dB
 RUK Ai + 2nd Harm. = 5.1dB



Real data – Site A

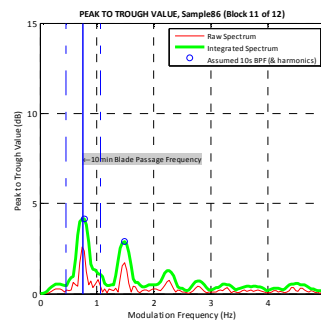
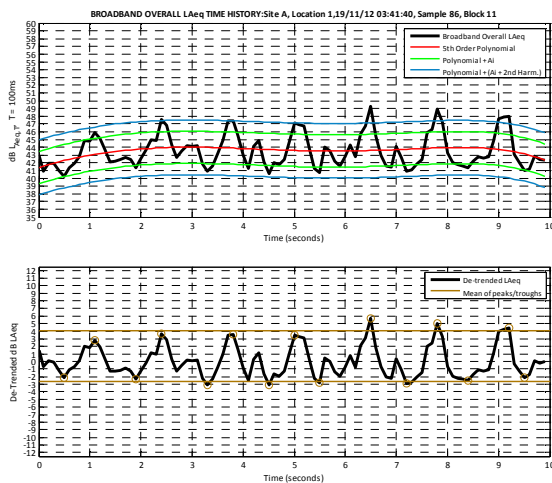


Modulation Results:

- RUK Ai = 4.8dB at 0.8Hz
- Mean Peak to Trough = 8.2dB
- RUK Ai + 2nd Harm. = 7.1dB



Real data – Site A

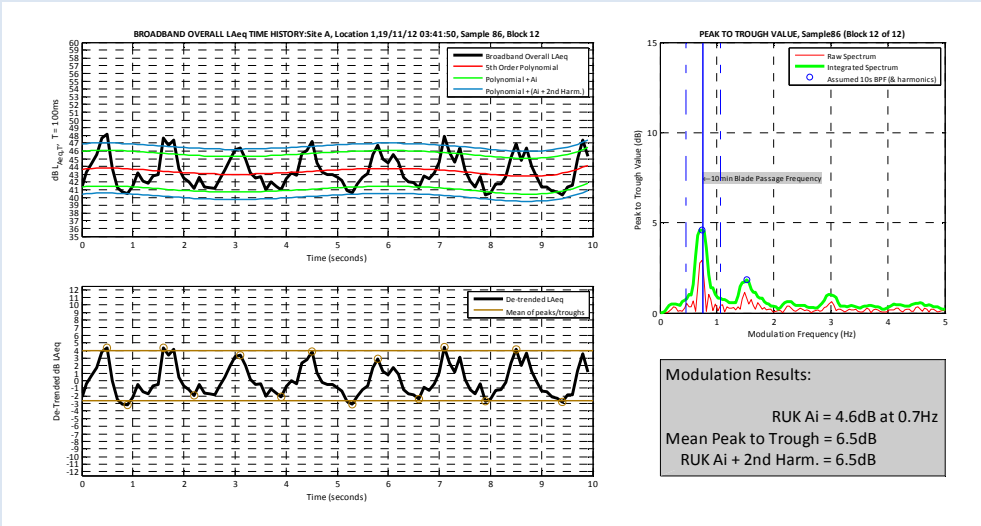


Modulation Results:

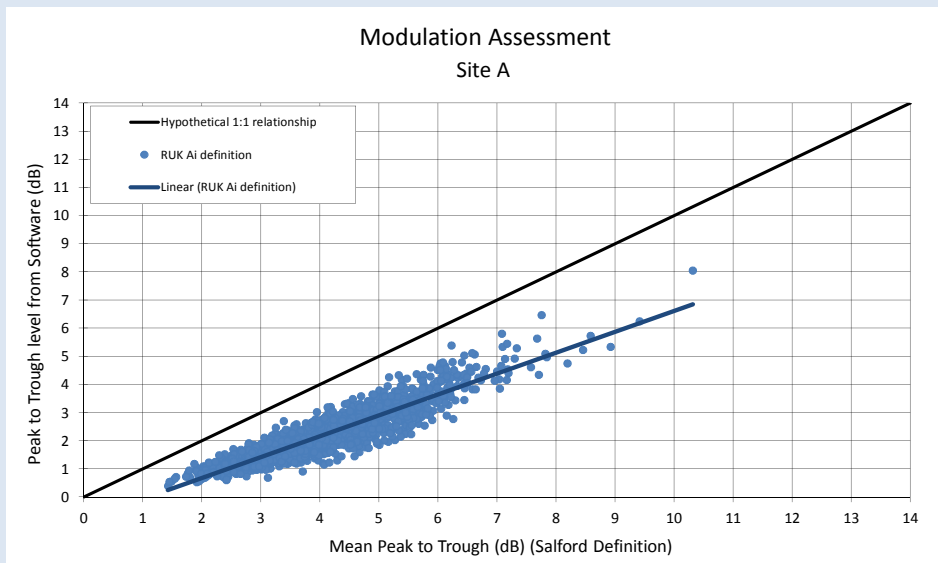
- RUK Ai = 4.2dB at 0.8Hz
- Mean Peak to Trough = 6.7dB
- RUK Ai + 2nd Harm. = 7.0dB



