A GENERIC AUTOMOTIVE (TIER1) EMC TEST STANDARD

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Abstract: The number of different EMC test standards available from the vehicle manufacturers (VM's) is large, disparate and often not always the most logical for the product under design or test. It can be particularly frustrating for an automotive application innovator to design a product to a suitable EMC standard that allows them to take the product around to the VM's prior to implementation on a vehicle itself. This is similarly true of aftermarket suppliers wishing to take their products directly into the VM's, but being either unsure of what tests or levels each VM will require, and being unable to justify on a speculative product the cost of testing to all the VM standards that they can obtain.

Presented here is a suggested "Generic Automotive Tier 1 Supplier EMC Test Standard", available as an open-source document, that is essentially derived from consideration of most of the larger VM EMC standards and compiled to give a "best fit" to all the data that was available to the author at the time of writing. The resulting standard is not as comprehensive as some of the VM standards, nor does it necessarily give any guarantee that meeting this standard will give a supplier easy or even easier access into a VM than any other route. What it provides is an independent perspective on what the most sensible EMC tests and test levels are, for a vehicle environment which meets the majority of VM requirements. The resulting test document gives the supplier a measure that they can present to a VM to demonstrate that their product can meet the basic VM requirements, and if not a particular full VM requirements first time, then at lower cost than a completely untested or e-mark only tested product.

The tests cover the supply of electrical products to a VM only and do not extend to whole vehicle testing, which remains exclusively the domain of the VM. The test methods employed are all based on international standards (CISPR and ISO) and the levels suggested are derived from the aggregated VM standard levels and frequency ranges.

Introduction

When I was designing satellite navigation and vehicle tracking products the management at my company would always ask if I could design the product to meet a VM standard, of course the answer was always "Yes, but to which VM standard?" The management had the belief that there was a mythical "Generic VM Standard" that would satisfy all VM's and hence make the product easier to get accepted as either a certified aftermarket product or as a line-fit item. A design to meet the Ford standard for example might meet the General Motors (GM) requirements for some test, but not others, ditto for BMW, Peugeot-Citroen (PSA), Daimler-Chrysler (DC) etc. Worse was that each VM not only have different test levels (otherwise it would have been easy to design for the worst), but they also have different frequency ranges and more problematic different methods of testing the same phenomena, for example BMW had no free field test method for radiated emissions in their standard at one point. Some VM standards also contain what might be considered as errors, such as using the IEC 61000 generic ESD test method rather than the automotive specific ISO 10605 methods.

There are significant cost implications in trying to meet multiple VM standards, both in the on-cost of additional design and circuits/components to meet all the requirements and in the test costs themselves. Some of these requirements are difficult to justify; will a radio from a Fiat car work in a BMW vehicle without problems? Of course, yet it is unlikely to have been designed or tested to anything like the same standards. There must be some middle ground where a series of sensible tests targeted at most, if not all, of the more stringent EMC specifications of the VM's can be collated. The tests must include all of the most pertinent phenomena; radiated emissions, radiated immunity, conducted emissions, conducted (transient) immunity and ESD, while avoiding the odd-ball tests that are specific to any single VM. This is what this paper set out to achieve, the output of which is an EMC Test Specification that can be adopted (or ignored) by suppliers wishing to gain VM tier 1 status but without having to over-design and over-test their product to prove its EMC capability to every individual VM's specification. Test service suppliers can also use the resulting specification as an open standard if their customers ask them the same question my management used to ask me. Essentially the result is as close as this author can get to the mythical "Generic VM EMC Standard".

Background

The background to this work was a study of the test specifications from all of the VM's that I could gain access to, this is relatively comprehensive (see references). I owe a debt of gratitude to many people who provided the necessary information for the compilation of this paper, including most VM's who gave me permission to discuss their standard even though they are not public domain documents. This impression of secrecy surrounding some VM EMC specifications is also another argument for an independent generic specification, but that in itself was not the driver for this work.

The task was divided into 5 specific test types (radiated and conducted emissions, radiated and conducted immunity plus ESD) and as already mentioned excludes any non-standard methods (i.e. non CISPR, ISO or EN referenced). While the number of test methods for each test type is not as exhaustive as some of the VM standards, the most commonly used methods are included so that there are some options available.

