FSV: an introduction

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Aim

The purpose of this talk is to introduce the FSV (Feature Selective Validation) method, to describe its origin, the process, some applications and possible other areas for investigation

Structure

- Origins
- What is the nature of the data
- FSV: the equations
- An illustrative SI/PI application
- Next steps

In the early 1990s I was involved in validating the Transmission Line Matrix (TLM) electromagnetic simulation technique.

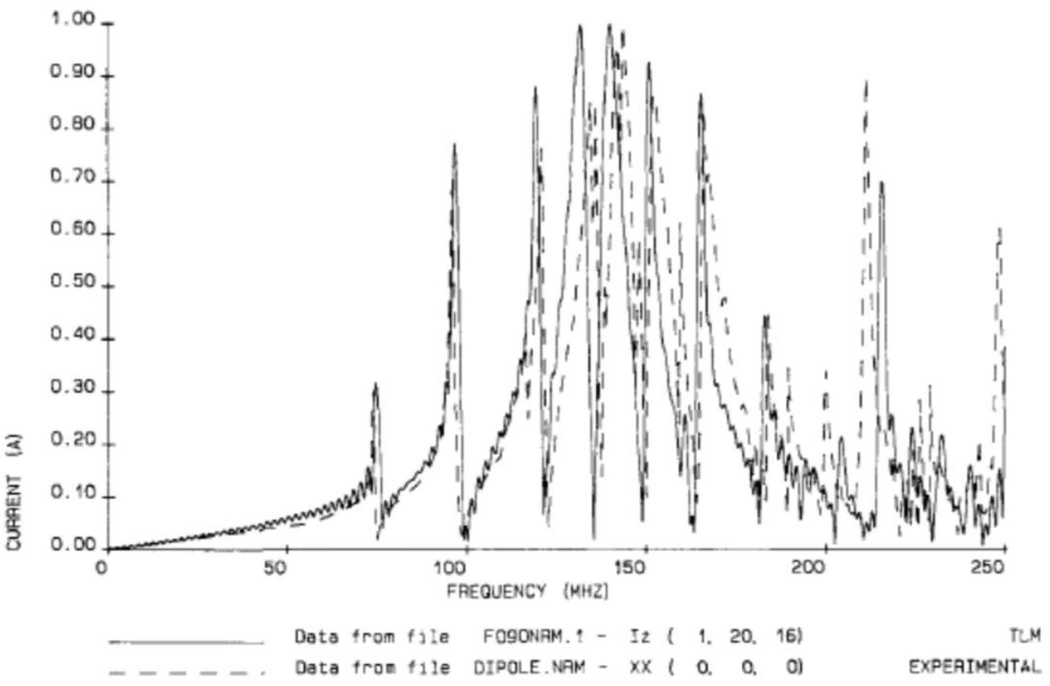


Fig. 10. Dipole current comparison, hybrid variable mesh with experiment.

Validation was frequently done against measurements or other (different) simulation techniques.

Usually, just by looking at the results and commenting on whether they look ok.

It was not robust but there was little alternative: correlation really did not work well for the sort of data being investigated

This is typical of the results being compared.

Duffy *et al*, T-EMC, 1993

More to the point, how could I decide which of these is better

If at all

And if so, by how much … is the benefit of the “improvements” worth the extra time and cost to the method?

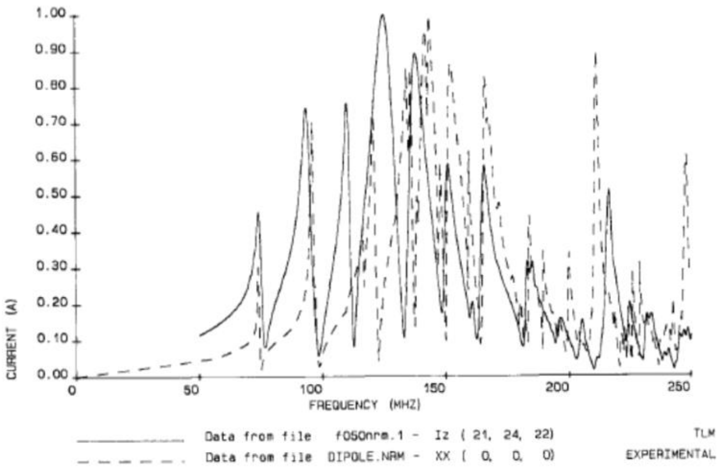


Fig. 8. Dipole current comparison, regular mesh TLM with experiment.

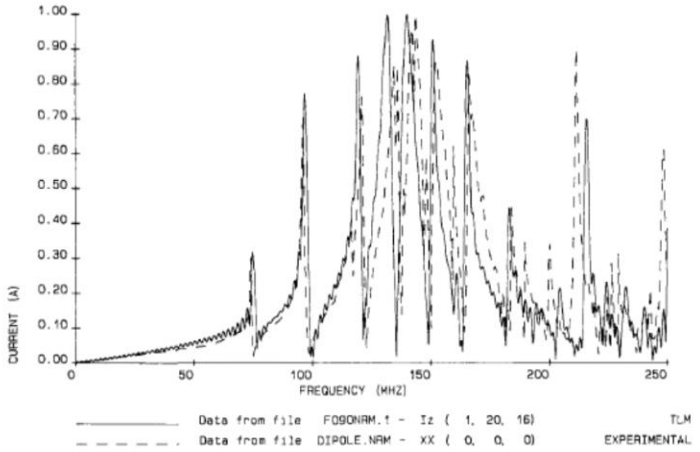


Fig. 10. Dipole current comparison, hybrid variable mesh with experiment.

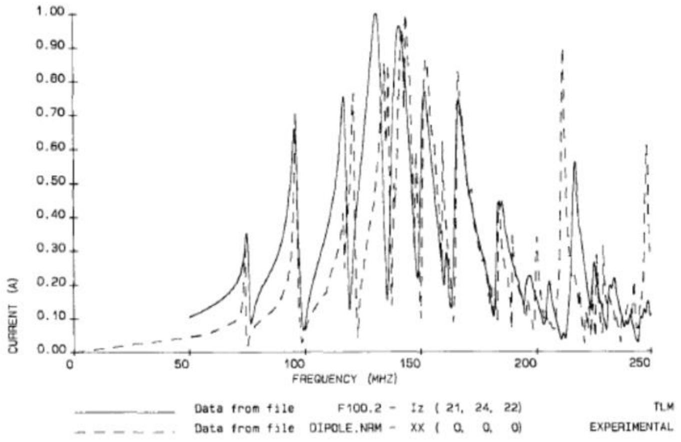


Fig. 12. Dipole current comparison, approximate corrective method with experiment.

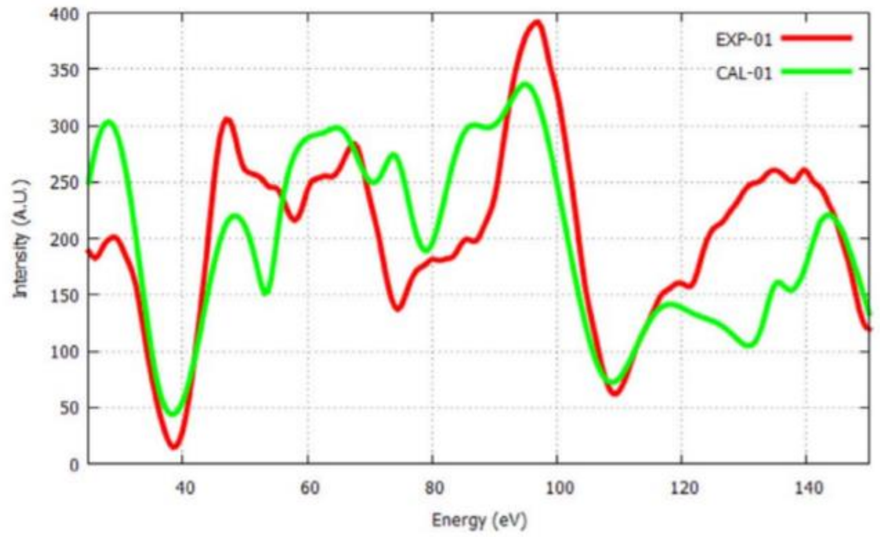
Or here, is the approximate method “good enough” compared with the (then) accurate hybrid mesh method?

Clearly, something needed to be done… there was no way to add objectivity to discussions.

Correlation did not really work – on its own, all of the previous figures came out about the same

One class of approaches that seemed to have merit were the Reliability Factors used by surface crystallographers to validate models (Low Energy Electron Diffraction)

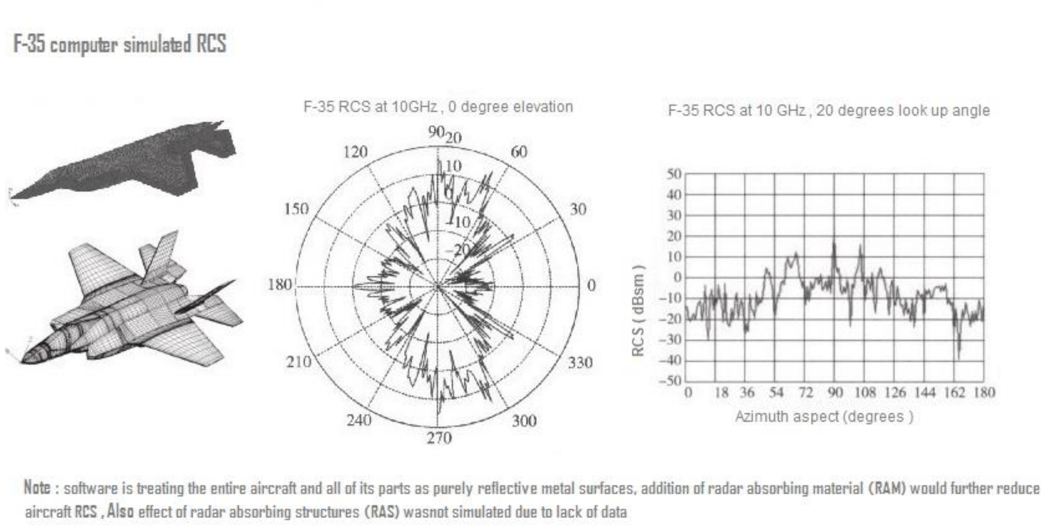
(e.g. Pendry, Van Hove, etc.)