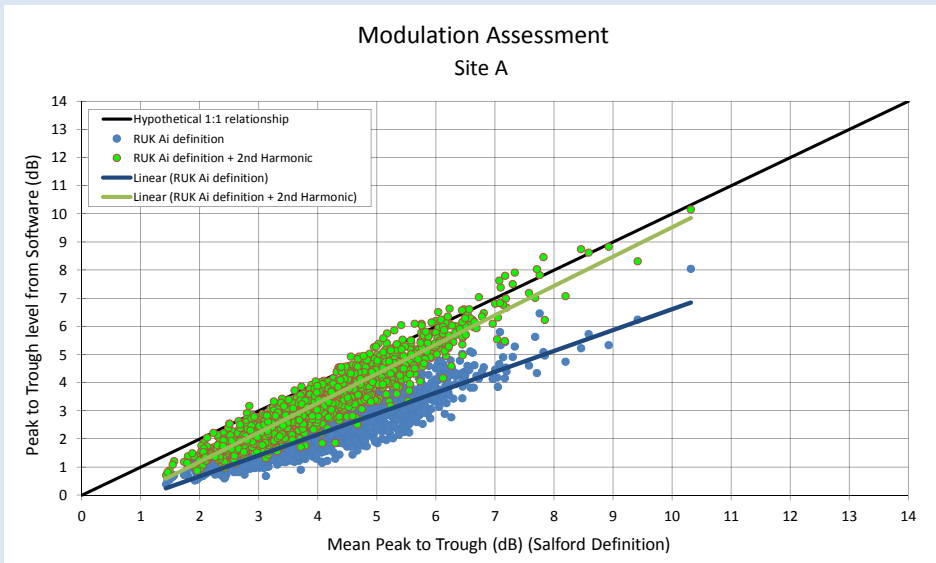
Real data – Site A



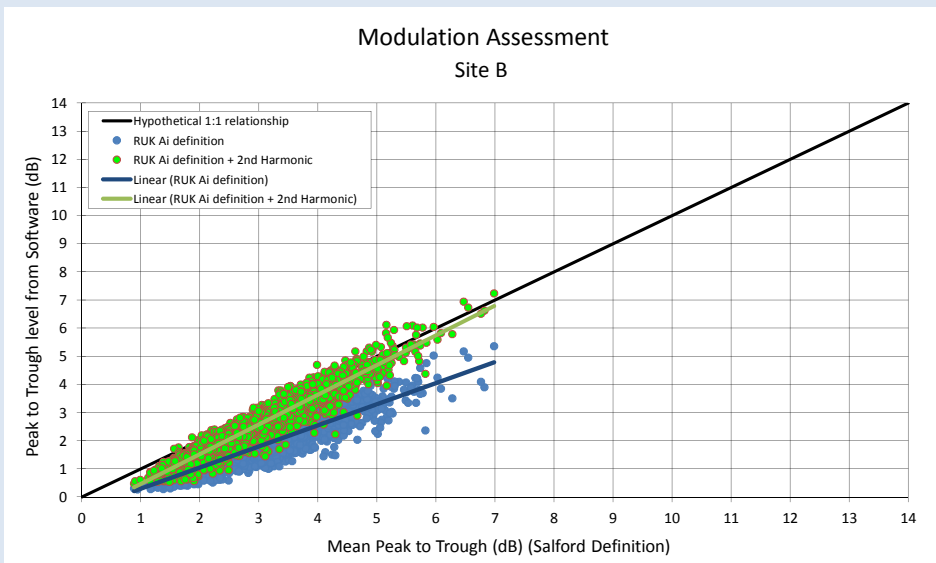
Real data – Site A



Real data – Site A



Real data – Site B



Issues – Variation in Modulation

- Real data not often constant over 10s
- Why not have overlapping windows?
 - Then the worst modulation bits will always be captured in the centre of window, rather than being split in half at a window intersection
 - Then, an increased chance that each block will have constant modulation, and it would be better able to relate to dose-response curves
- Why not use band limited data with frequencies specific to dynamic stall noise?
 - As suggested in places within RUK reports.
 - We know this is the reason for unexpected and elevated modulation.
 - That would reduce the chance of false positives from non-turbine sources.