In-Vehicle Application Classification and Test Severity

One problem often encountered from outside a VM development is what severity level should be applied to a product? There are many levels available within most internationally recognised standards (CISPR and ISO typically having 5 severity levels) and very little information on which to apply. Most VM standards tend to have one or two severity levels only, the higher for power train and safety functions and the lower severity for comfort and convenience functions (some VM's do have as many as 4 application classifications and associated test levels). Here I have adopted the more common VM approach of using 2 of the published severity levels in the CISPR/ISO and suggest the higher severity is used in most applications.

Table 1: Application Classifications

Application Group	Typical In-Vehicle Applications
I	Powertrain and Safety: engine management unit (EMU), ABS, SRS, immobiliser, body control modules (BCM), exterior lighting, central locking, wiper controls
II	Comfort and Convenience: in-car entertainment (ICE), HVAC, telematics (satellite-navigation, phone-kit), instrument illumination, auto dimming mirrors

Failure Mode Severity Classification

There are again multiple definitions within VM specifications for the failure mode and its acceptability for specific application functions, however, I have adopted the failure classifications defined in the ISO standards (see appendix A for full listing). There are only 2 classifications within the 5 listed that will be used; class A for application group I products and class C for application group II products.

Table 2: Accepted ISO Test Classifications

Classification	Description
A	all functions of a device or system perform as designed during and after exposure to interference.
C	one or more functions of a device or system do not perform as designed during exposure but return automatically to normal operation after exposure is removed.

The distinction between classes A and B as defined in the ISO specification is very difficult to prove. It would require test equipment monitoring all the input-output parametrically to prove if a product is really passing at class A or B during the testing (i.e. in the EMC test facility). Therefore the reality is that these 2 classifications are never clearly identified and is assumed to be class A if a product continues to function throughout the test cycle without a functional deviation.

The classifications below class C are in my opinion all outright failures. In a vehicle nothing should require a user interaction to revert to normal operation, even non-critical features, hence only a selfrecovering temporary loss of function could be considered acceptable (for example losing radio reception while close to a radar installation).

Generic Test Methods and Levels

Where available the tests discussed as "generic" below are all based on the available international standards with no deviation from test conditions as defined in these standards. The VM specifications almost always make what initially appear as small deviations from some of the generic set-ups and conditions, maybe a slightly different harness length or pulse rise time and sometimes a different resolution bandwidth (RBW) for signal measurement. In providing a generic specification the tests noted here are all reverted to the original set-up of their base standard with no deviations in set-up or method. Some deviations for extended frequency or applied level may be made, but not for the set-up itself.

Radiated Emissions

The test set-up for most VM free-field radiated emissions is CISPR-25, but with most VM standards that is where the similarity ends. The most obvious deviation is the test limits, but many VM standards also deviate from the test frequency range as well. Several keep the banding of the CISPR-25 limits (i.e. have sections in the frequency range where no limit is applied) and some fill in these intervals with a variety of different methods (PSA for example adopt the limit level of the previous frequency range, but at a severity level less than the in-band level).

The situation can be further complicated by some VM specifications that do not include any free-field test, as well as making inter-VM comparisons difficult this also makes these manufacturers test results un-usable for e-mark testing (for which most CISPR-25 based tests will be suitable after the adoption of 2004/104/EC in July 2006).