(c) (01) beam, bulk 2H-MoS_2

Image taken from: Zhongwei Dai, Wencan Jin, Maxwell Grady, Jerzy T. Sadowski, Jerry I. Dadap, Richard M.Osgood Jr., Karsten Pohl
Surface structure of bulk 2H-MoS_2(0001) and exfoliated suspended monolayer MoS_2: A selected area low energy electron diffraction study
Surface Science, Volume 660, 2017, pp. 16-21

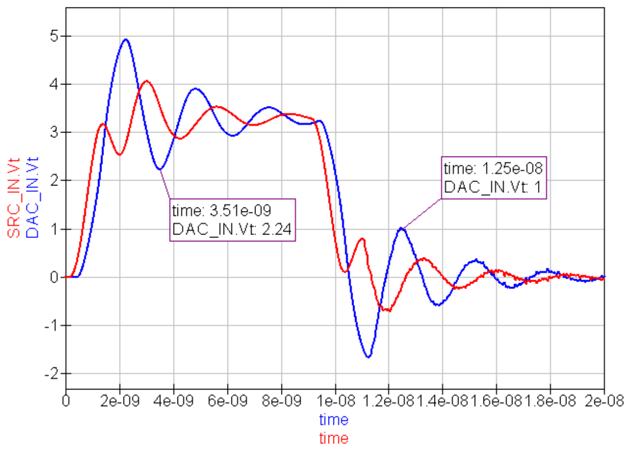
Unfortunately those techniques did not properly discriminate or give the flexibility required



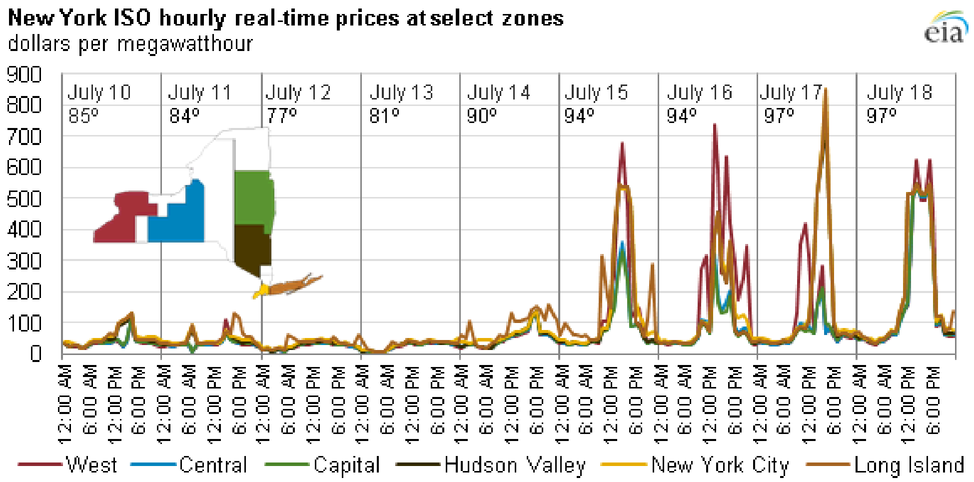
The challenge was then to design a method that could work for EMC data ...

Noting other areas have similar data structures. For example in antennas and propagation

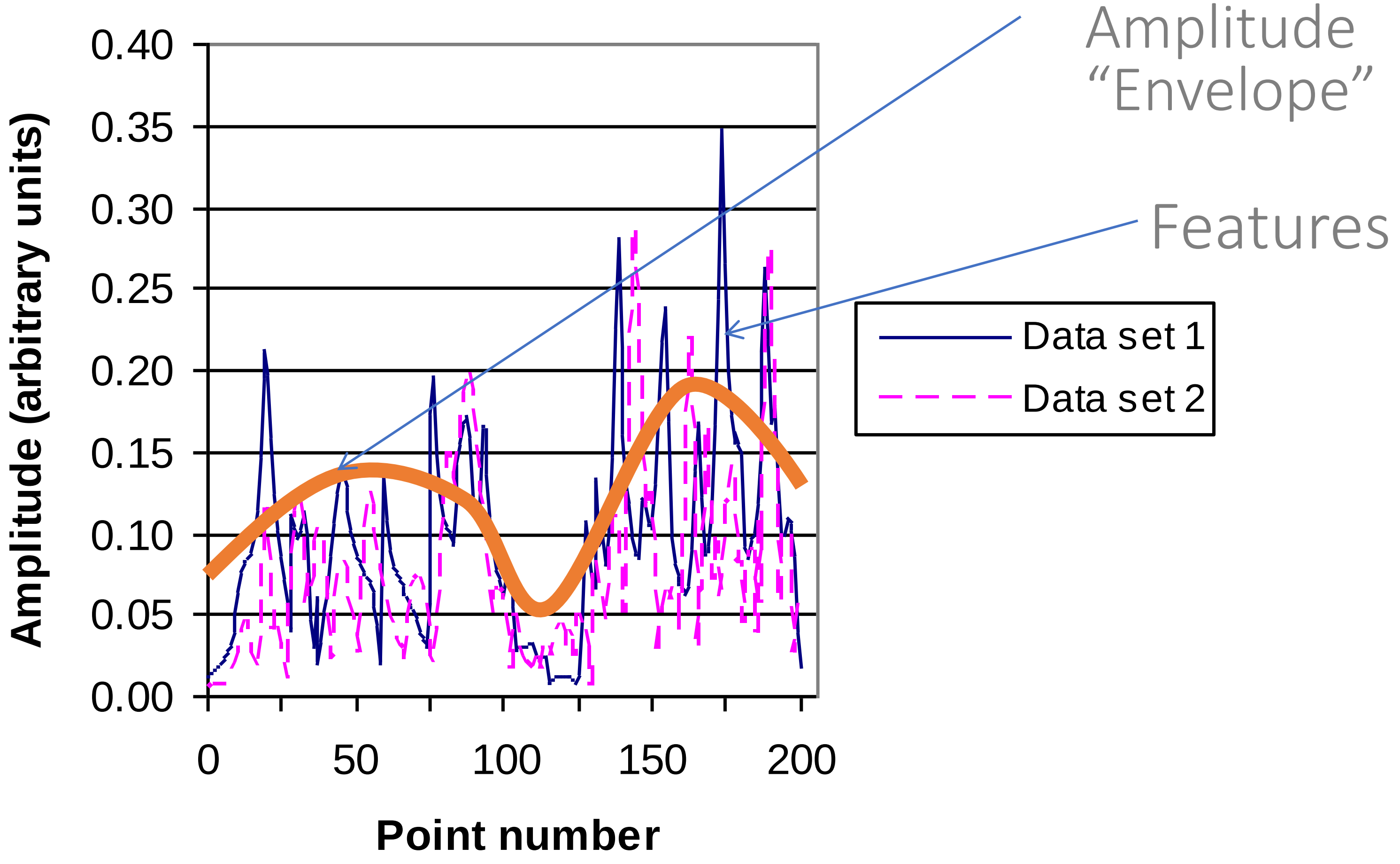
Or signal integrity



Or even energy related...



The nature of data?

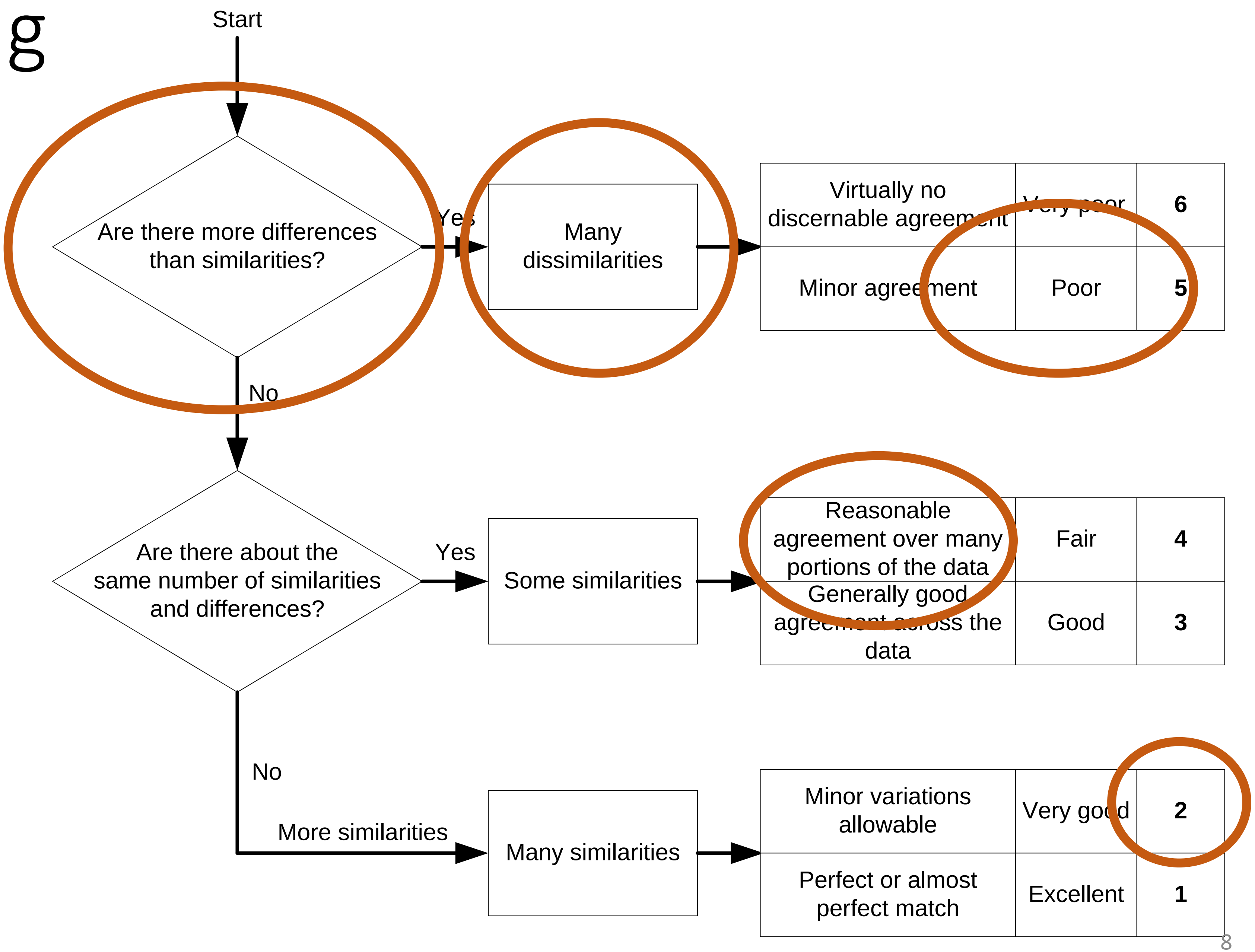


This suggests we need an overall measure comprised of measures based on the envelope and the features.

But we also need to capture how people view the data.

