EMC-signatures of microcontrollers under thermal stress analyzed by FSV

Jos Knockaert
University College of West-Flanders, Ghent University
Kortrijk, Belgium
jos.knockaert@howest.be

Mohamed E. A. Malki
IRSEEM – École Supérieure d'Ingénieurs en Génie Électrique
Saint-Étienne du Rouvray, France
Mohamed.malki@esigelec.fr

David Baudry
IRSEEM- École Supérieure d'Ingénieurs en Génie Électrique
Saint-Étienne du Rouvray, France
David.baudry@esigelec.fr

Mohamed Ramdani
GRACE – École Supérieure d'Électronique de l'Ouest
Angers, France
Mohamed.ramdani@eseo.fr

Davy Pissoort
FMEC - Catholic University College Bruges – Ostend
Catholic University Leuven
Ostend, Belgium
Davy.pissoort@khbo.be

***Abstract*— The EMC-signature of devices containing microcontrollers can differ due to thermal or mechanical stress. Research is presented to prove the feature selective validation method (FSV) to be sensitive enough to analyze differences in signatures.**

Keywords-component; EMC-signature, FSV, thermal stress

I. INTRODUCTION

The EMC-signature of devices can change due to several external influences. Examples of these are thermal and mechanical stress, tolerances on the components or replacing obsolete components. The idea was given to use the EMC-signature as a quality assessment tool [1]. A difference in EMI can alert the manufacturer something has gone wrong during the production process. An interesting method to compare measurements is FSV (Feature Selective Validation). In this paper, practical measurements on a microcontroller on different temperatures are used to see if FSV is sensitive enough to detect the differences and useful to make conclusions.

II. EMC-SIGNATURES

The EMC-signature of a microcontroller can change due to thermal stress. Thermal stress or an environmental temperature differing from the temperature at measurement time will influence the emitted spectrum. Measurements show drifts of both amplitude and frequency [2]. Drifts in frequency are due to a changing clock frequency and harmonics. Due to the temperature coefficient of passive components the initial spectrum can change up to 10 dB or more [3]. Changing passive components can also shift specific peaks and dips in the spectrum because of changing resonance frequencies.

A second reason is aging. Aging has its influence on passive components and connections. During years, thermal cycles can degrade the used materials, changing the values of the components. During time the permittivity ε of capacitors will decrease and leakage currents will increase. As capacitors are a main component of filters it will influence both conducted and radiated emissions.

Mechanical stress and vibrations are a third cause of degraded EMC performance. Mechanical stress and vibrations can influence connections. Especially capacitors are susceptible to mechanical resonances, where the connection (solder point) to the PCB can suffer. Harsh environments for electronics are automotive and agricultural applications.

III. FSV

For simulation of electromagnetics, engineers and scientists have to choose from a vast amount of Computational ElectroMagnetics (CEM) methods. Examples are Finite Element Method (FEM), Method of Moments (MoM), Finite Difference Time Domain (FDTD), etc. As these methods are numerical, discretisation both in space and time is used and a simplification of a complex reality is needed. Therefore, all methods may give different results. This raises the question which method is correct or gives at least the best approximation. This unanswered question resulted in the start of the IEEE standard project P1597.1 in 2001 "Standard for Validation of Computational Electromagnetics (CEM) Computer Modelling and Simulation".

Two key areas for benchmarking can be distinguished. The first area is the validation by canonical models. This investigation results in a set of standard EMC problems usable to evaluate modelling tools [4]. The second area is the validation by simulation versus measurement. Validation methods like FSV and IELF are in this area.

FSV is a method for validation of computational electromagnetics, with applications in EMC and Signal Integrity. This method has shown its usefulness in the validation of EMC-models [5]. When comparing two datasets, normally measurements and simulations, FSV decomposes both datasets into two parts, trend and feature data. The trend data can be seen as the low frequency part, while the feature data or fast variations can be seen as the high-frequency part. Analysing the low-frequency part gives a measure of similarity of the trend (ADM or Amplitude Difference Measure). Analysing the high-frequency part of both datasets gives a measure of the similarity of the feature (FDM or Feature Difference Measure). These figures combine to a global goodness-of-fit value (GDM or Global Difference Measure). The strength of the FSV-method is the point-by-point comparison showing at which data points the comparison fails. Combination of all measures to one figure, expressed by a natural language description ("excellent" up to "very poor"), is a further strength.