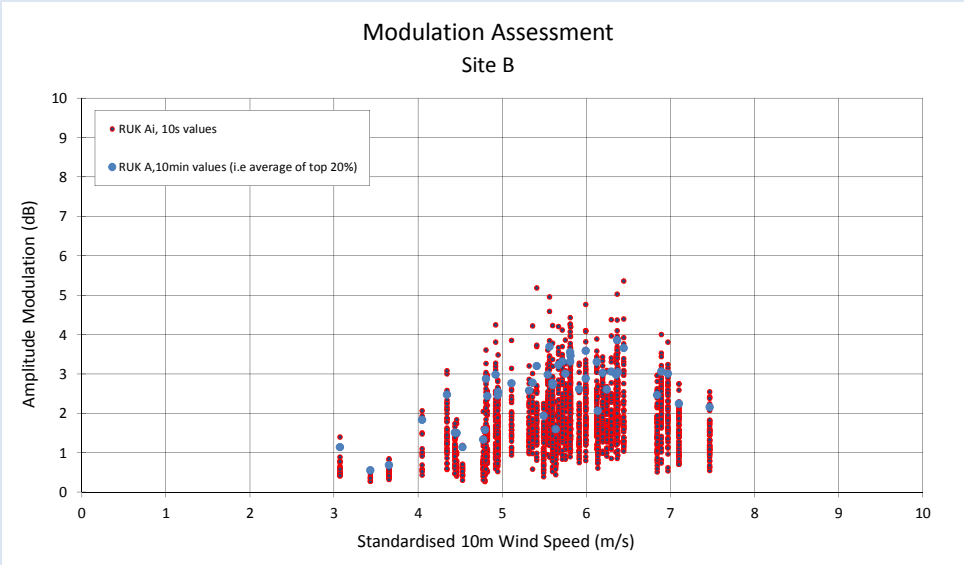


Issues – Modulation shape

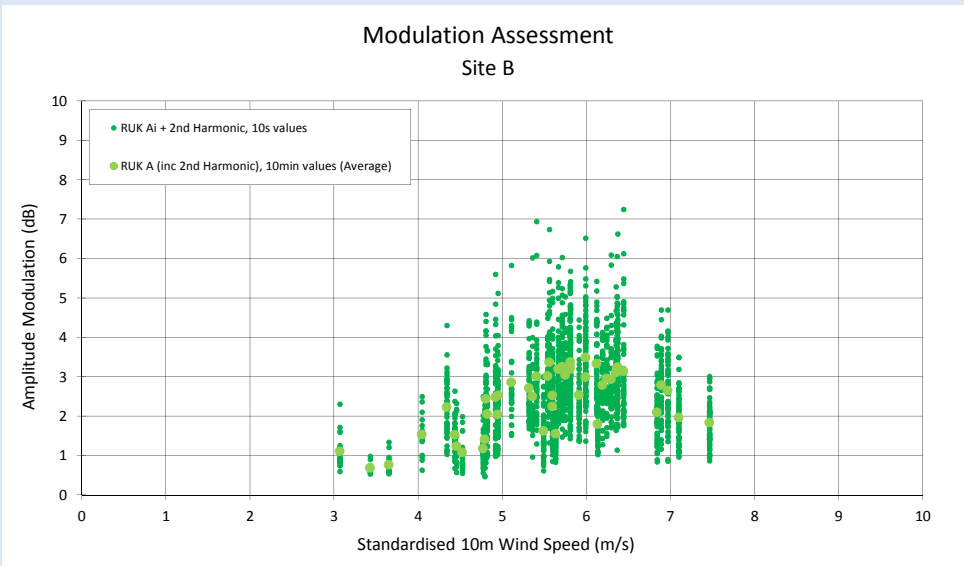
- With non-sinusoidal modulation, deriving the amplitude of the modulation from purely the fundamental is not sufficient
- On a 10s basis, the RUK method under-estimates
- But, the proposed condition takes the average of the top 20%
- Average of 2nd harmonic result is similar to the top 20% of RUK Ai results
- Both are still a bit under the average Peak-to-Trough value



Real data – Site B



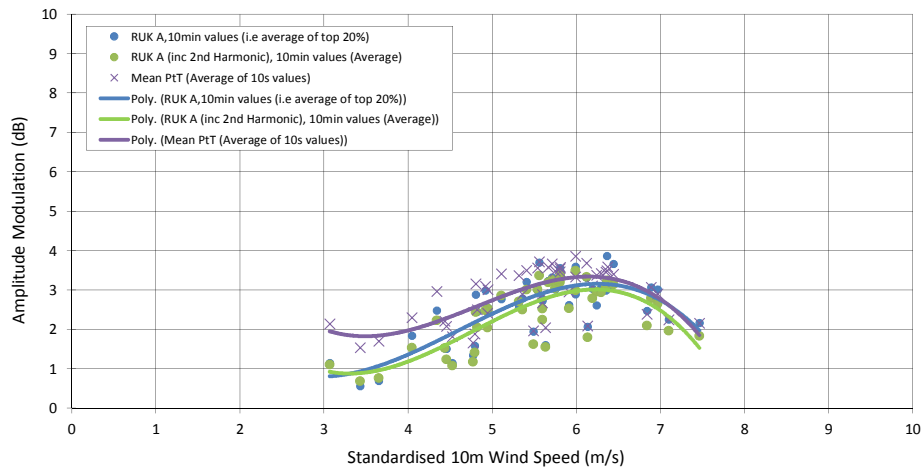
Real data – Site B



Real data – Site B

Modulation Assessment – 10 minute Results

Site B

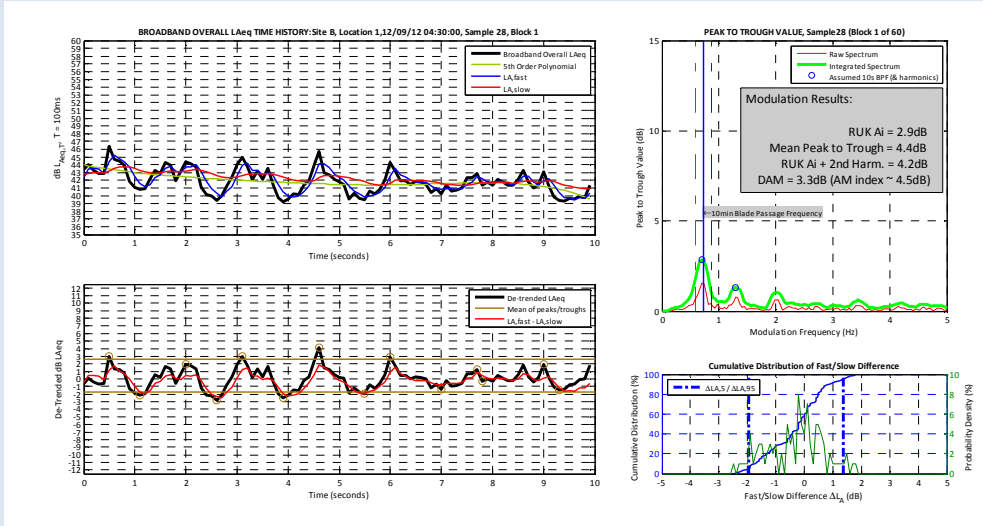


Other Methods: Fukushima et al/Yokoyama et al 2013 Fast/Slow AM Assessment Methodology