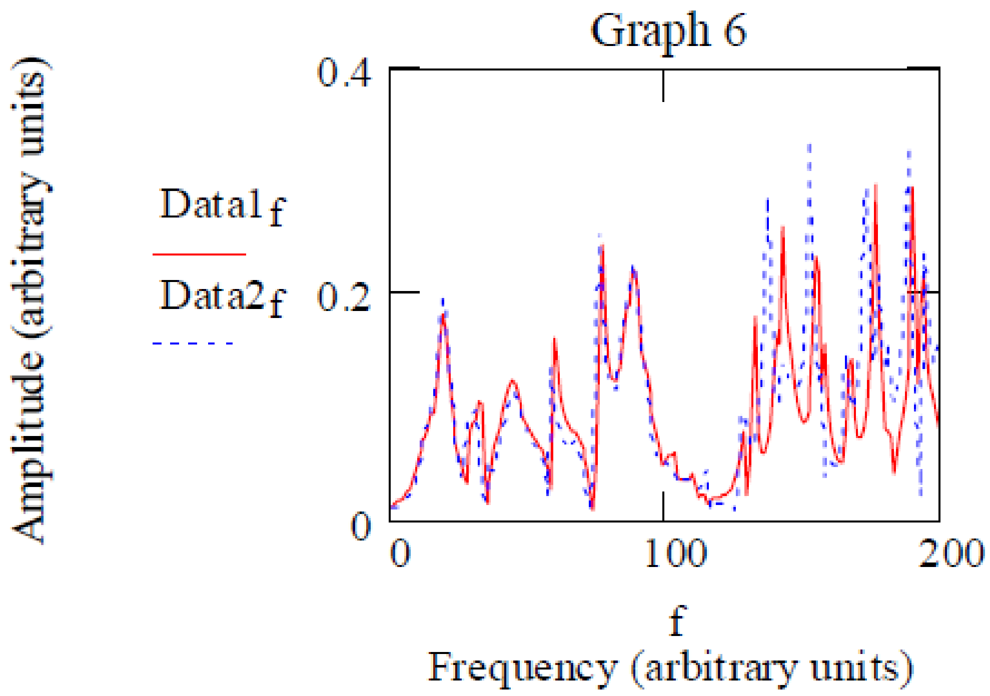
Visual rating scale

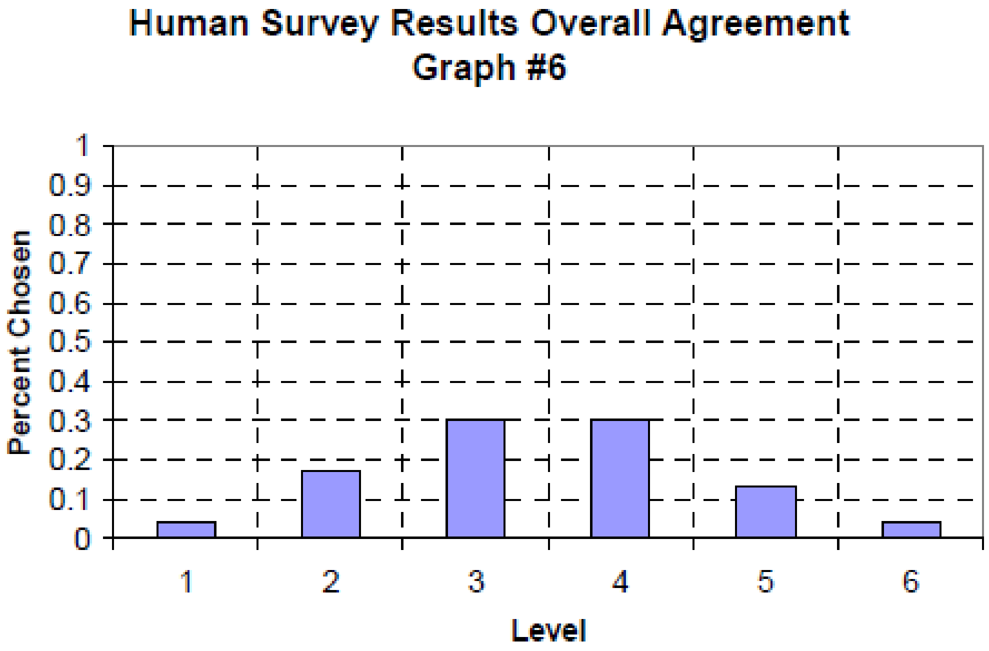
- “yardstick” for visual comparison
- Based on Cooper-Harper scale.



Visual rating scale

Get histograms from groups.





FSV implementation

The following slides show the mathematical detail of the method and its interpretation.

ADM

Amplitude difference measure

Trend comparison term

Compensation for linear offsets

$$ADM(n) = \left|\frac{\alpha}{\beta}\right| + \left|\frac{\chi}{\delta}\right| \exp\left\{\left|\frac{\chi}{\delta}\right|\right\}$$

$$\alpha = \left(\left|\mathrm{Lo}_1(n)\right| - \left|\mathrm{Lo}_2(n)\right|\right)$$

Difference between (absolute) intensities

$$\chi = \left(\left|\mathrm{DC}_1(n)\right| - \left|\mathrm{DC}_2(n)\right|\right)$$

$$\beta = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\left|\mathrm{Lo}_1(i)\right| + \left|\mathrm{Lo}_2(i)\right|\right)\right]$$

$$\delta = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\left|\mathrm{DC}_1(i)\right| + \left|\mathrm{DC}_2(i)\right|\right)\right]$$

Compensation for linear offsets

FDM

- The Feature Difference Measure is constructed from:

$$FDM(f) = 2\left(\left|FDM_1(f) + FDM_2(f) + FDM_3(f)\right|\right)$$

FSV

- Where

Note the weighting factors to help balance the overall contribution

$$FDM_1(f) = \frac{\left|\mathrm{Lo}_1'(f)\right| - \left|\mathrm{Lo}_2'(f)\right|}{\frac{2}{N}\sum_{i=1}^{N}\left[\left(\left|\mathrm{Lo}_1'(i)\right| + \left|\mathrm{Lo}_2'(i)\right|\right)\right]}$$

$$FDM_2(f) = \frac{\left|\mathrm{Hi}_1'(f)\right| - \left|\mathrm{Hi}_2'(f)\right|}{\frac{6}{N}\sum_{i=1}^{N}\left[\left(\left|\mathrm{Hi}_1'(i)\right| + \left|\mathrm{Hi}_2'(i)\right|\right)\right]}$$

$$FDM_3(f) = \frac{\left|\mathrm{Hi}_1''(f)\right| - \left|\mathrm{Hi}_2''(f)\right|}{\frac{7.2}{N}\sum_{i=1}^{N}\left[\left(\left|\mathrm{Hi}_1''(i)\right| + \left|\mathrm{Hi}_2''(i)\right|\right)\right]}$$

FSV

- The Global Difference Measure (GDM) is given by:

$$GDM(f) = \sqrt{ADM(f)^2 + FDM(f)^2}$$

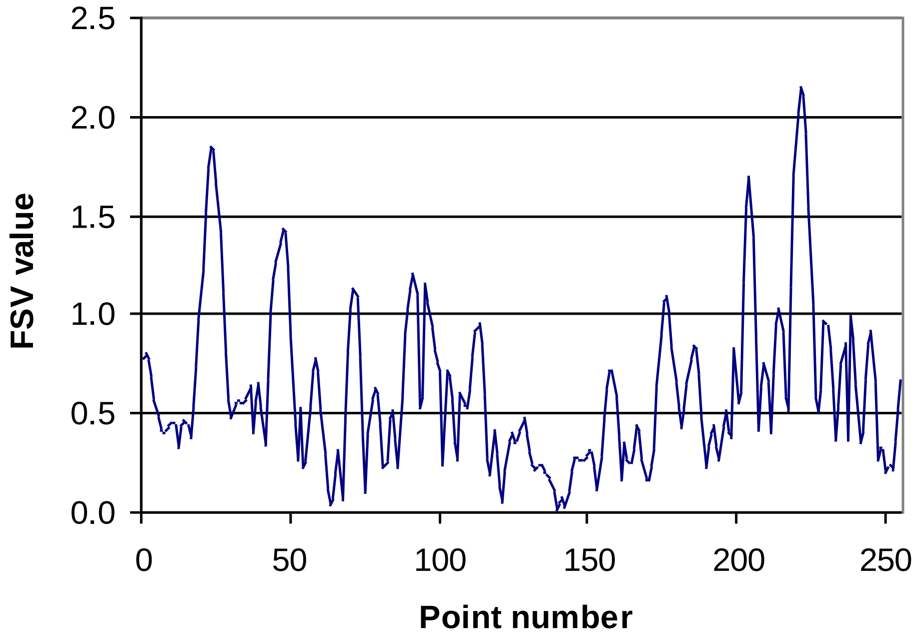
- Single figure ‘goodness-of-fit’ values are obtained by taking a mean value of the ADM, FDM and GDM.

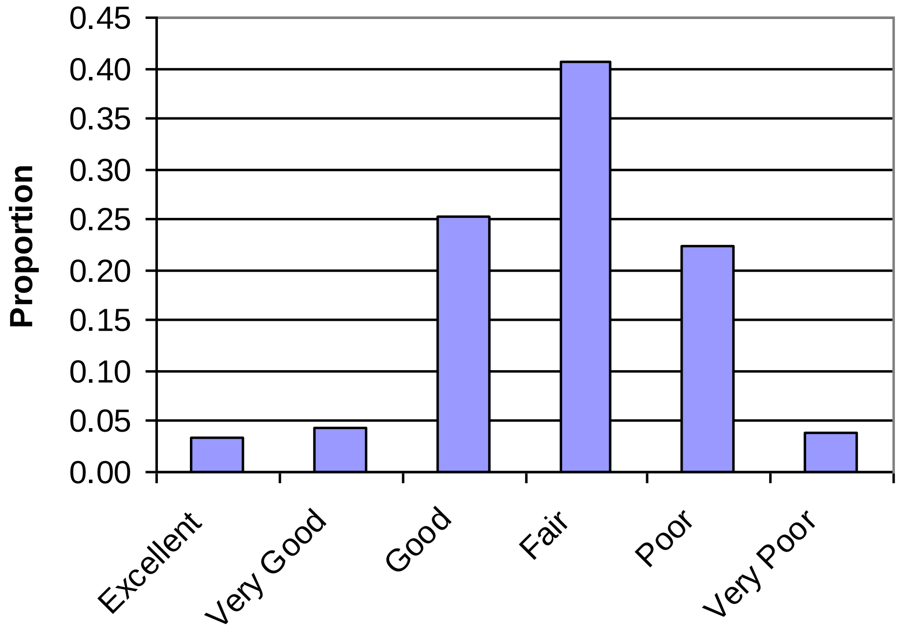
FSV

- Values can be related to natural language descriptors:

FSV value (quantitative)	FSV interpretation (qualitative)
Less than 0.1	Excellent
Between 0.1 and 0.2	Very good
Between 0.2 and 0.4	Good
Between 0.4 and 0.8	Fair
Between 0.8 and 1.6	Poor
Greater than 1.6	Very poor