IV. Test Method

Measurements were performed on an Atmel microcontroller AtTiny261/461/861 with 8 MHz core frequency. As described by the standard IEC 61967-4 [6], a part of the emitted power across a resistance of 1Ω is retrieved. The microcontroller is mounted on a 4-Layer PCB board especially managed to apply the standards IEC 61967-2 and 4. This is rendered possible using a ground system in order to combine the both standards [7]. Several measurements at different temperatures ranging from -40°C to 150°C with chosen intermediate points were performed. Fig. 1 gives the measurement results. The data is collected in two frequency sweeps, one from 100 kHz to 30 MHz with resolution detection filter at 10 kHz and one from 30 MHz to 1 GHz with a detection filter at 100 kHz. This change in the detection filter bandwidth explains the sudden transition in the mean noise level of the measurements.

For evaluation, an envelope is calculated and given in the same figure. The envelope shows that the emission increases with increasing temperature below 30 MHz, especially at low temperatures. The emission decreases with increasing temperature from 50 MHz to 200 MHz. At higher frequencies, a shift in the spectrum can be noticed. These conducted emission results match those obtained using a developed heating enclosure dedicated to the Near-field/thermal tests [8].

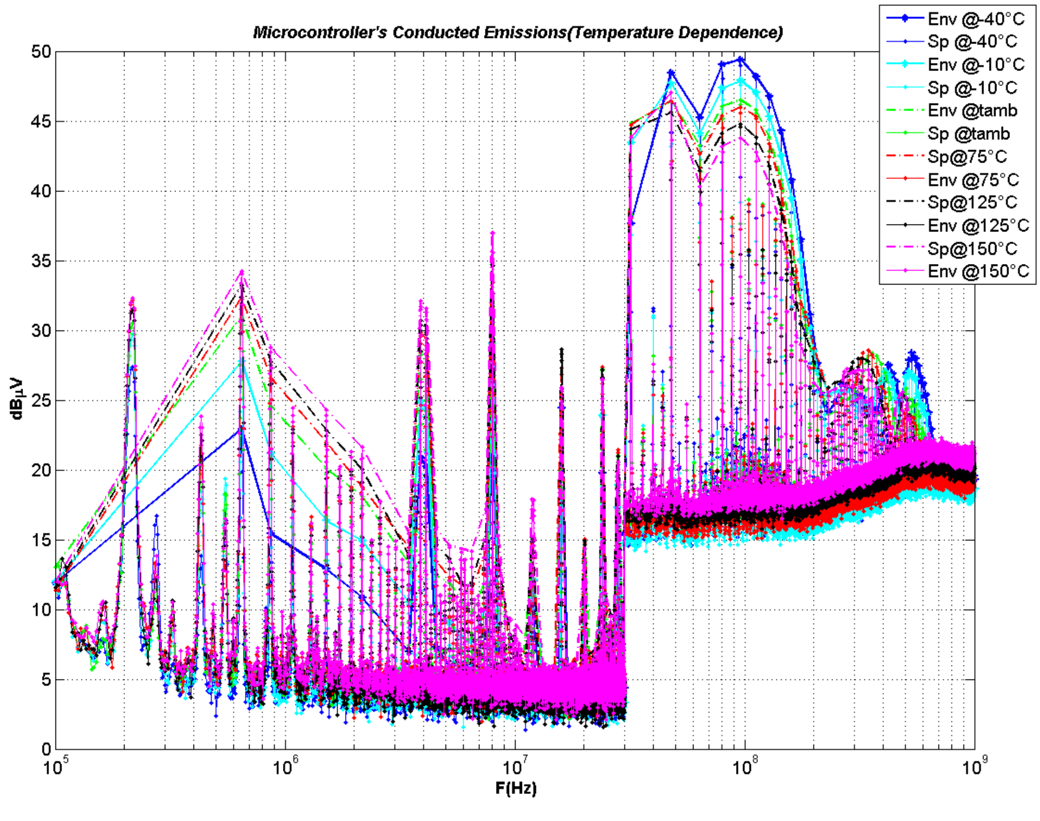

Figure 1. EMI-signature of a microcontroller at different temperatures

The spectrum's envelope tendencies have been previously obtained in the EMC/Thermal investigations. The external thermal stress in the near-field zone gave the same radiated emission behaviour of the microcontroller, in the frequency range of 500 kHz-200MHz, and for ambient temperatures of 25°C and 120°C. The difference in the emission spectrum level was between 2 and 5 dBm [8]. Recent works in Near-Field/thermal investigations showed similar results, and pointed out the temperature dependence of the radiated magnetic field on the supply pins [9].

V. Ranking with FSV

If FSV can be used to compare EMC-signatures, validating the comparison by FSV has to give the same results. The datasets were split into two parts. The first datasets contain the measurements up to 30 MHz. With FSV, the measurements of -40°C were compared with the measurements at the other temperatures. The measurements were averaged by the EMI-receiver (average of 10 measurements), so no preprocessing of the data was necessary [10]. Comparing the measurement