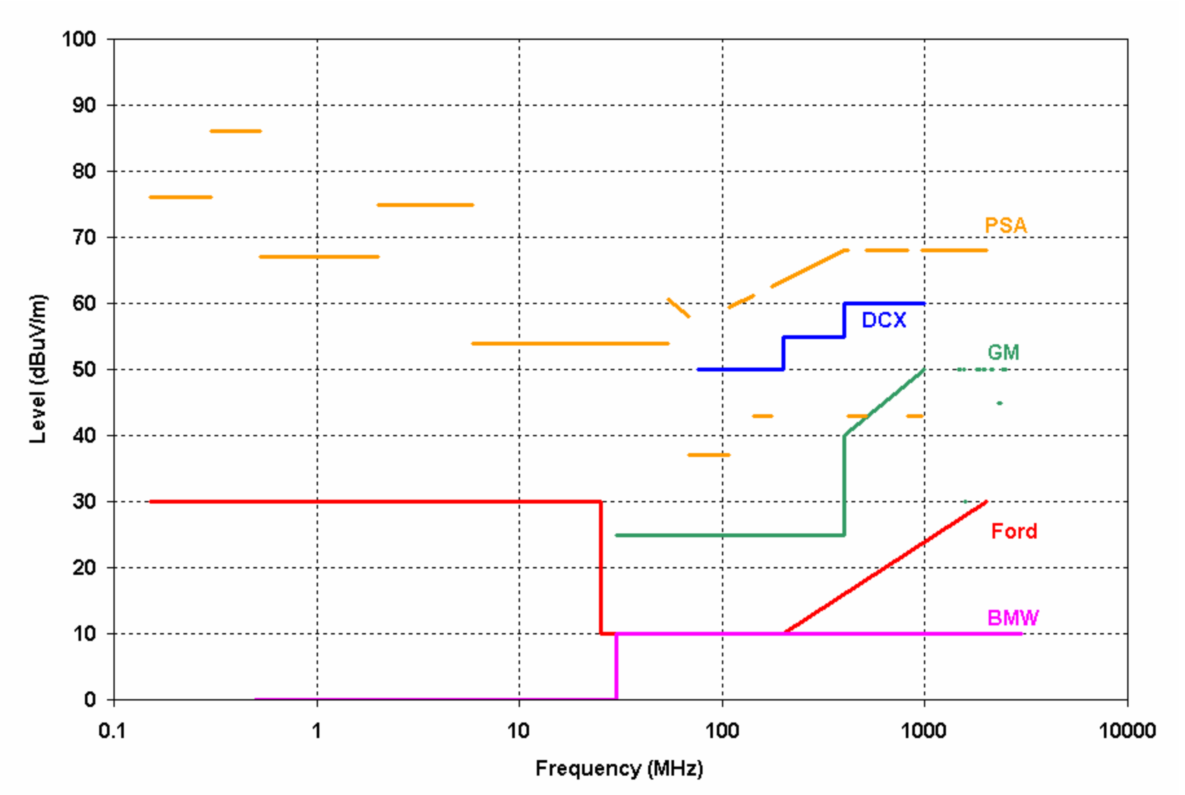

Figure 1: VM Radiated Emissions Limits

The graph (figure 1) shows the range and illustrates the significant variance in levels and frequency range, some of the differences can be explained by difference in RBW, but not all of them. The BMW test for example is significantly different from any other OEM test and is not based on the CISPR-25 test method. There are also some VM standards that simply use the CISPR-25 levels. These are not explicitly shown, except for the PSA limits that are based on level 3 of CISPR-25.

There is such a disparity between the frequency ranges and levels that it is very difficult to conceive of an easy common ground between VM tests. Even the usually common range between 30MHz and 1GHz has no common levels between any of the VM's listed. It should also be noted that the above are only the basic radiated emission and not the extended tests some of the VM's apply specifically for GPS and automotive radar applications for example.

Many of the tests extend to 2.5GHz or 3GHz, so cover the inclusion of Bluetooth and other wireless in-vehicle technologies, but undoubtedly future products will extend this to 5GHz and beyond. Even at 5GHz, only the first harmonic of Bluetooth is covered. At the low frequency end most VM's don't go below the CISPR-25 lower frequency of 150kHz.