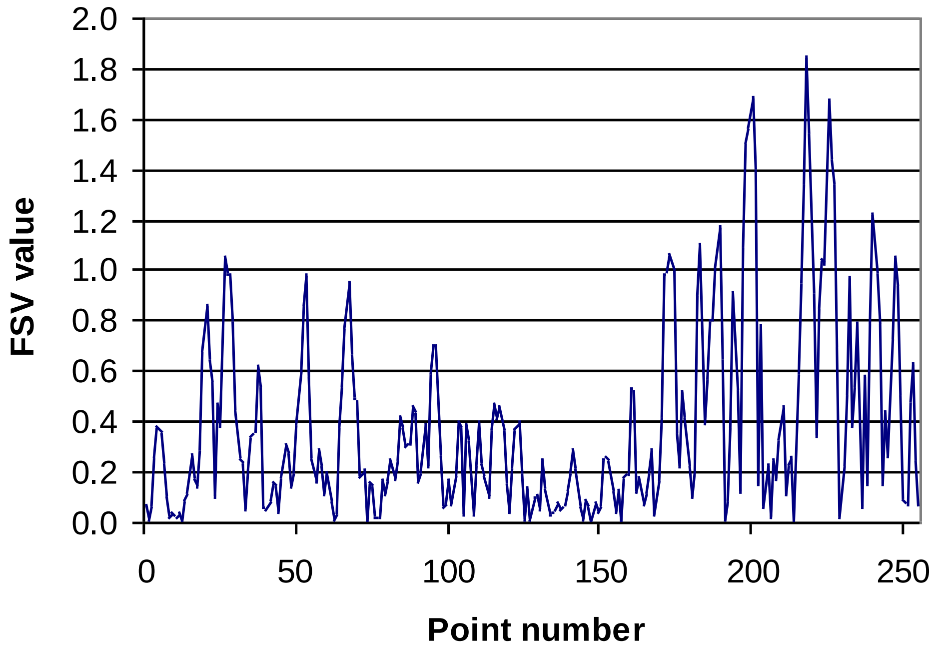
ADM

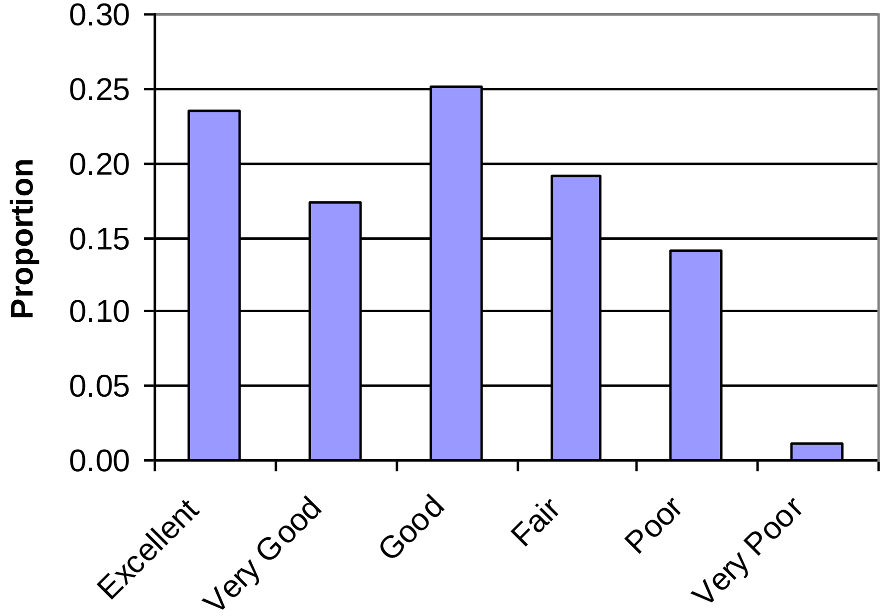




- Mean value = 0.62

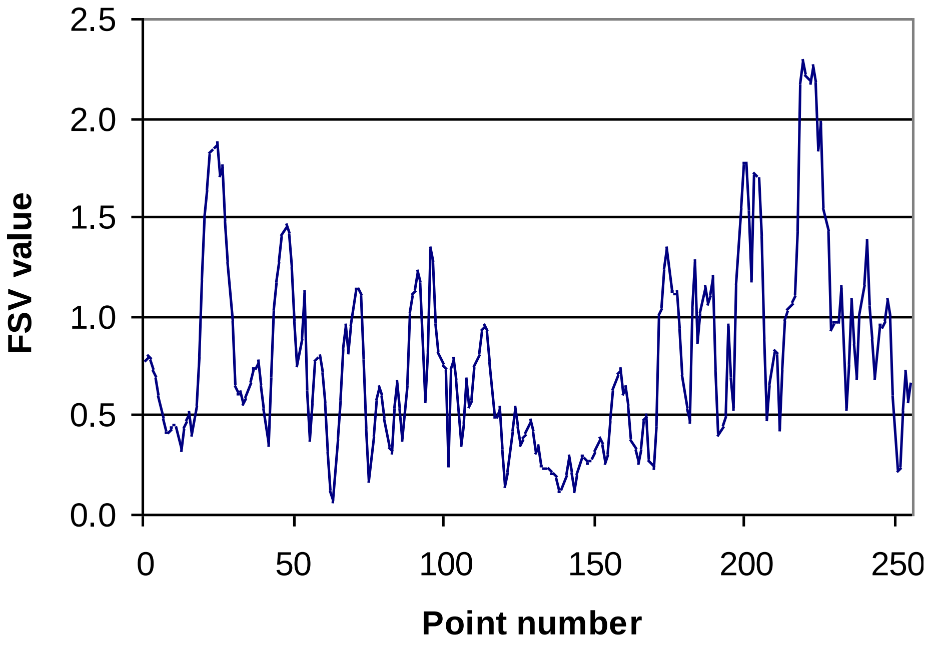
FDM

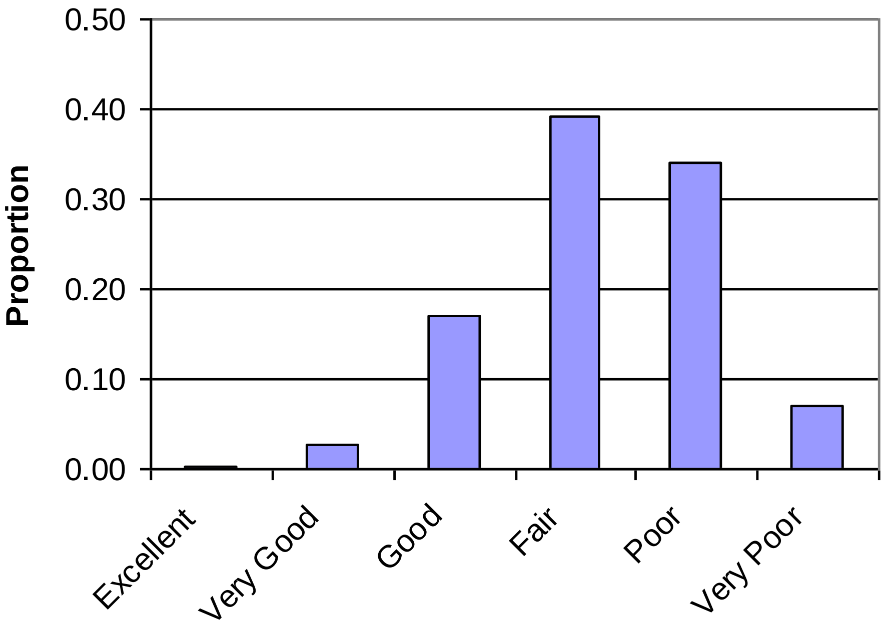




- Mean value = 0.39

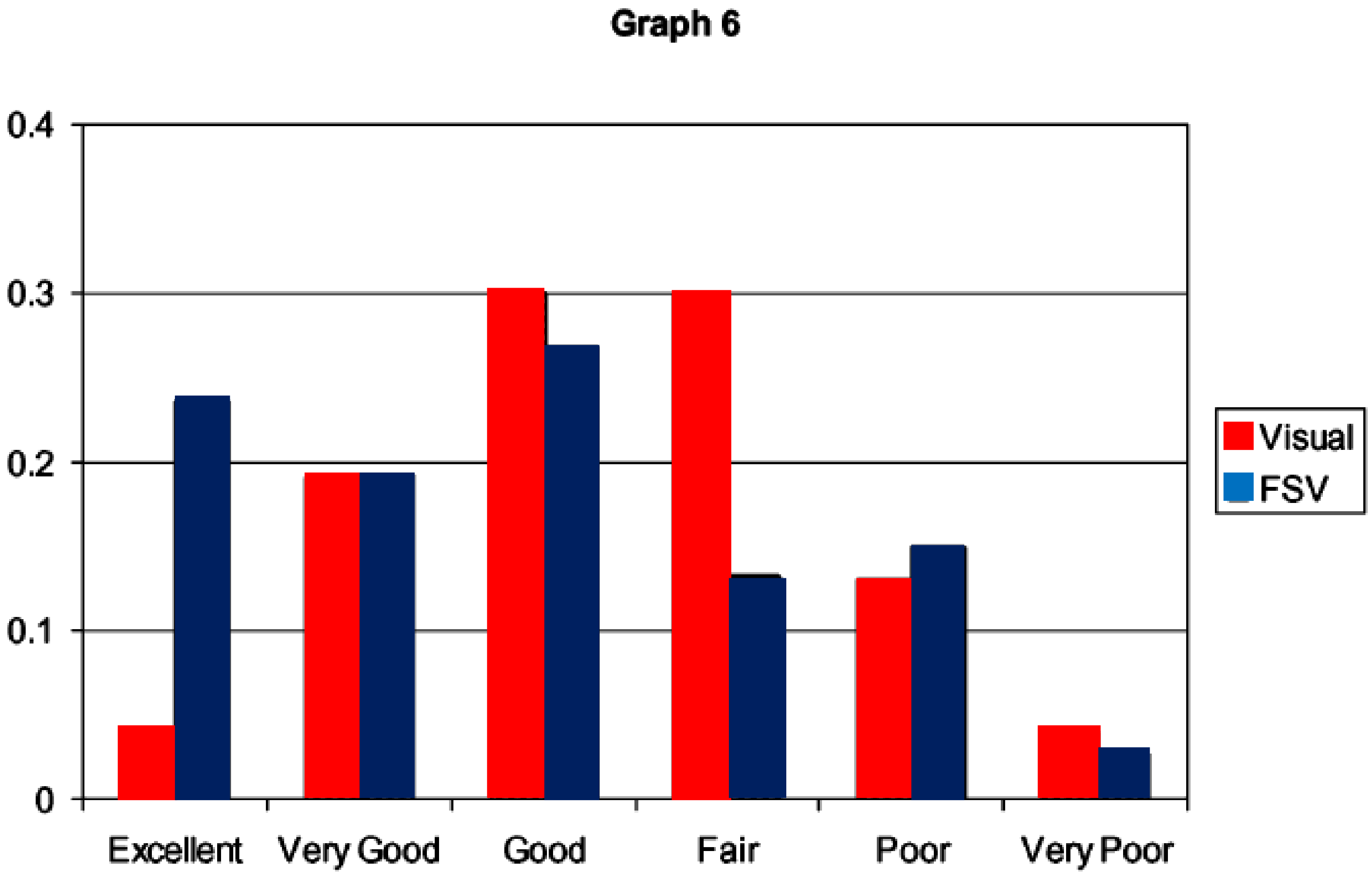
GDM





- Mean value = 0.8

Comparison - typical agreement from similar comparison (2004 survey)