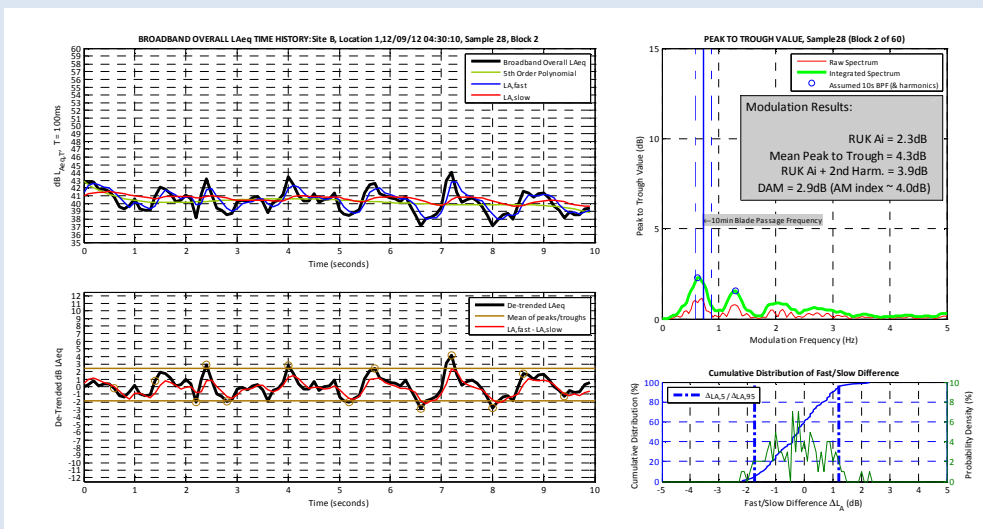
- Based upon the difference between Fast/Slow channels, and the 90% range of such differences within a measurement period
- Resulting AM Index (10s) gives a higher value than RUK Ai value
- Overly sensitive when there is significant drift in the underlying overall level, and quite susceptible to extraneous sources
- AM Index (10s) generally comparable to:
 - Mean Peak-to-Trough
 - RUK Ai + 2nd Harmonic