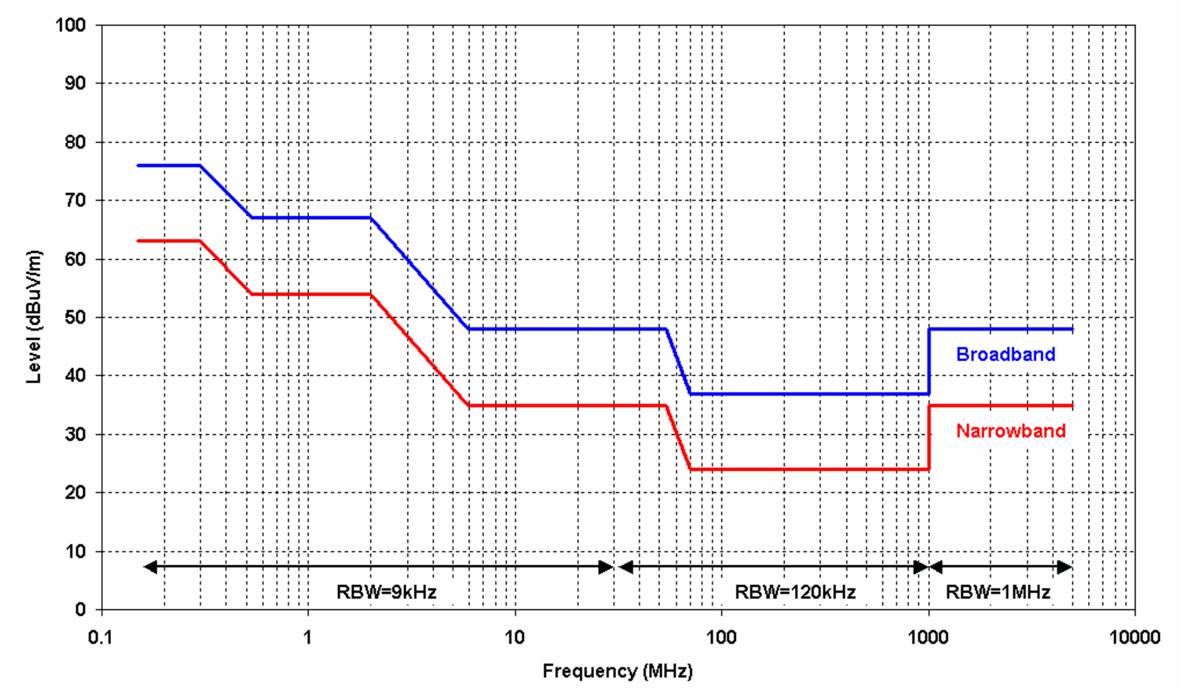

Figure 2: Generic Limits based on CISPR-25 Level 3

Since most VM's use the methods of CISPR-25, we have used the limits as well, using level 3 of CISPR-25 radiated emissions, without the omitted bands (see figure 2). This meets the PSA and DC requirements fully and covers the GM requirements above 420MHz. On first glance it would appear that the proposed generic limit does not meet the Ford specification at all, but due to the RBW used in the Ford specification (9kHz) the limits are not that dissimilar over the 5MHz-25MHz and above 70MHz (the same argument can be applied to the GM limits below 420MHz).

The above limits are also specified for testing at the CISPR-25 RBW filter sizes of 9kHz below 30MHz and 120kHz from 30MHz to 1GHz. CISPR-25 does not have a specified RBW above 1GHz but for expediency of the test over the 1GHz to 5GHz range a 1MHz RBW has been chosen with the corresponding increase in limit level of 11dB above the pre-1GHz level. It is worth noting that as in CISPR-25 we have not implemented a change in level at the 30MHz RBW change, this gives the limit just above 30MHz a significantly more stringent requirement that immediately below 30MHz, but this is done for consistency of method and application with CISPR-25 rather than any genuine test case reason.

Radiated Immunity

This is the test requirement that has the most numerous number of method employed in its application, not only in VM specifications but also within the international standards (ISO11452 has 7 parts, 1 general then 6 for different test methods). Many VM's do utilise the ISO 11452 test methods for some of the set-up and calibration, but most have significant deviations in many of the harness placement, lengths and placement of equipment under test and support equipment (as well as the usual frequency and level differences, see figures 3 and 4).