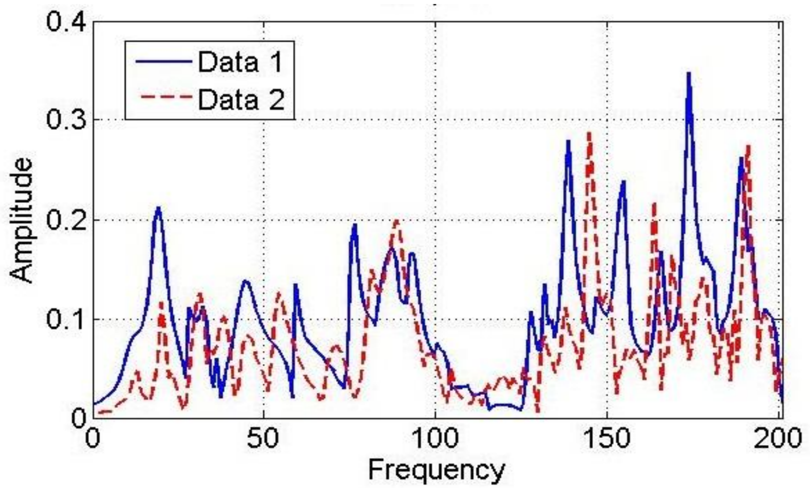
FSV Developments

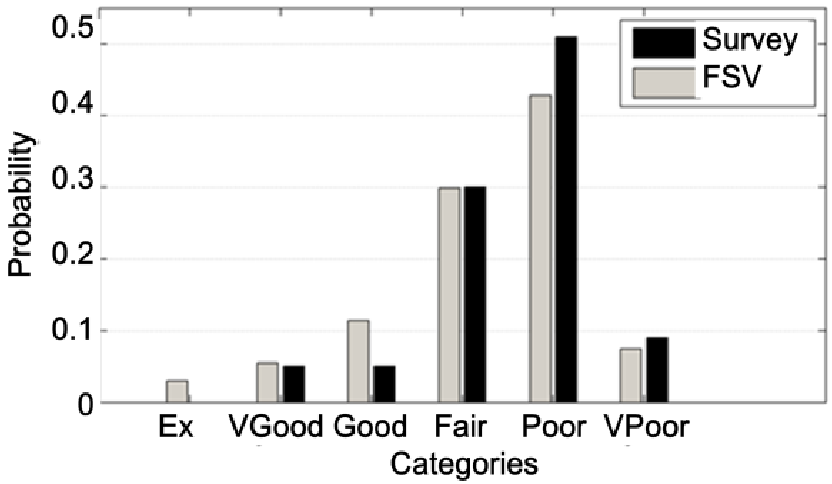
- Before moving into multiple degrees of freedom, it is interesting to look at some developments in 1D that will migrate to nD

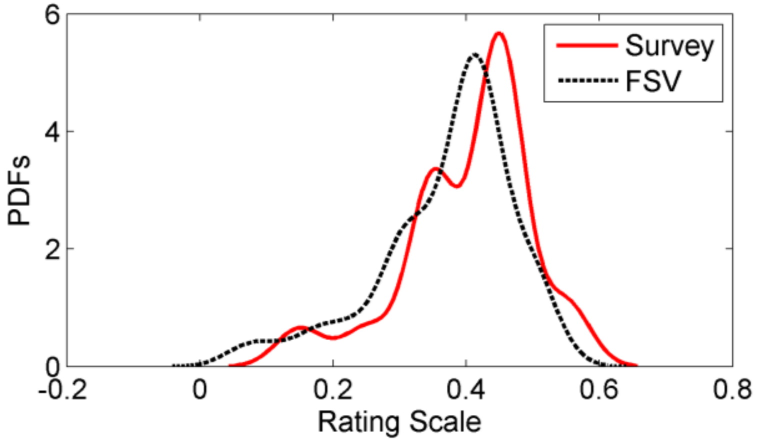
- First, histograms and density functions

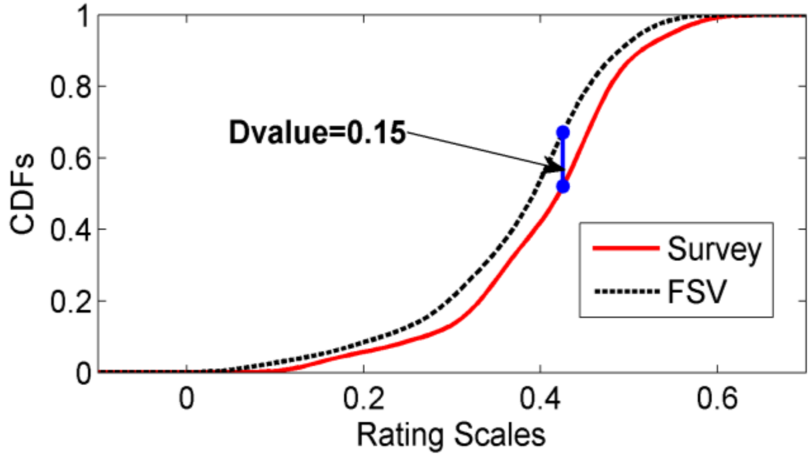
- The original approach used six ‘bins’.
- “Excellent” etc. can be confusing
  - E.g. it may have a different meaning for EMC or microwave engineers.
  - So, what benefit might there be to using a continuous distribution function rather than a histogram?
    - More refined comparison
    - The use of non-parametric statistics (e.g. Kologorov- Smirnov test)

Probability density function / cumulative density function example – FSV verification

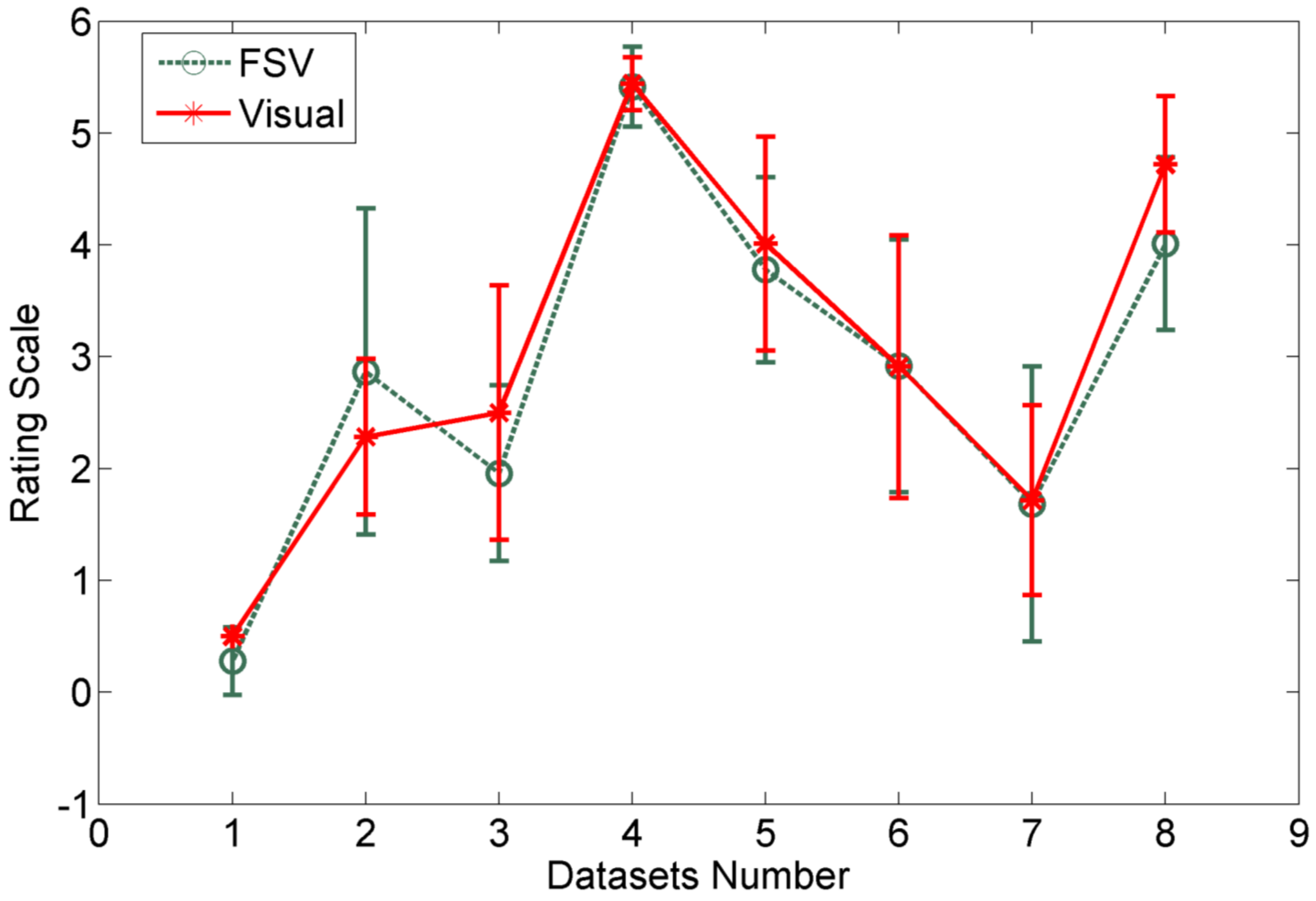






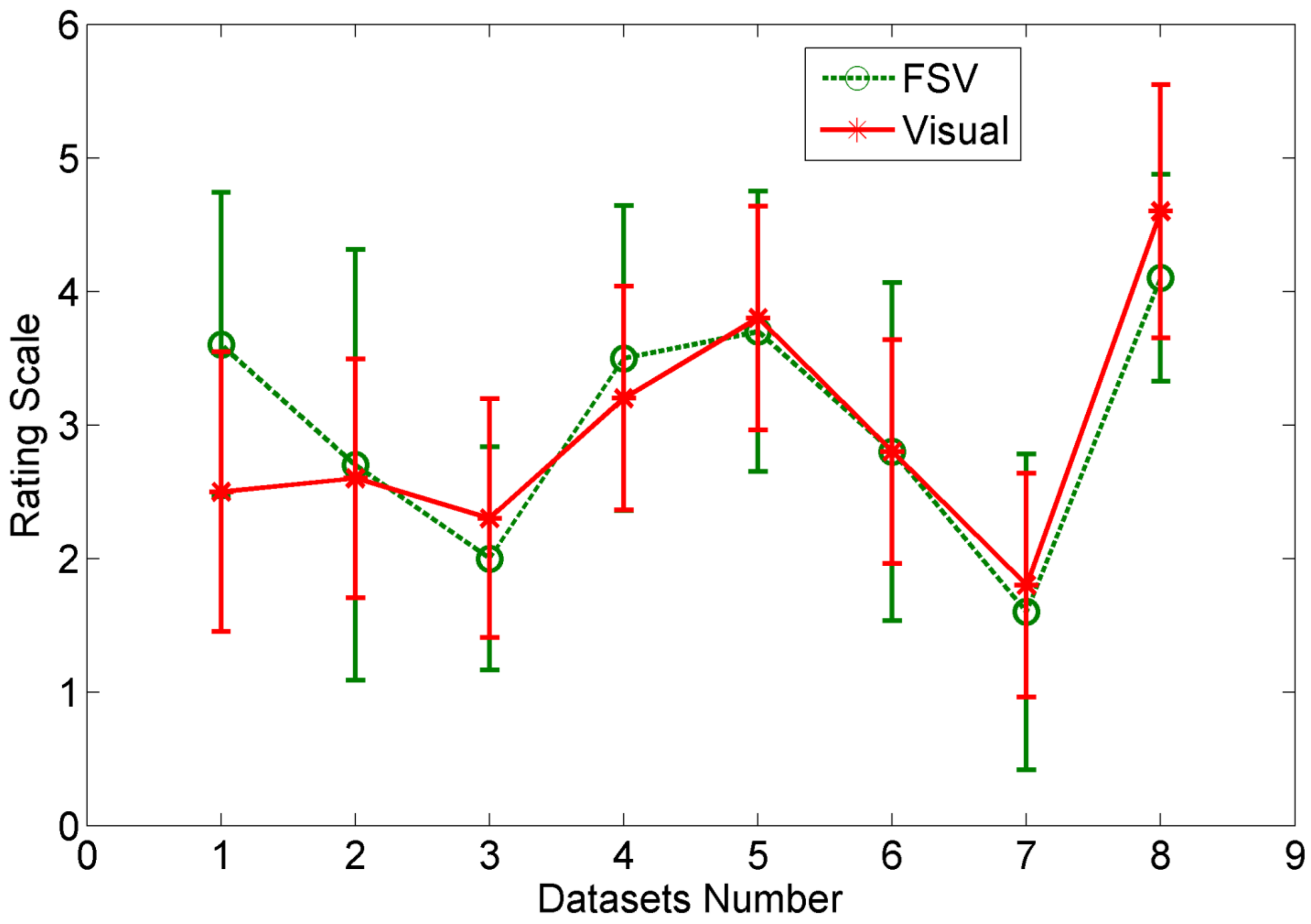


Applying this to various survey results – adding in 1 std. dev. error bars from the distributions



