Quantifying the Quality of Agreement between Simulation and Validation Data for Multiple Data Sets

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***Abstract* - The FSV is used to compare multiple data sets. These data sets may be comparing modeled data for model validation purposes, or may be multiple measurements of related data, to determine the agreement between them.**

I. INTRODUCTION

The Feature Selective Validation (FSV) technique has been introduced [1-2] as a method to quantify the agreement between data sets to closely match how a human expert would rate the agreement [1-4]. While the origin of this was in validating numerical models against measurements for electromagnetic compatibility (EMC) applications, it is finding that it is being used in a number of other applications such as comparing antenna directivities. Recently, IEEE Standard 1597.1 calls for the use of FSV to quantify the agreement between simulation results and validation comparisons. FSV has a tiered approach to presenting the comparison data, thus providing a number of various ways to rate the comparisons and use the resulting validation output. This work extends the use of FSV to compare multiple data sets and demonstrates the results of using averaging with FSV.

II. FEATURE SELECTIVE VALIDATION TECHNIQUE OVERVIEW

Details concerning the FSV technique can be found in the references [1-4], and a free software to calculate the FSV can be found at [5]. As an overview however, the FSV can be broken into two major components, the Amplitude Difference Measure (ADM) and the Feature Difference Measure (FDM). The ADM and FDM can be combined to give the Global Difference Measure (GDM). The ADM is a measure of the overall agreement of the general amplitude trend between the data sets. The FDM is a measure of the overall agreement of the rapidly changing features between the data sets. In both the ADM and the FDM the data sets are compared on a point-by-point basis (to create the ADMi and FDMi) and a lower 'score' means better agreement.

The ADMi and FDMi can be used to create a histogram of the number of points in various agreement categories. The current agreement categories are excellent, very good, good, fair, poor, and extremely poor. These histograms are referred to as the ADMc and FDMc. The data sets in this work will focus on the ADMc since the data is slowing varying and the amplitude is the most important feature to match.

III. EXAMPLE #1 – MULTIPLE MODELING TECHNIQUES APPLIED TO SAME PROBLEM

A relatively simple problem of characterizing a via transition on a printed circuit board was to be performed to above 50 GHz. It is very difficult to measure the via effects at such high frequencies, so it was decided to use multiple modeling techniques and tools to characterize the via transition. If all modeling techniques and tools agreed, it would indicate the models were Likely accurate. A representation of the initial model is shown in Figure 1.

The first set of modeling for this structure was performed with Finite Difference Time-Domain, Method of Moments, Finite Element method, and Partial Element Equivalent Circuit technique. Each modeling technique was used by a different person. The results shown in Figure 2 did not show good agreement.

The FSV was used to compare all the curves to all other curves. Figure 3 shows the ADMc comparison between all curves. The 'FAIR' and 'POOR' categories had the highest amount of points in the ADMc. This indicates that none of the curves match any others.