done at -40°C with the measurement at -40°C gives an ADM, FDM and GDM of 0, meaning they are equal. Comparing the measurement at -40°C with the measurement at -10°C gives an ADM, FDM and GDM of 0.251, 0.326 and 0.451 respectively (fig. 2). The results of all comparisons are given in the left part of fig. 3. It can be concluded that the ranking is correct. The GDM value increases monotonically with increasing temperature. This means that emission increases (or decreases, as FSV only detects a difference) with increasing temperature. The previously made conclusion that the difference is larger at lower temperatures is noticed by the FSV-method. Also the difference at very low temperatures is more distinct than at higher temperatures, which is also a correct interpretation.

The GDM-value is composed by the ADM and FDM value. As can be seen, the FDM-value follows the same trend, nevertheless the ADM-value is not. The ADM-value even lowers between 75°C and 125°C. This is not noticeable when comparing the measurements or by the envelopes. Fig. 4 shows the difference between the measurement at 125°C and at 75°C. In the second part of fig. 4, the difference between 150°C and 125°C is given. From these it is obvious that the ADM-value is correct. The trends of the measurements at 125°C and 75°C are nearly equal, as the difference is located around the mean value of 0.19. This results in a low ADM-value. The mean value of the second difference is around 0.72. This explains the correct higher ADM-value.

The second set of measurements ranges from 30 MHz to 200 MHz. The same procedure gives the FSV results in the right part of fig. 3. One of the disadvantages of FSV is that only the difference is validated, but there is no direction. This means the values are always positive. Nevertheless, the conclusion is correct. The emission decreases with increasing temperature.

VI. Conclusion

It is shown that FSV is a valuable method to compare EMC-signatures. This creates possibilities to use FSV for other applications than the basic purpose. In this research FSV is used for ranking and for validating the emission of a microcontroller at different temperatures. The conclusions made can be considered as correct. A few disadvantages of the method were noticed. First problem is the noisy datasets giving non correct results, which can be solved by averaging the measurement. Second problem is that FSV is not giving a direction of the difference. This means that only the difference can be ranked.