2004 Survey

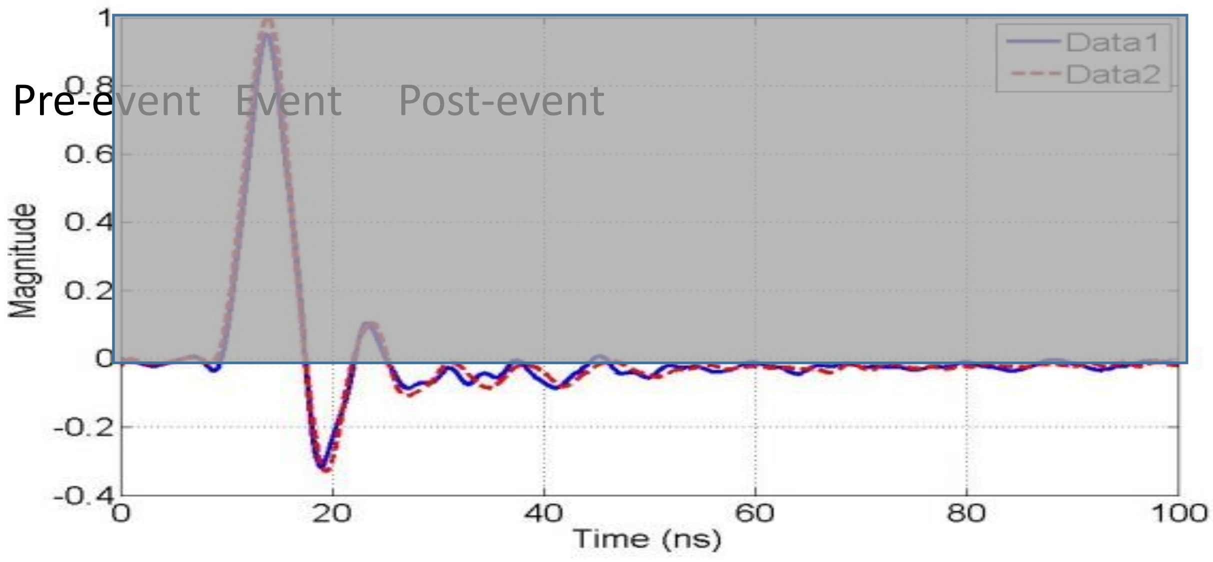
Applying this to various survey results – adding in 1 std. dev. error bars from the distributions



2013 Survey

FSV Developments – Transients

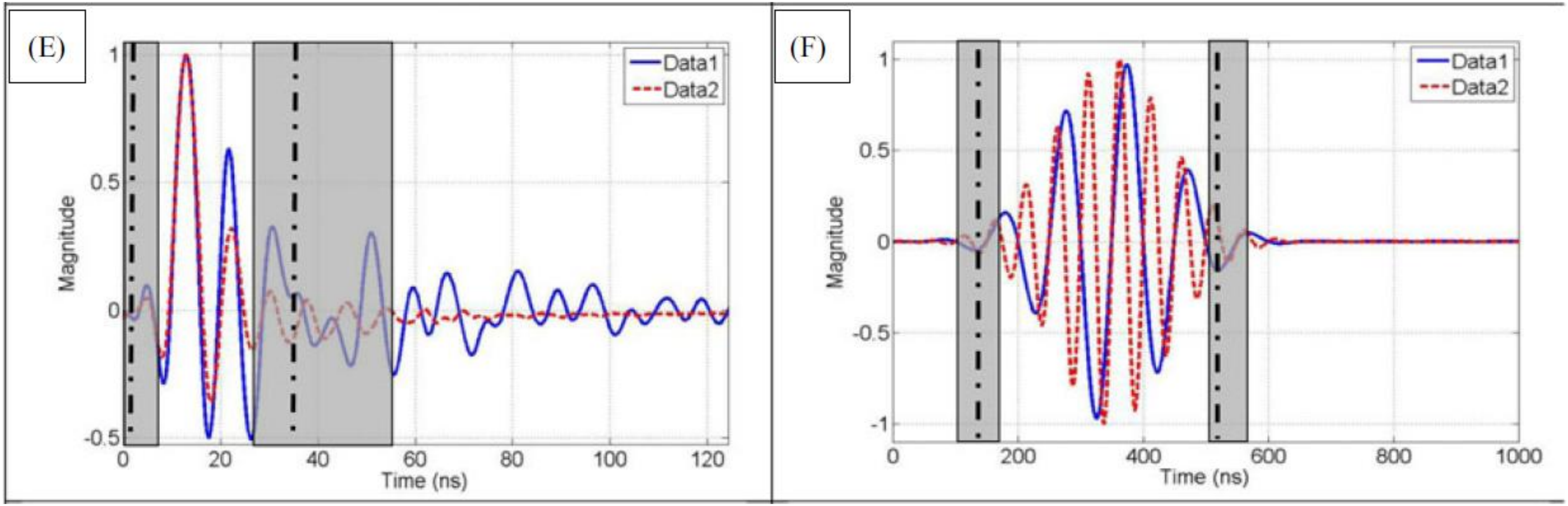
- Transient-type phenomena can be difficult.
  - Particularly with variability in periods.
  - Negative going portion



Transients

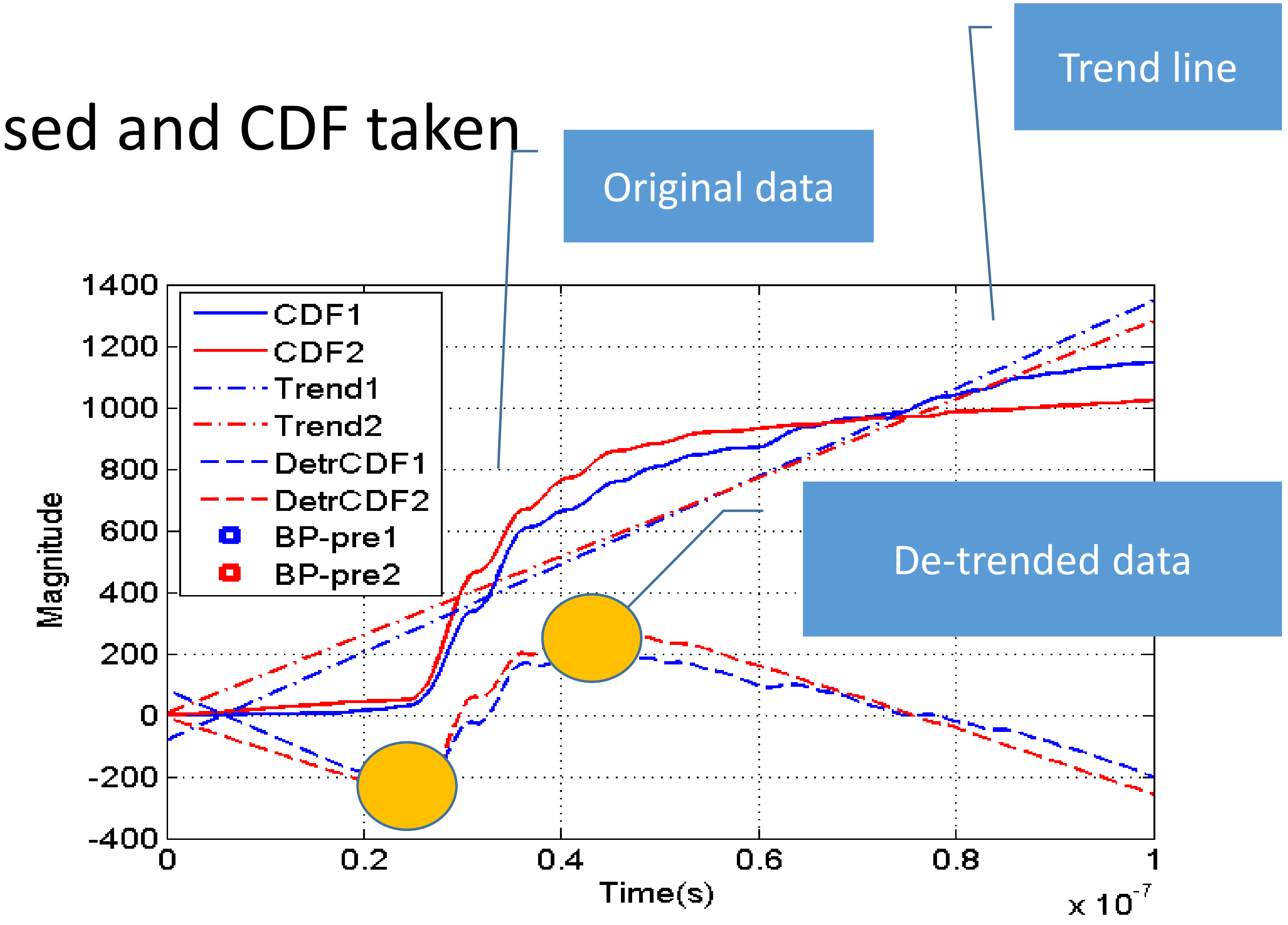
- Negative going data
  - Translate to the positive half plane
    - Does not appear to affect results
  - Needs further investigation
- Weight individual regions separately
  - Pre-event = 5%
  - Event = 70%
  - Post-event = 25%
  - Again, for further study
- Dynamically allocate region boundaries

Where do people put boundaries between regions?