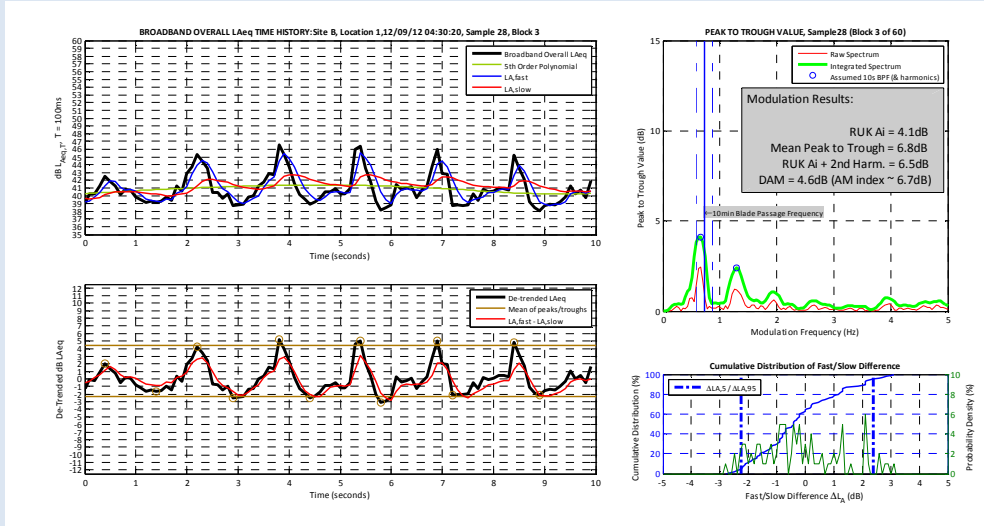
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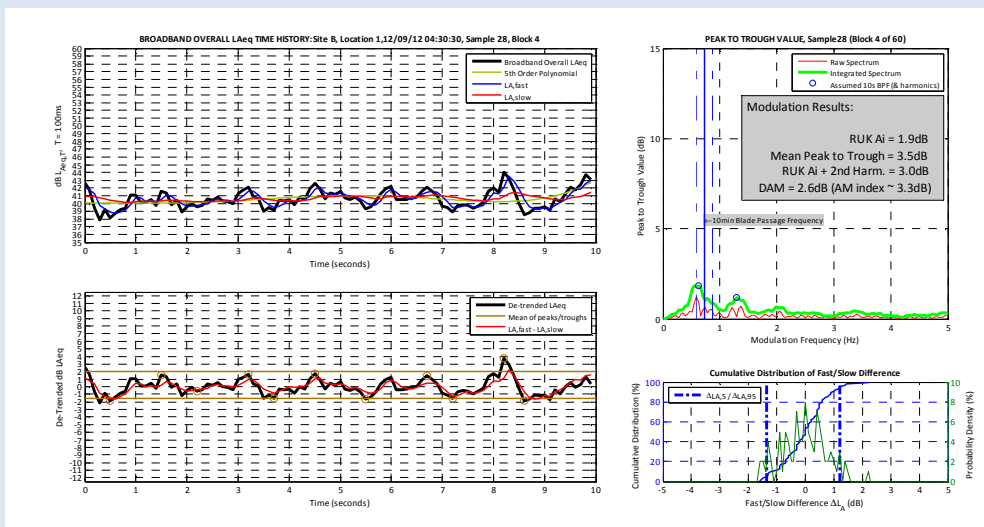
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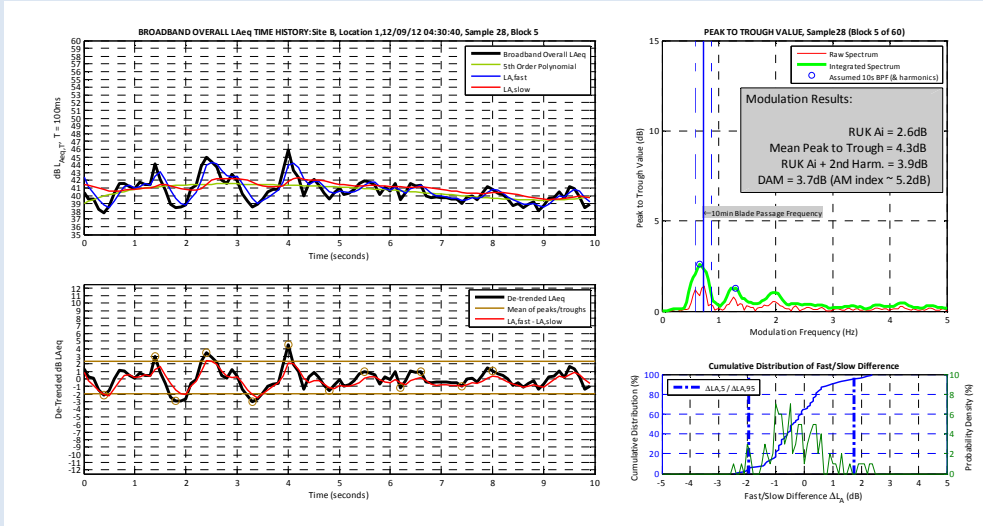
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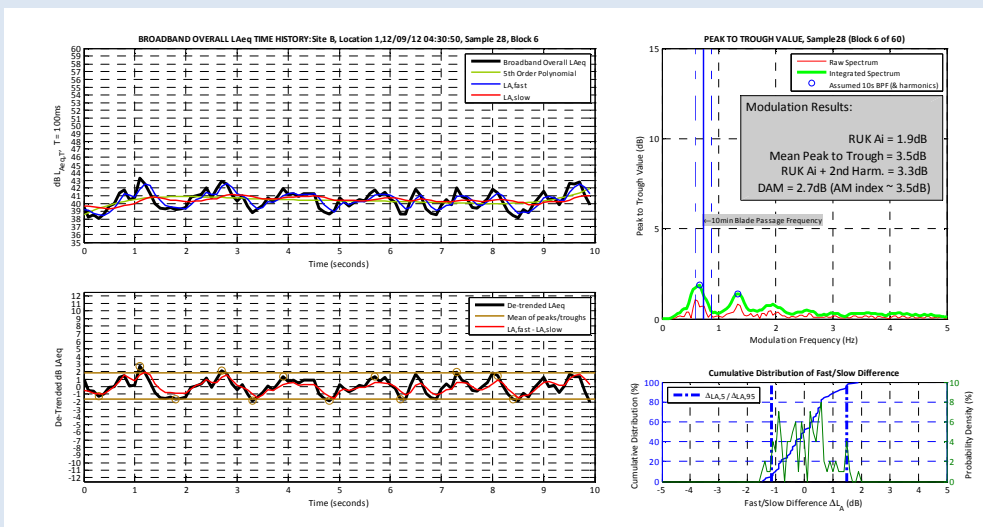