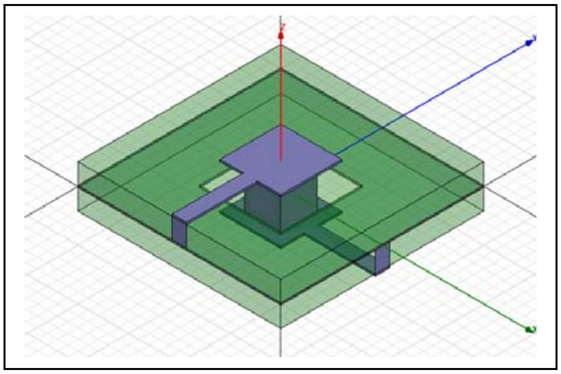

Figure 1 Via to be modeled

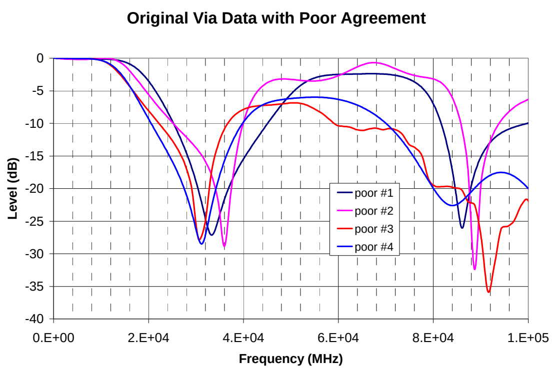

Figure 2 First pass model data

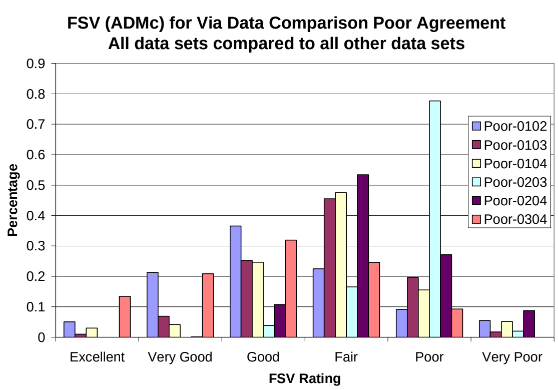

Figure 3 FSV ADMc for first pass data

It was discovered that these different models were all slightly different. Certain critical dimensions were not matched between modeling techniques. Therefore the discrepancies were corrected, and the simulations repeated. Figure 4 shows the new results, and much better agreement is achieved.

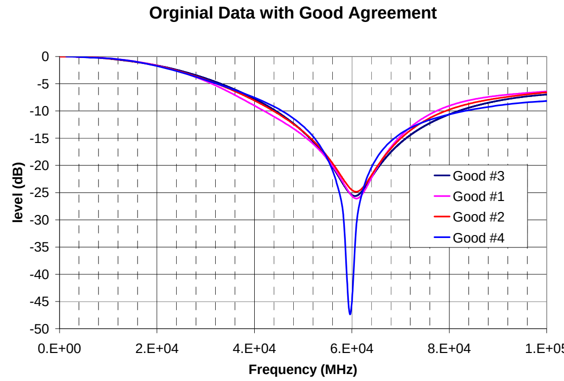

Figure 4 Second pass data comparison

The ADMc for the new set of data comparing all data sets with all others is shown in Figure 5. The agreement is definitely showing a better agreement with most of the results between ‘GOOD’ and “EXCELLENT’. However, three of the comparisons do not have large representation in the ‘EXCELLENT’ category. This is due to the deep dip at 60 GHz for curve #4.

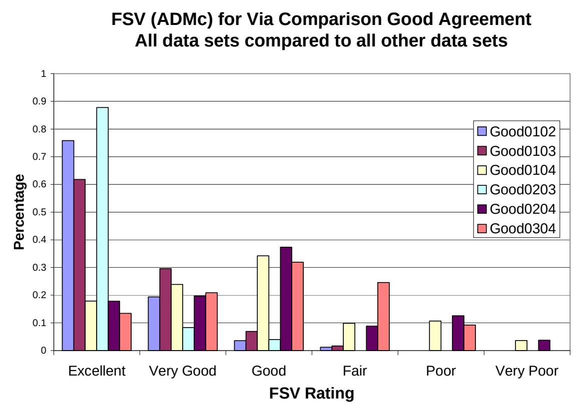

Figure 5 FSV ADMc for second pass data

It can sometimes be useful to reduce the number of comparison using an average. The ADMc in Figure 3 and Figure 5 were averaged, and the results are shown in Figure 6. The improvement in the ADMc between the initial round of modeling and the second effort is clearly shown.

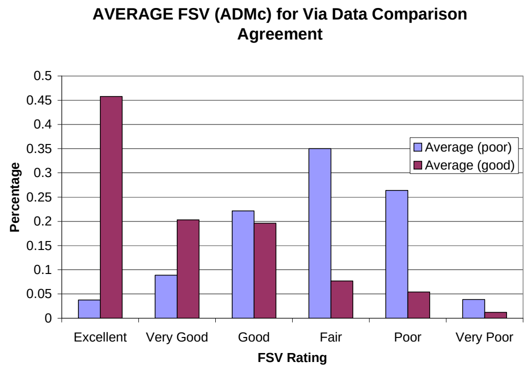

Figure 6 Comparison of average ADMc for first and second pass data

IV. EXAMPLE #2 – MULTIPLE MEASUREMENTS FOR HIGH SPEED CABLE

FSV does not only apply to comparing modeled and measured data. It can be used to compare any two sets of data. When measuring high speed data cables for qualification, a tremendous amount of data is created when each data channel is measured. Figure 7 shows an example of this raw data.