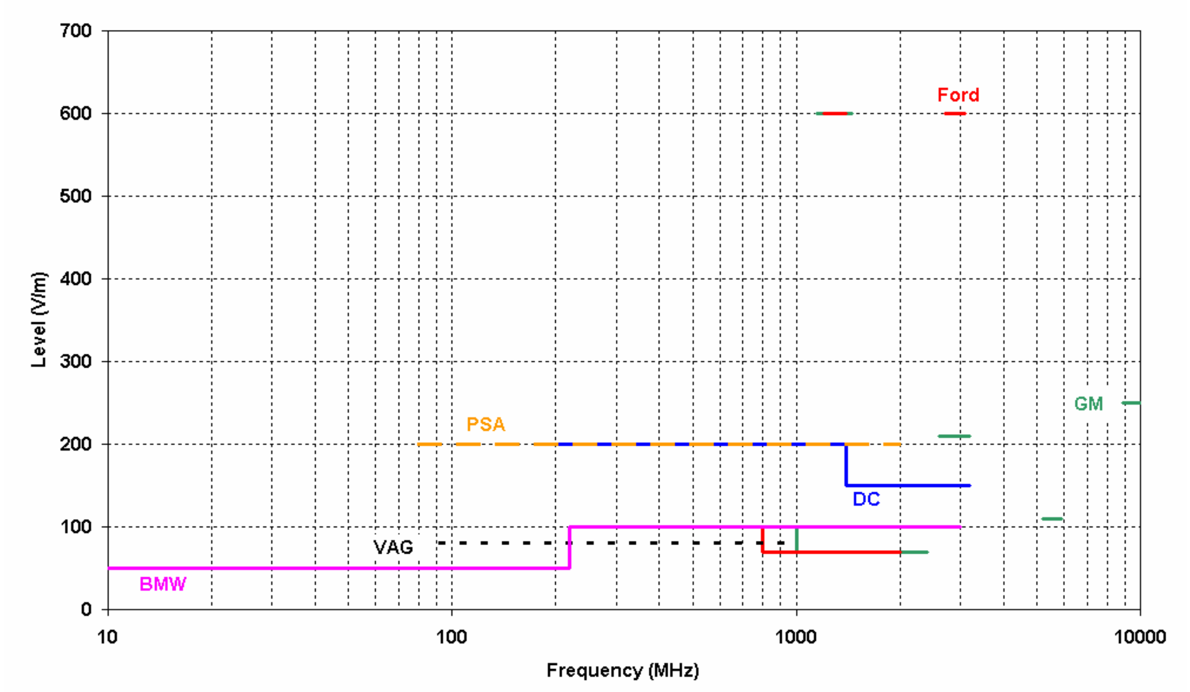

Figure 3: VM Free-Field Radiated Immunity Levels

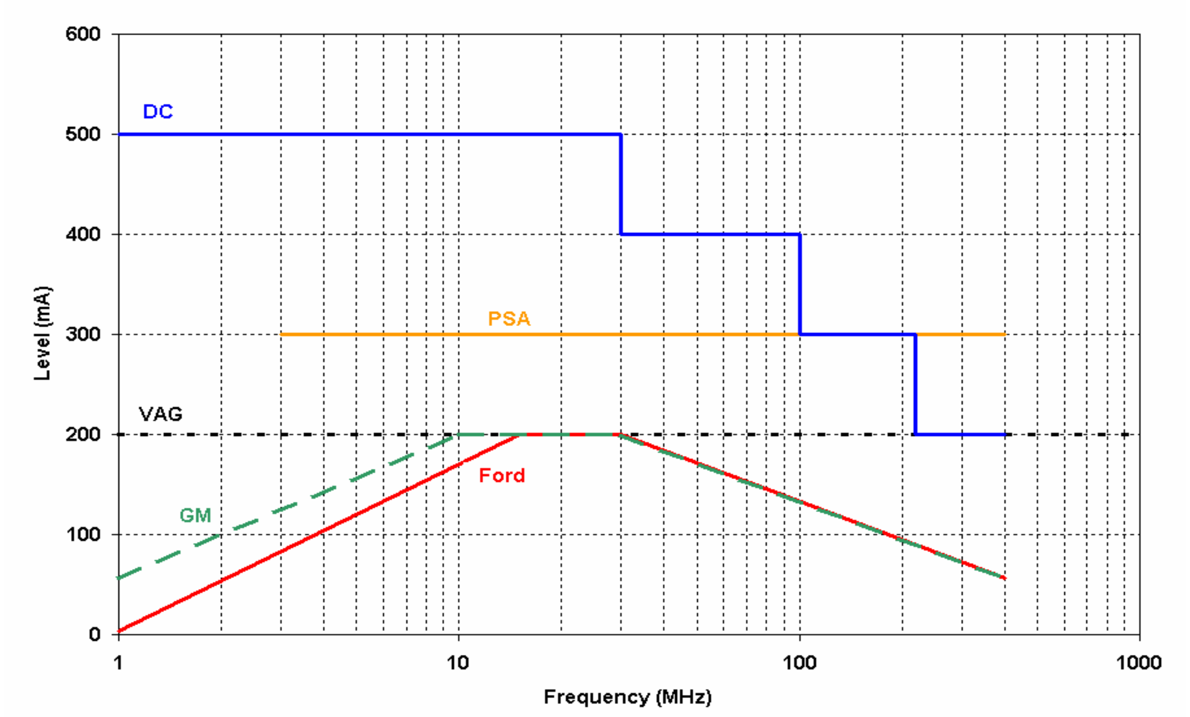

Figure 4: VM BCI Immunity Levels

Here we are only going to use 2 test methods; BCI for the lower frequency range (1MHz-400MHz) and free field (measured in an absorber-lined screened enclosure; ALSE) for higher frequencies (20MHz-5GHz). There is a considerable cross-over in these ranges, but this is to enable test costs to be optimised and at the same time keep an eye to the EU automotive directive and meeting its requirements with the same data. In practice what this means is that ALSE testing can commence at 200MHz rather than 20MHz if it is a lower cost option or there is some benefit to using BCI for the lower frequencies, but if ALSE testing can be performed down to 20MHz BCI testing may be omitted entirely.

Table 3: Generic Radiated Immunity Parameter Summary

Frequency Range (MHz)	Test Method	Modulation	Polarisation	Application Group I		Application Group II	
				Limit	Pass Criteria	Limit	Pass Criteria
1 - 400	ISO 11452-4: BCI	CM/AM	Not applicable	200mA	A	100mA	C
20 - 1000	ISO 11452-2: ALSE	CW/AM	Vertical & Horizontal	200V/m	A	100V/m	C
800 - 5000		PWM	Vertical				

The majority of VM requirements are met with these limits for ALSE, with the exception of the few higher limits of Ford and GM. The free-field limits also exceed the frequency range used by most, but this is to cover WiFi hotspots and some short-range roadside communications systems. The BCI limits likewise cover most VM requirements with the one exception of the higher DC limits at low frequency (DC are out of alignment with the other VM's here).

It should also be noted that the limits in figures 3 and 4 are the maximum limits used by the VM's and many have lower limits depending on the application or physical location in-vehicle. Some VM's have 4 separate application categories for radiated immunity and this can make determining the correct limits to apply difficult. Here we have used the 2 previous defined application groups and functional classifications of passes.