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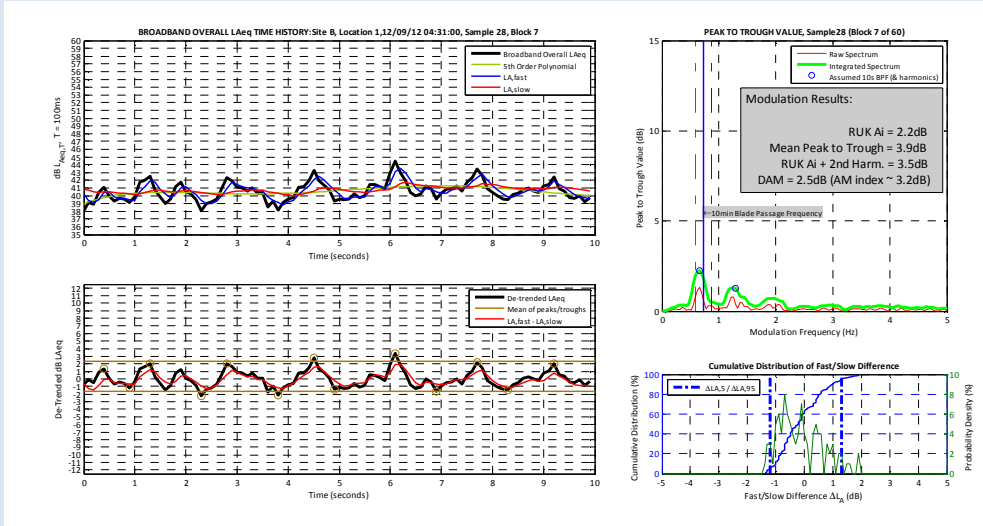
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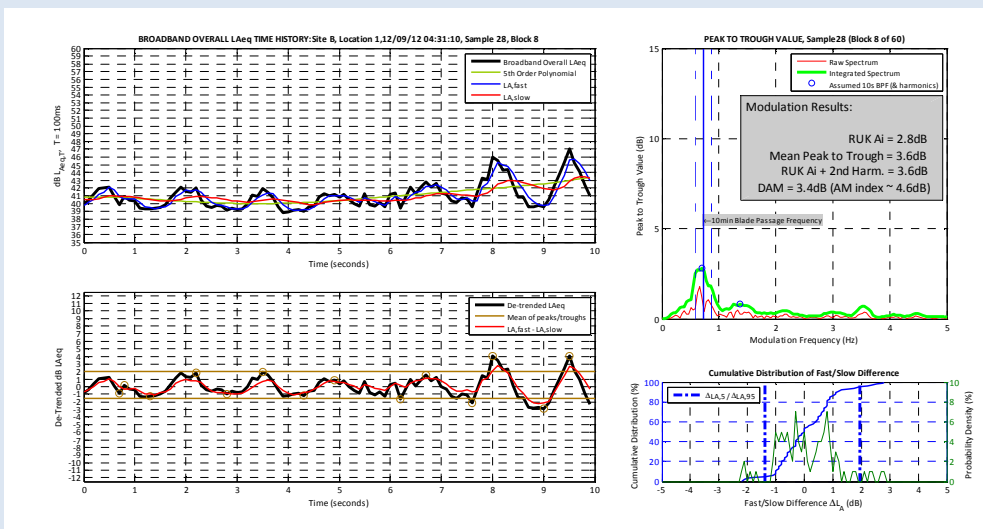
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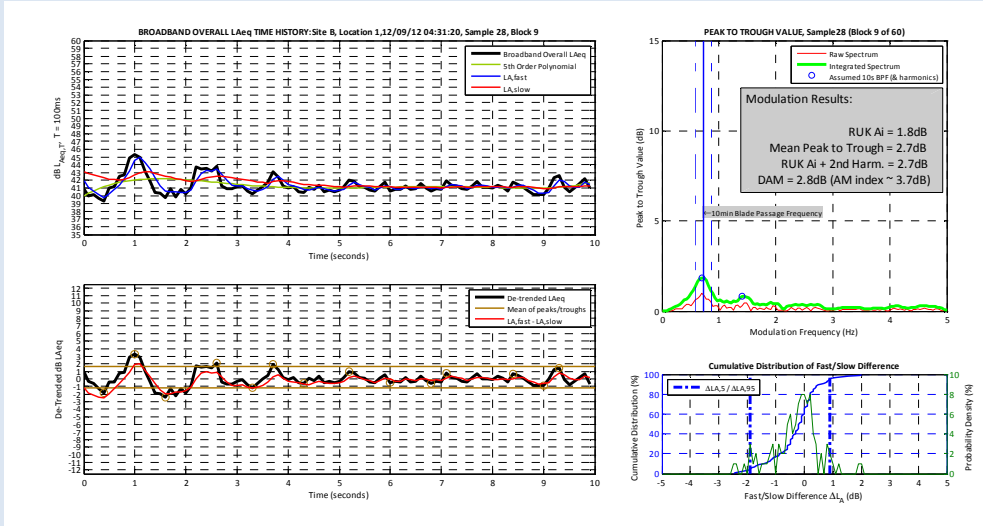
Other Methods: Fukushima et al/Yokoyama et al 2013 Fast/Slow AM Assessment Methodology