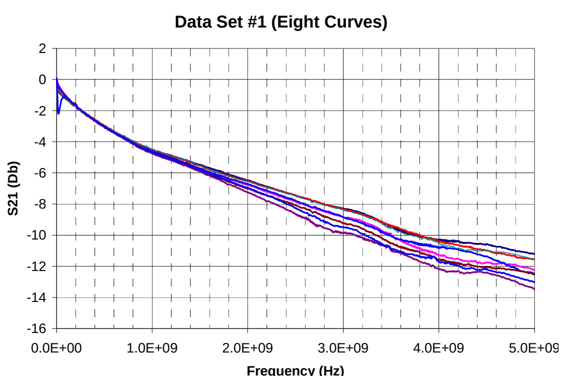

Figure 7 Measurement data from cable #1

The FSV can be applied to this set of data by comparing each curve with every other curve. This creases many ADMc results, as shown in Figure 8. These results show that most of the curves agree quite well, but a few have low values in the ‘EXCELLENT’ category.

The results in Figure 8 are very ‘busy’ and take some time to fully digest. An attempt to simply this analysis took the average of the curve sin Figure 7 and then ran the FSV between this average and all the eight individual curves. The new FSV results for the average data is shown in Figure 9.

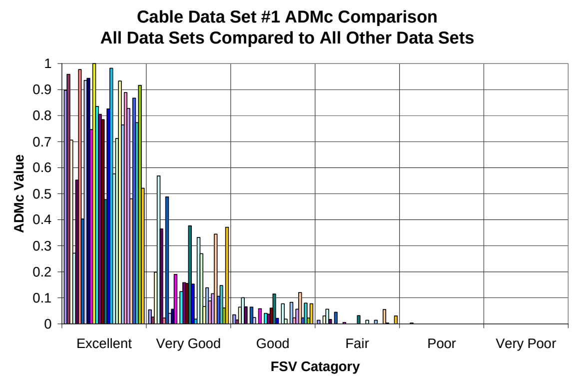

Figure 8 ADMc between all curves for cable #1

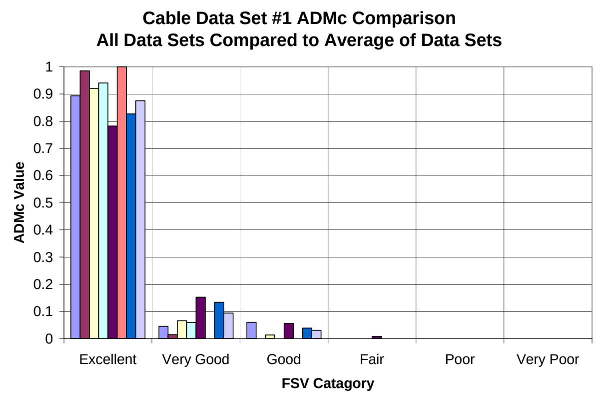

Figure 9 ADMc between data set average and each curve

However, the general sense while comparing Figures 8 and 9 is that they show different results. It appears that comparing each curve against an average for all curves gives a better apparent agreement than when comparing each curve to each other curve individually. Figure 10 shows a comparisons of the average of the data shown in Figures 8 and 9. The optimistic results from performing FSV between average of the data sets and the individual curves is apparent.

IV. EXAMPLE #3 – MULTIPLE MEASUREMENTS FOR HIGH SPEED CABLE

A different data cable is examined for similar trends. Figure 11 shows the initial data. The ADMc for each curve individually with each other curve is shown in Figure 12, and the ADMc of each curve against the average of the initial curves is shown in Figure 13.