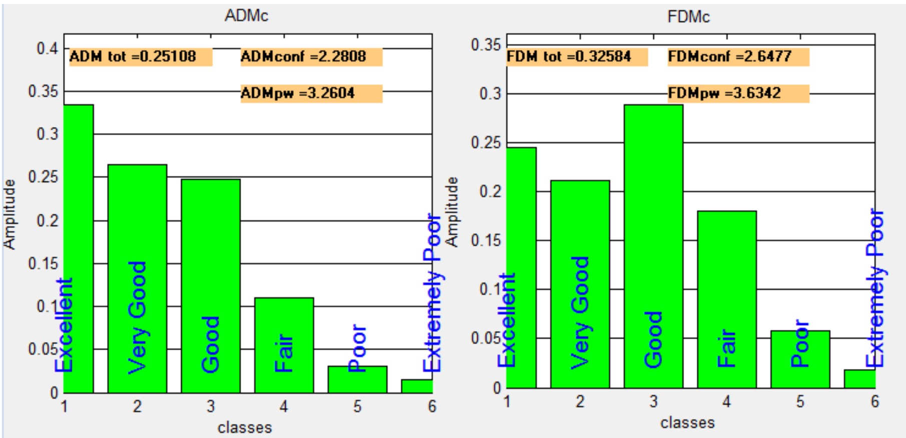

Figure 2. Comparison measurements -40°C and -10°C, frequency range 100 kHz – 30 MHz

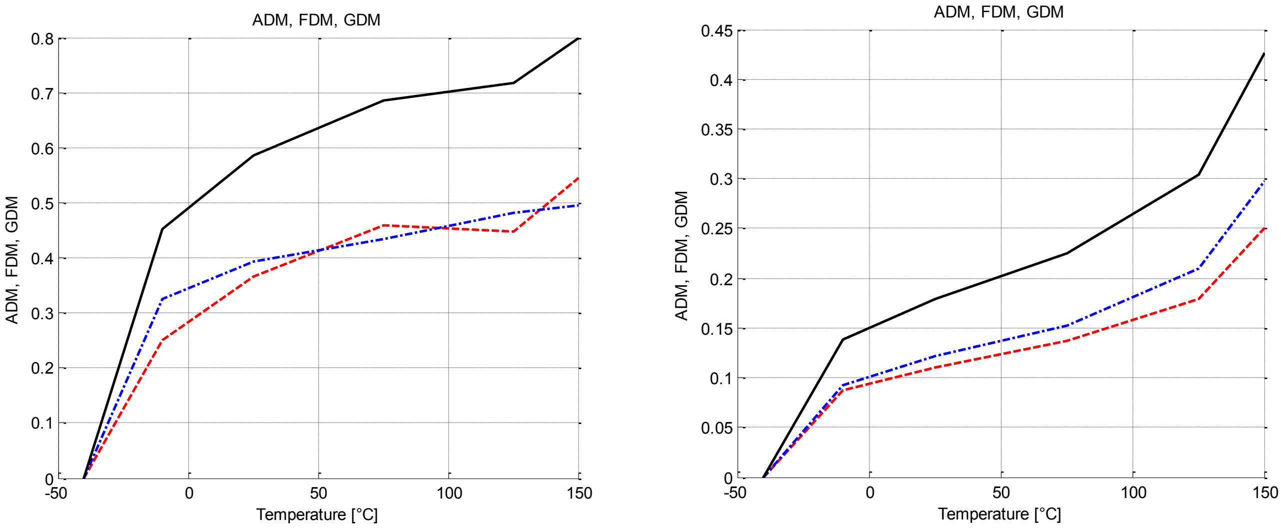

Figure 3. FSV-results (ADM red dashed, FDM blue dashed-dotted, GDM black solid) for frequency range 100 kHz – 30 MHz (left) and 30 MHz – 200 MHz (right)