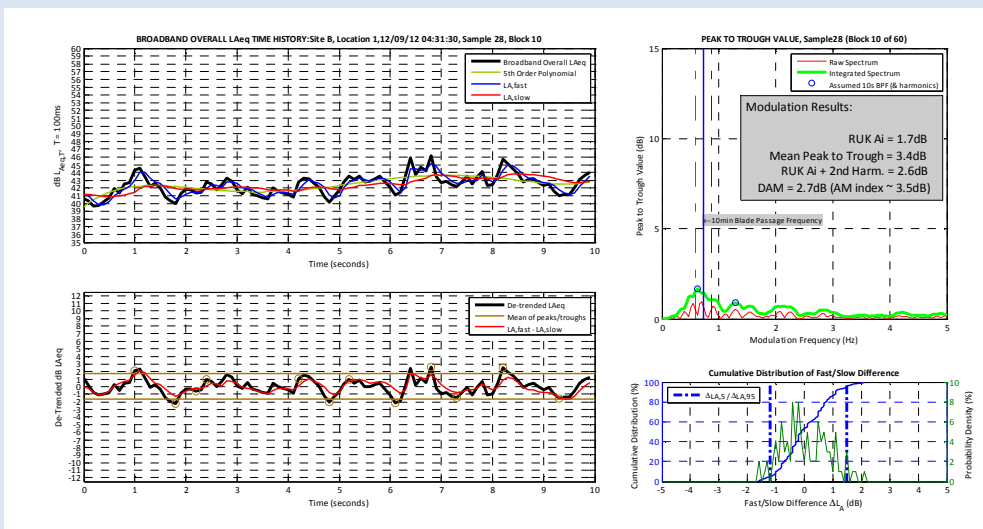
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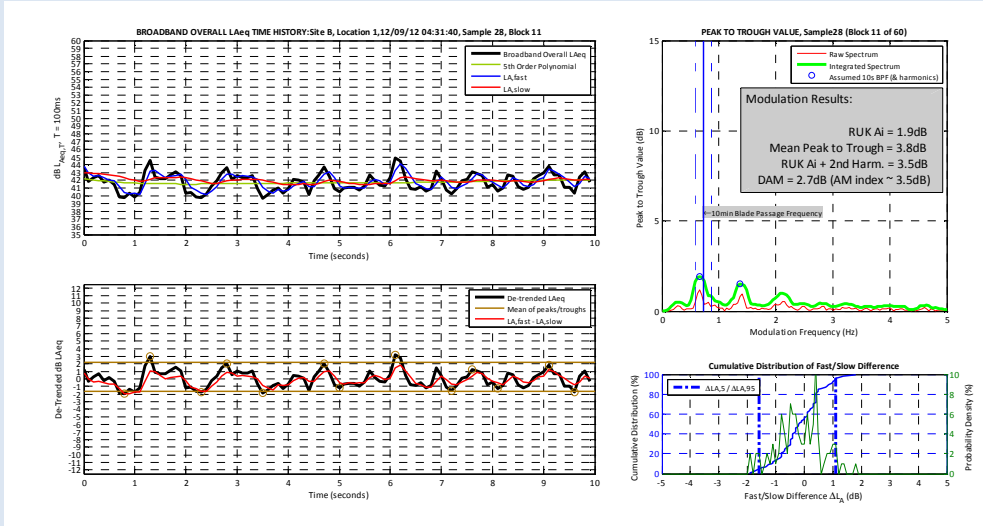
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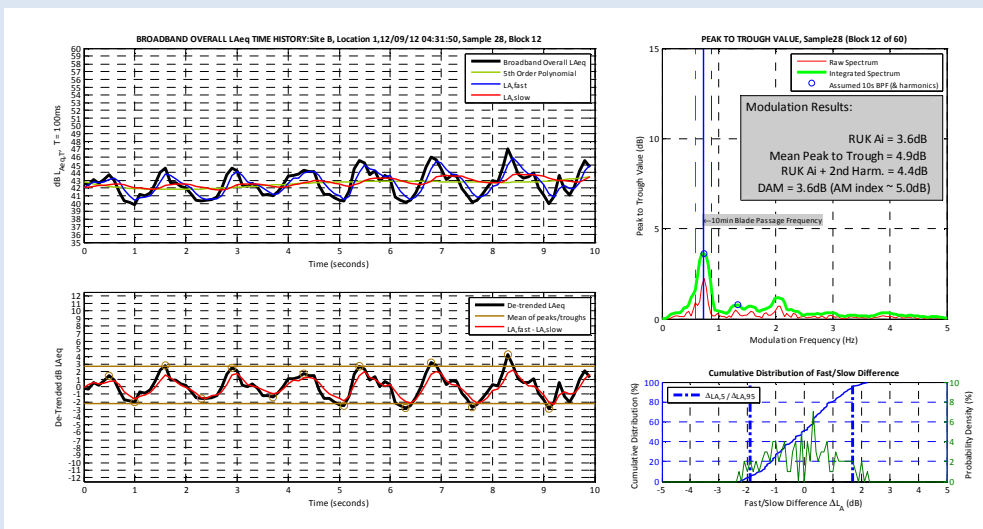
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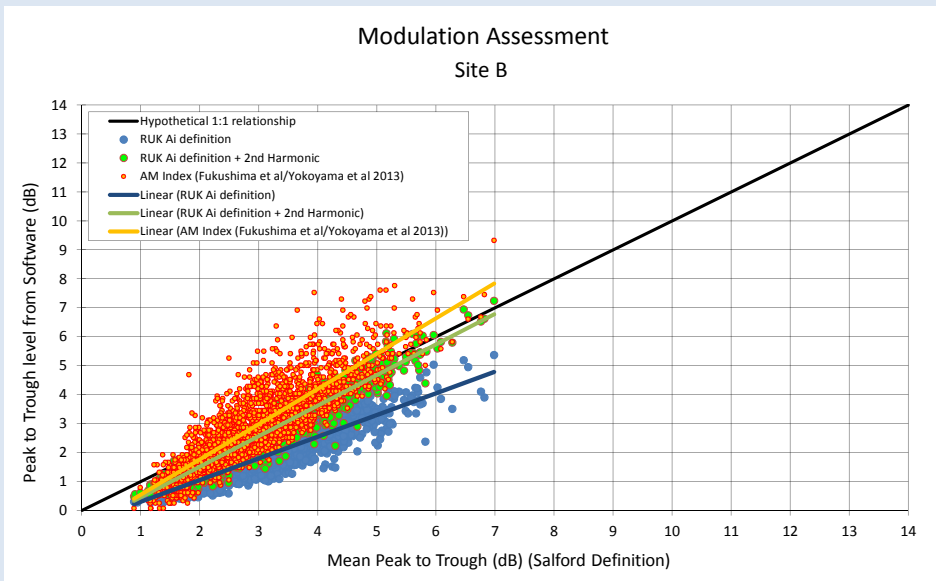
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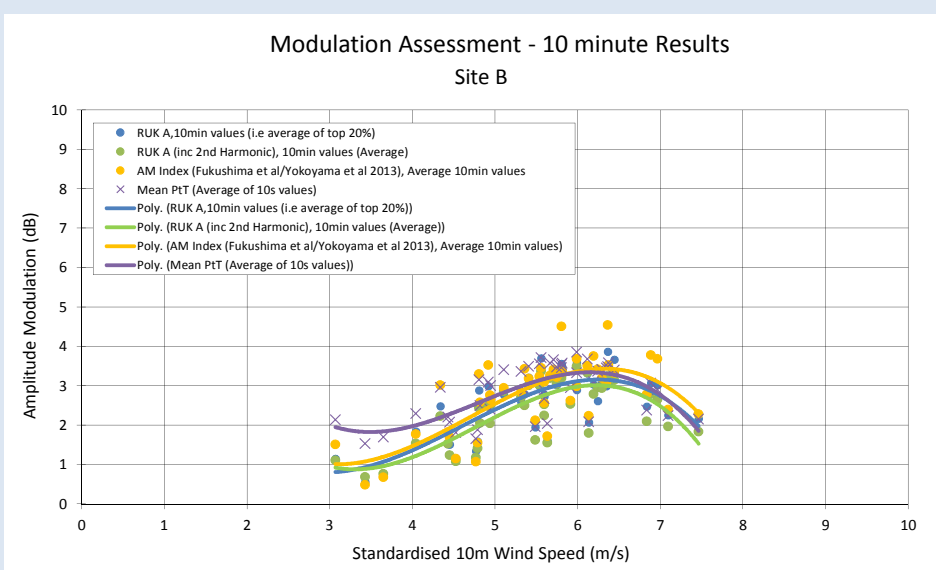
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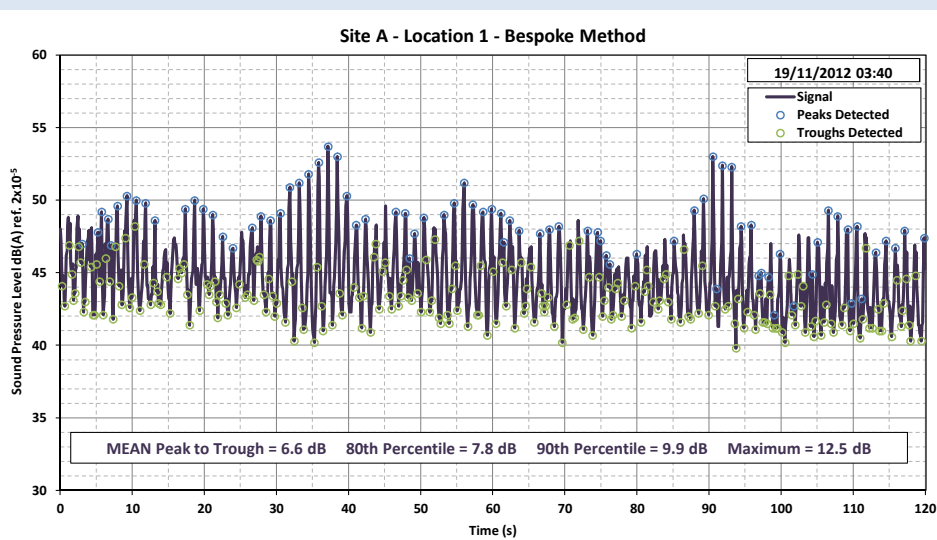