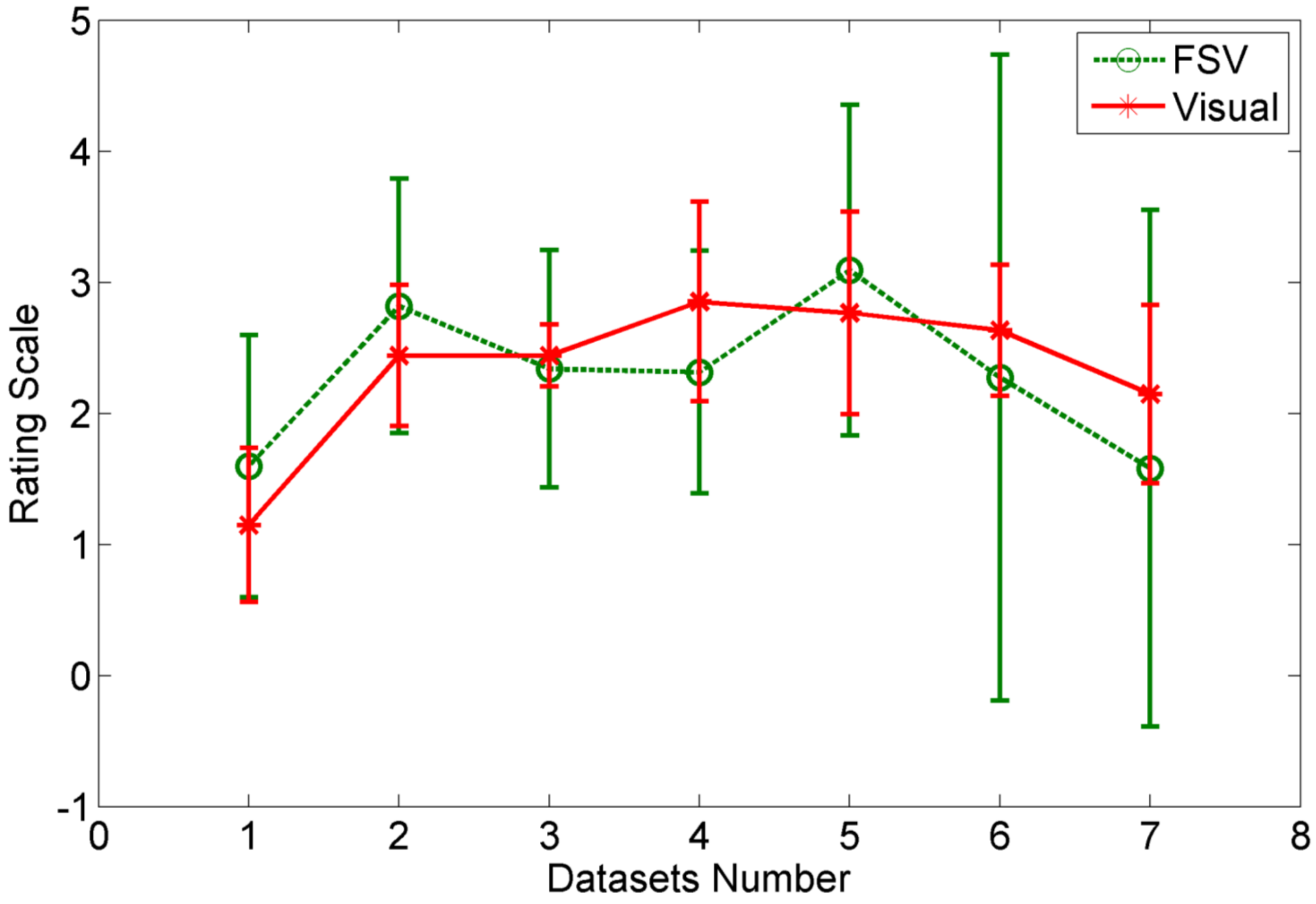
Transients – region allocation

- Magnitude used and CDF taken



Region boundaries occur at the turning points of the de-trended curve

Applying this to various survey results – adding in 1sd error bars from the distributions



2011 Survey

Transients using dynamic boundary allocation.

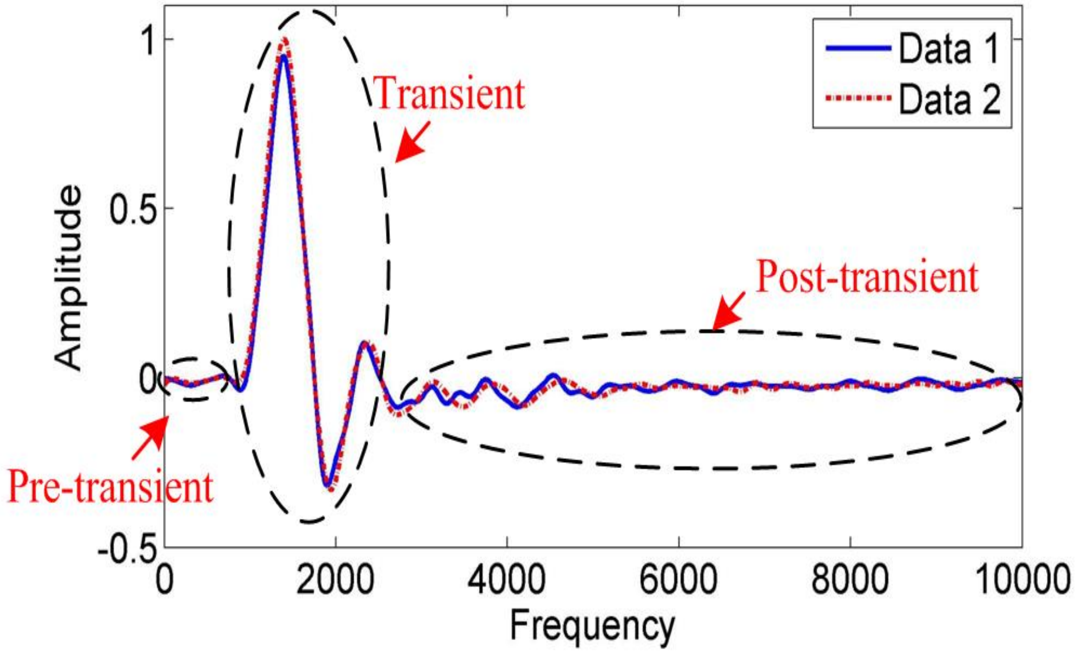
The next challenge in transients

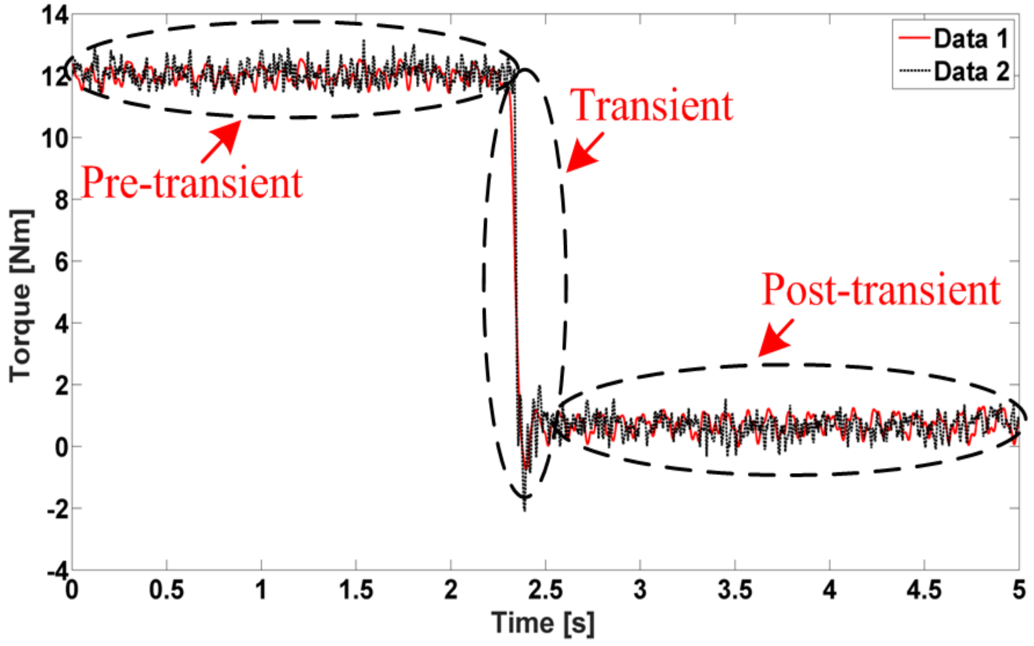
Dealing with step-functions

Convert a step to a pulse as a derivative

Avoid pre- or post-transient regions unwittingly (or wittingly) dominating

Weight the regions (5%, 75%, 25%)





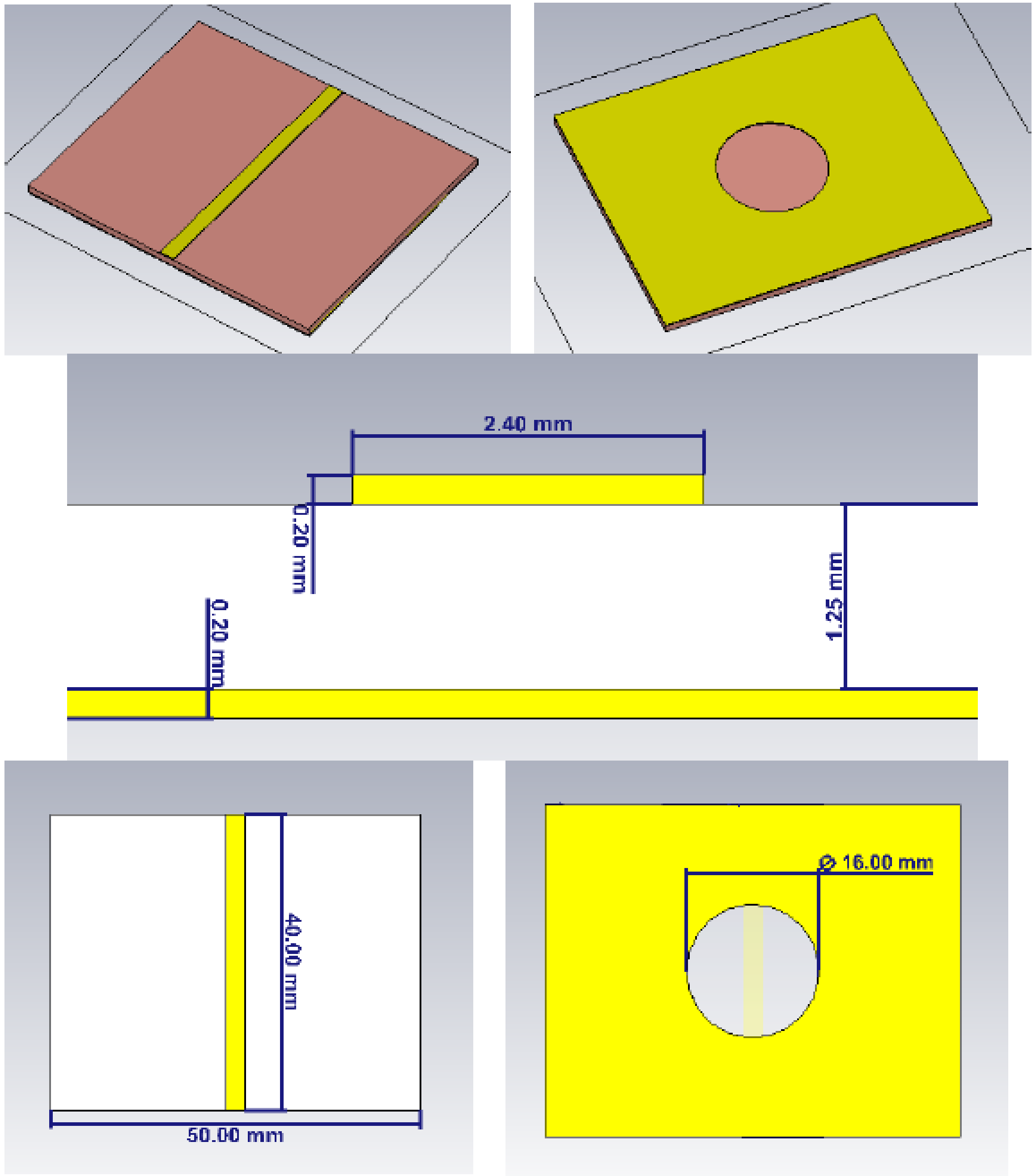
FSV in SI/PI applications

The final version of record is available at http://dx.doi.org/10.1109/LEMCPA.2021.3064420