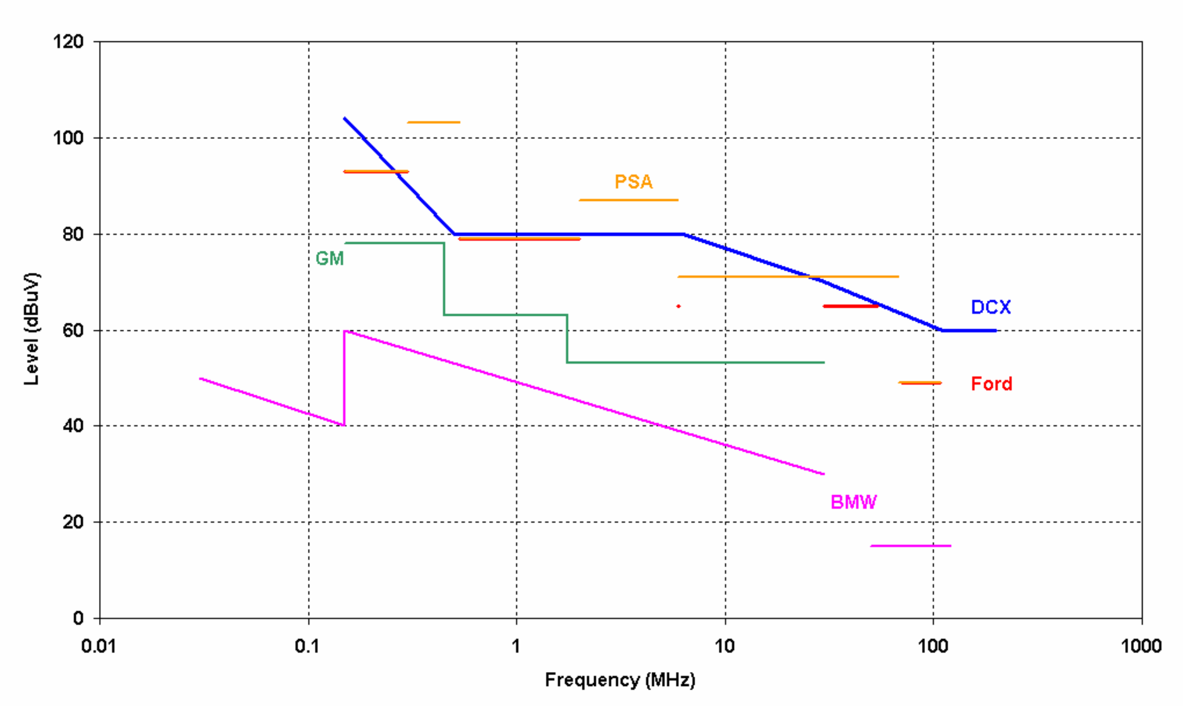

Figure 5: VM Conducted Emissions Limits

Conducted Emissions

The CISPR-25 test method for conducted emissions is almost universally adopted by VM's within their test specifications. The frequency range of 150kHz to 108MHz is generally maintained, with a few exceptions; DC go up to 200MHz and BMW start at 30kHz. Beyond this, however, nothing else appears a common commodity (see figure 5).

Both Ford and PSA use the limit levels from CISPR-25, but most other VM's apply different levels. It is possible that some of the other applied limits are similar, but is obscured by the use of different resolution bandwidth (RBW) filters applied across different frequency ranges. Even with the Ford and PSA standards, which both apply the level 3 limits of CISPR-25 for power line conducted emissions, PSA apply level 2 in the out-of-band ranges whereas Ford omit limits in the out-of-band regions. The lack of limits out-of-band in CISPR-25 is a strange omission for a VM specification and Ford are one of the few VM's that do not apply limits within these missing bands, although there is no consistency with the VM's on how these out-of-band regions are regulated.

The level 3 of CISPR-25 will also meet the DC levels and as well as PSA and Ford if simply linked directly across the out-of-band levels. The main problem with using this level is in failure to meet the GM specification, however the narrowband of level 3 is still lower than the GM limits. The GM limits are termed for spark generated and non-spark generated sources (not shown) hence not as clear-cut as the CISPR-25 limits or other VM definitions. The RBW of 10kHz for GM is similar to the CISPR-25, Ford, DC and PSA value of 9kHz for frequencies below 30MHz. A low RBW of 200Hz helps explain the lower limits below 150kHz for BMW and above 50MHz where BMW maintain a 9kHz filter, but the reason for such low values across the 150kHz to 30MHz range is difficult to explain. Having examined the powernet of these vehicles myself I can state that it is not possible to claim they are any quieter than other vehicle powernets.