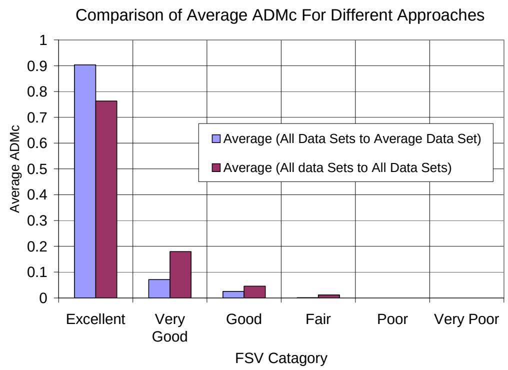

Figure 10 Average ADMc for both averaging approaches

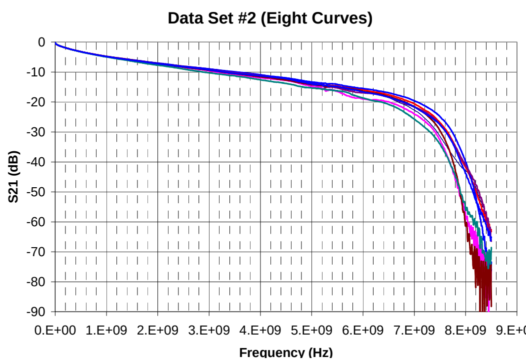

Figure 11 Measurement data from cable #2

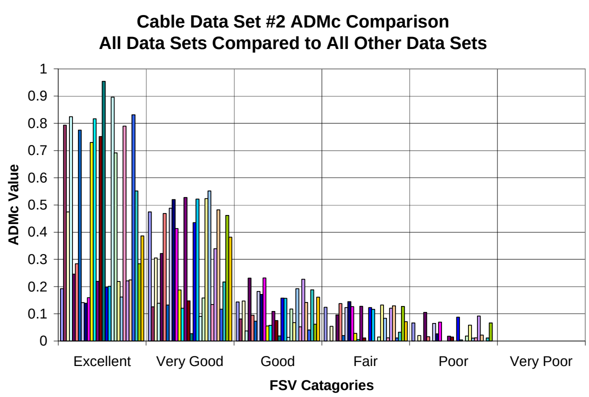

Figure 12 ADMc between all curves for cable #2

When the two methods of comparing average data is performed, Figure 14 again shows that using the average of the initial data sets is optimistic and shows better agreement than when each data set is compared individually, and then the average of the ADMc performed.

V. Summary

The FSV was used to compare multiple data sets, both between modeled and measured data as well as between data sets for multiple (related) measurements. The individual comparisons between data sets and then taking the average of the ADMc results appears to be a better indication of the data set's agreement than using an average of the data set to compare each curve against.

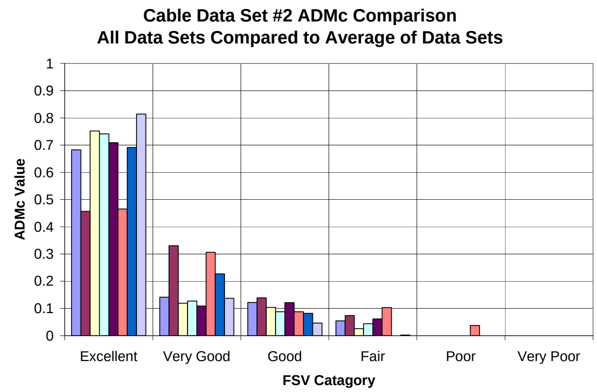

Figure 13 ADMc between data set average and each curve

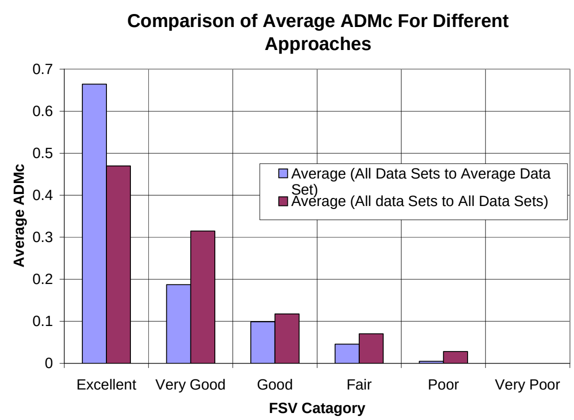

Figure 14 Average ADMc for both averaging approaches

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