IEEE EMC SOCIETY | Letters on Electromagnetic Practice and Applications

Applying FSV to the comparison of return path integrity in high speed circuit designs

Gang Zhang, *Senior Member, IEEE, and* Alistair Duffy, *Fellow, IEEE*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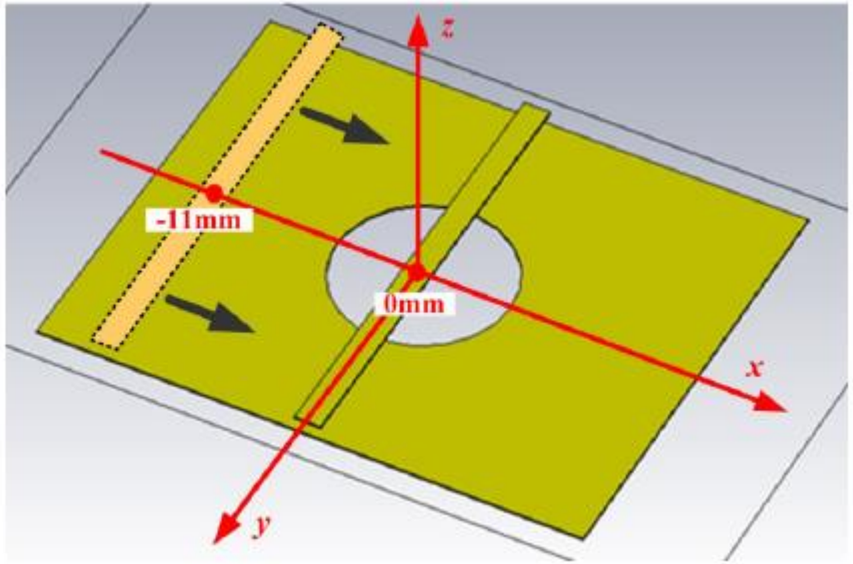
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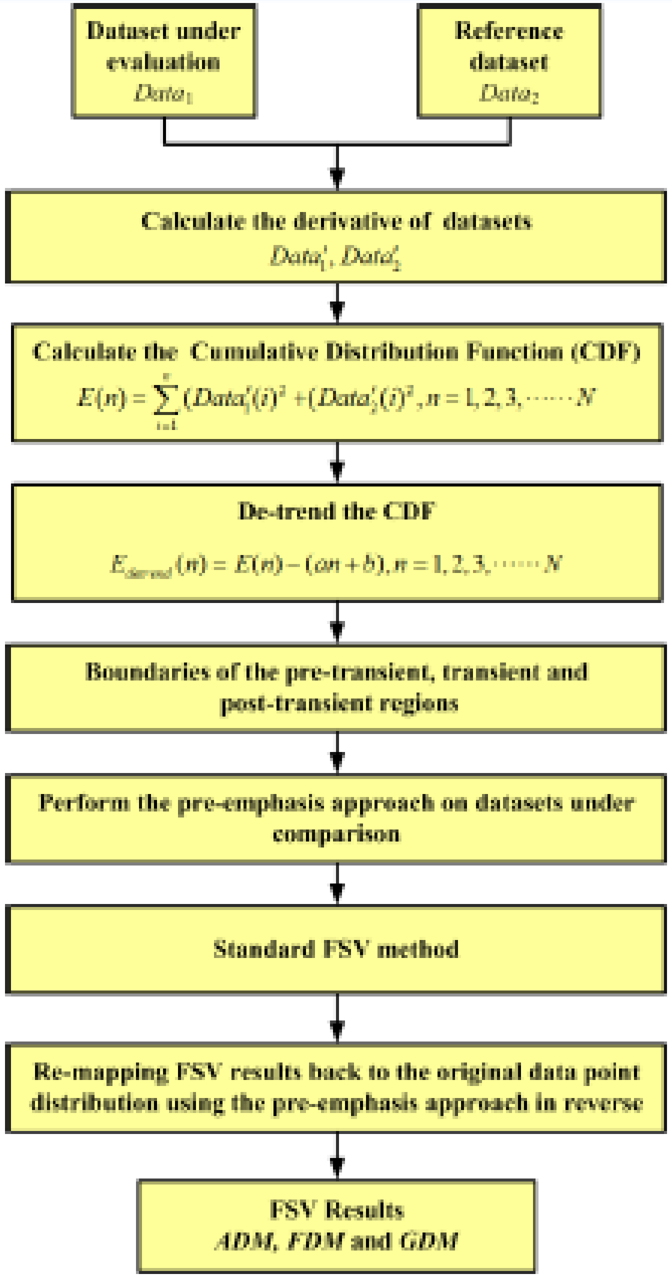
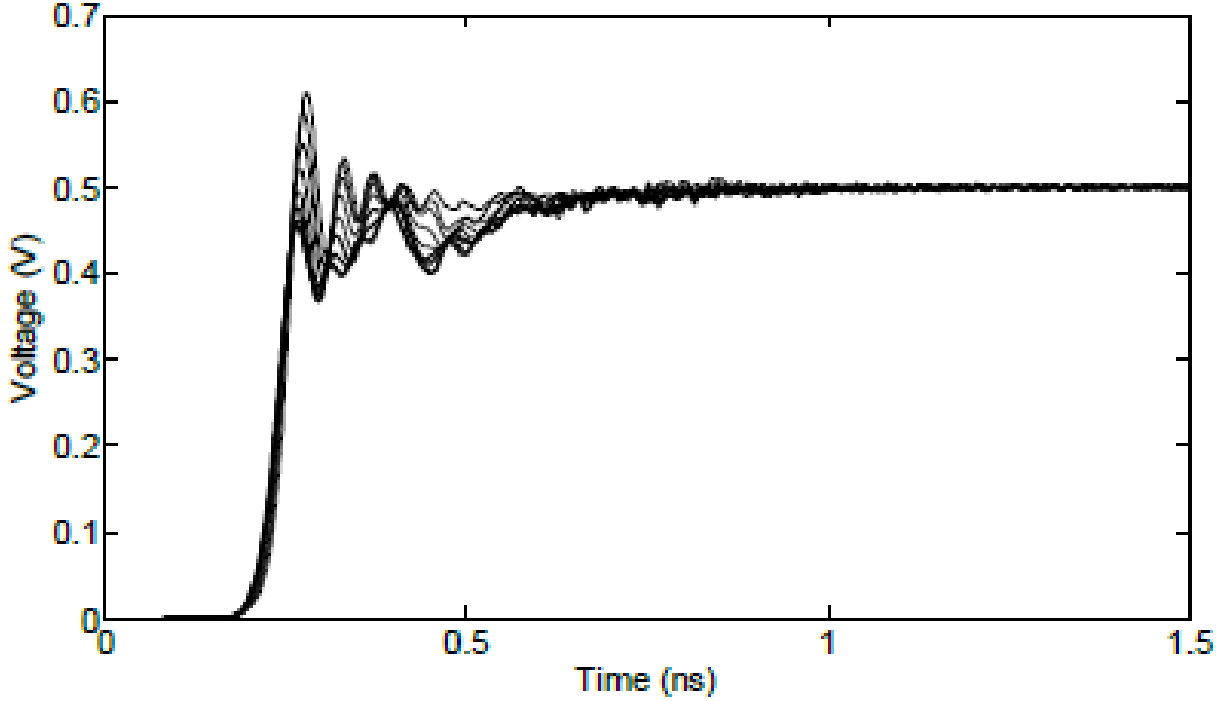


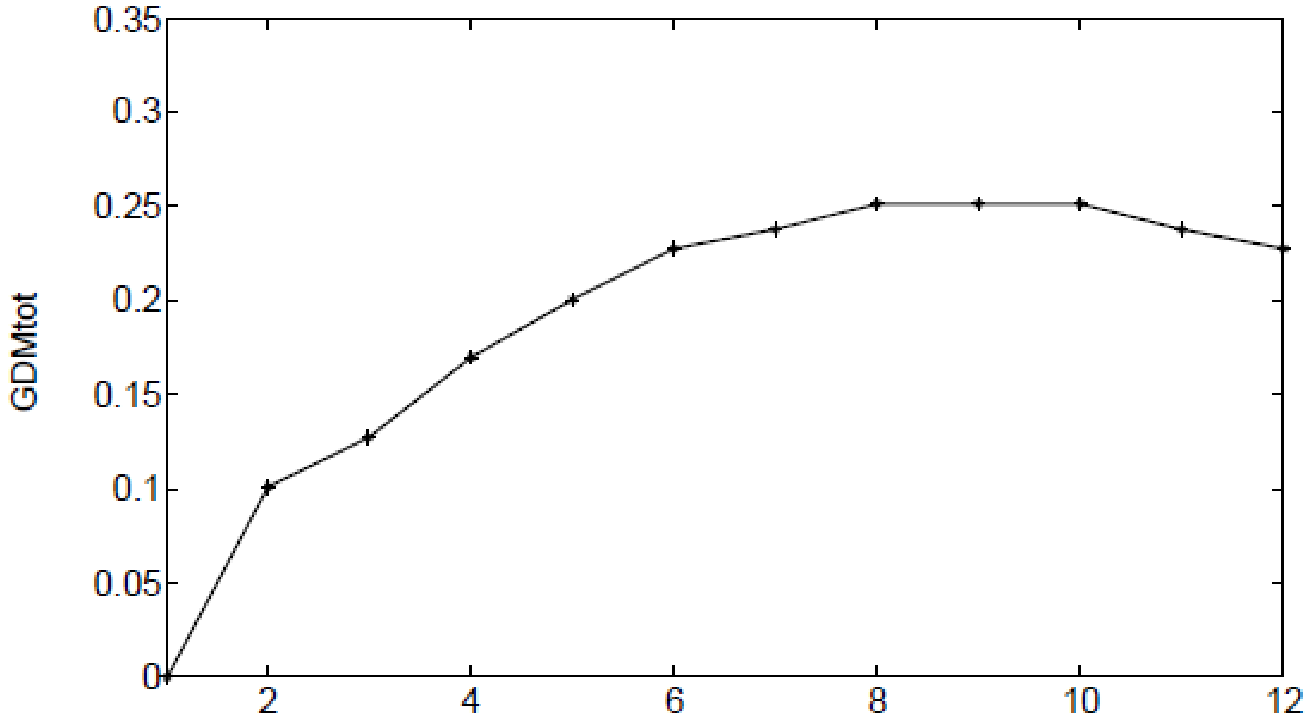
Generalized Feature Selective Validation method (Visual Summary)

Received waveform



- What can we learn from these waveforms?
- Assuming that the return current at the start position is continuous and symmetrical about the track.

GDM compared with start position



- Small positional differences can cause notable changes in the received signal: possibly due to perturbation of the current return path.
- In the centre of the gap, the symmetrical return current provides a better comparison to the reference than when the track is asymmetrical in the gap.
- No comment is made about what is acceptable and where any 'exclusion zone' should be drawn

Summary

- FSV is a technique that may have its place in the toolset of the SI & PI engineers.
- FSV exists to support decision making but not to make pass/fail, go/no-go decisions. Human expertise, and possibly other numerical tools, are needed to set those limits.