Other methods: Bespoke method

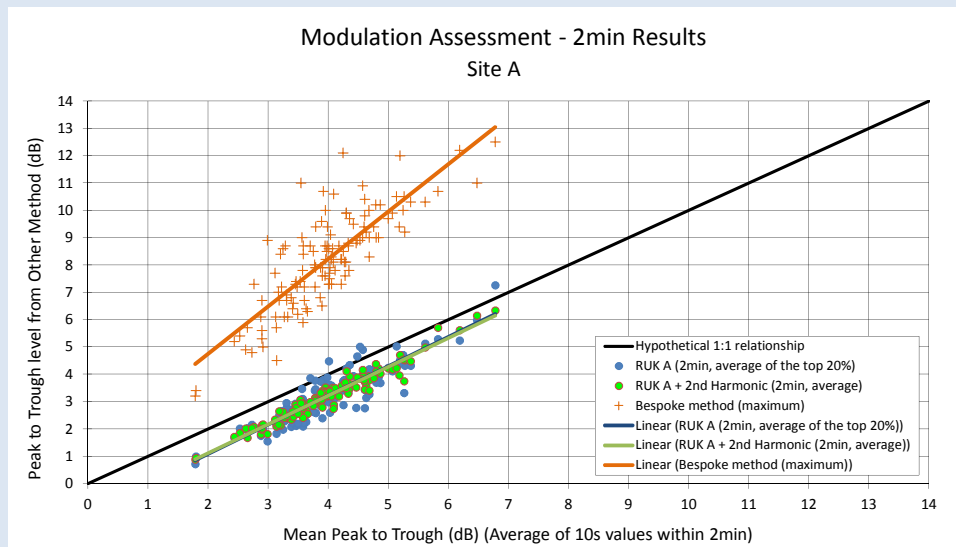
- Peaks are defined as any 100ms values where the two either side of it are lower and the next two either side are lower again
- Troughs are defined as any 100ms value where the two either side of it are higher
- For every peak determined, check the next 12 values for troughs and take the minimum
- Subtract the minimum trough value (if any) from the corresponding peak
- Take the average / XXth percentile / maximum, of the resulting values over each two minute period
- Taking the maximum would be indicative of Denbrook type condition



Other methods: Bespoke method



Other methods: Bespoke method



Conclusions

- Under-estimation with constant modulation
- Room for improvement in:
 - Normalisation value
 - De-trending step
 - Variability of modulation and division of 10s results
 - Addressing non-sinusoidal modulation
 - Include energy at harmonics when above certain criterion?
- Comparison with other methods
 - The average of top 20% does compensate for some of the above issues, to some extent



Thank You