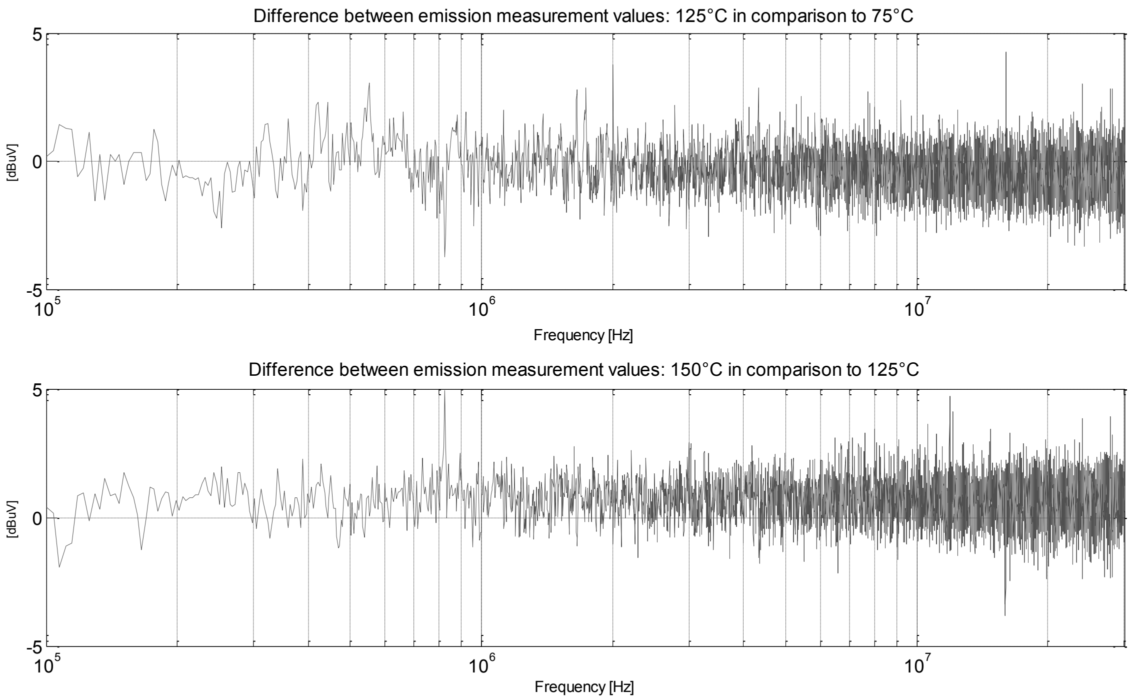

Figure 4. Difference between measurement at 125°C and 75°C (top) and 150°C and 125°C (bottom)

[1] J. Knockaert, D. Pissoort and F. Vanhee, “Comparing EMC-signatures by using FSV as a quality assessment tool,” Progress In Electromagnetics Research Symposium Proceedings, PIERS 2011, Marrakesh, Morocca, pp. 1099 – 1103.

[2] A.C. Nyod, S. Ben Dhia, A. Boyer, “Analysis of emission spectra evolution after accelerated aging of integrated circuits,” Proc. of the 7th International Caribbean Conference on Devices, Circuits and Systems ICCDCS2008, Mexico, Apr. 28-30, 2008, pp. 1-5.

[3] **F.** Lafon, F. De Daran, L. Caves, M. Ramdani, M. Drissi, “Influence of Aging and Environnement Conditions on EMC Performances of Electronic Equipment - Influence of Passive vs Active Components,” EMC Europe 2010,Wroclaw, Poland, pp. 215 – 220.

[4] B. Archambeault, S. Pratapneni, L. Zhang, D.C. Wittwer and J. Chen, “A proposed set of specific standard EMC problems to help engineers evaluate EMC modeling tools,” Proc. of IEEE International Symposium on EMC, Volume 2, 2001, pp. 1335 – 1340.

[5] A. Duffy, A. Martin, G. Antonini, A. Orlandi and C. Ritota, “The feature selective validation method (FSV) method”, Proc. of IEEE 2005 EMC Int. Symp., Chicago, USA, 8-12 August, 2005.

[6] IEC 61967-4 Ed1.1, “Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 4: Measurement of conducted emissions – 1 ohm/150ohms direct coupling method,” 2006.

[7] J-L Levant, “ATiny261 IEC61967-4 measurement report”, Atmel, 2008
[8] M. Malki, D. Baudry, M. Ramdani “New tool for characterizations of electronic components radiated emissions under thermal constraints”, 7th International Workshop on Electromagnetic Compatibility of Integrated Circuits, Toulouse, France, 17-19 November, 2009.
[9] M. Malki, D. Baudry, M. Ramdani “Investigations CEM avec contraintes thermiques sur un microcontrôleur 8-bits”, 3rd Workshop 2emc, Rouen, France, 18-19 November, 2010.
[10] J. Knockaert, J. Peuteman, J. Catrysse, R. Belmans R, “Using FSV to compare noisy datasets**,**” 23rd Annual Review of Progress in Applied Computational Electromagnetics(ACES 2007), Verona, Italy, March 19-23, 2007, pp. 538-543.