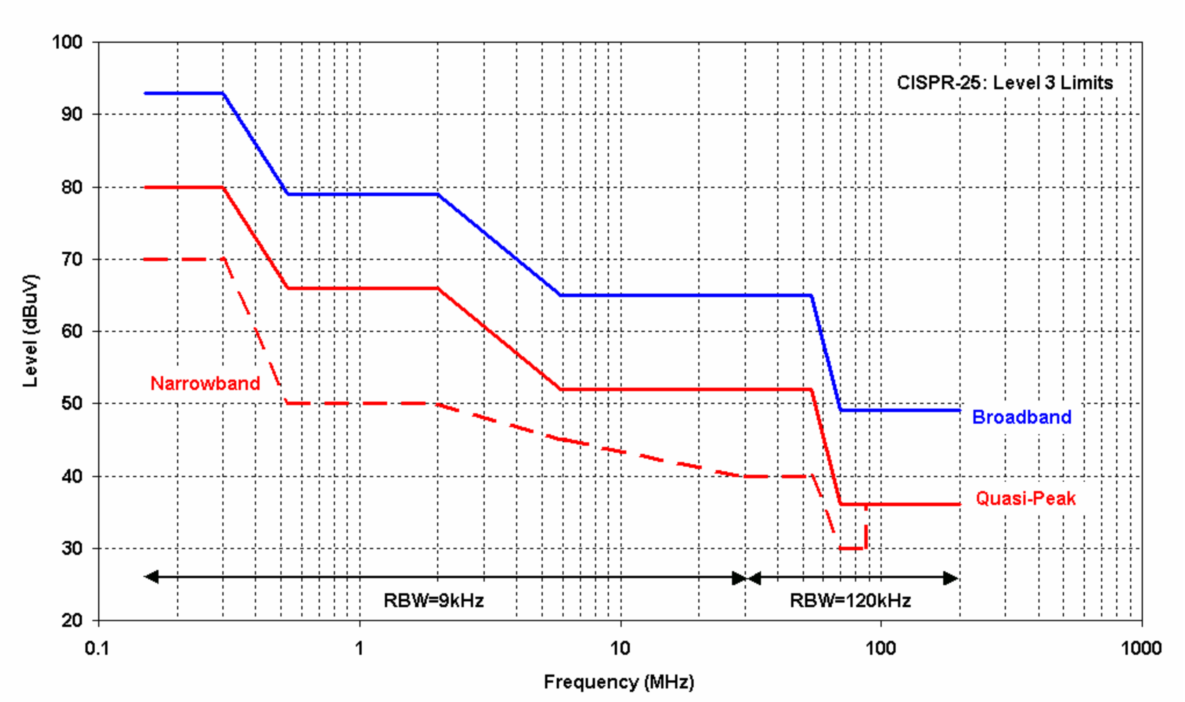

Figure 6: Generic Conducted Emissions Limits based on CISPR-25 Level 3

The pragmatic approach is therefore to adopt CISPR-25 level 3 without omitted bands (figure 6) and with the broadband and narrowband levels as they appear in the CISPR-25 document, while extending the upper test frequency limit to 200MHz to complete the DC requirement. The extension for DC may appear slightly at odds with the desire to minimise test costs, but including here adds only a few more minutes to a test sweep for the complete DC specification range and is a significantly lower cost than repeating the full test for this 108MHz to 200MHz extension.

The narrowband limits applied are in fact the quasi-peak limits from the appropriate table in CISPR-25 (table 6 of CISPR-25:2002) and not the quoted narrowband limits (table 7 of CISPR-25:2002), which are another 13dB lower and inconsistent with the definition of narrowband at the front of the CISPR-25 document (shown as dashed line in figure 6).

Conducted Transient Immunity

Conducted transient tests are one area it is easy to gain a consensus, the methods in the ISO 7637-2 standard have been around for over 15 years and were used before this by many VM's. These are basic good engineering tests for compatibility to the automotive electrical environment (powernet) as much as EMC specific tests. The biggest surprise is the relatively common set of pulse levels used, typically severity level 4 of ISO 7637-2 for pulses 1 to 4 (table 4).

Load dump, pulse 5, is the only signal that shows significant differences across the VM's and could be argued to be genuinely VM dependant. Some VM's will use some form of load dump suppression on their alternator (e.g. PSA, GM) whereas others clearly do not (e.g. Ford, BMW). It is probably also true that not all circuits within the vehicle need independent load dump handling capability, possibly the application group I products (Powertrain and Safety), but the group II (comfort and convenience) products could have a lower level applied (I think if you had a genuine load dump occurrence you wouldn't be too concerned that the radio stopped working).

Table 4: VM and Generic Transient Immunity Pulse Levels for ISO 7637-2 Pulses (values in Volts)

Pulse	GM	VAG	Ford	DC	PSA	BMW	Porsche	Generic
1	-100	-100	-100	-100	-100		-100	-100
2a	50	50	150	100	100		100	100
2b	10						100	10
3a	-150	-150		-150	-150	-112	-150	-150
3b	100	100		100	100	75	100	100
4	7	7			4.9	7.5	8	7
5	34		60		21.5	66.5	24	87 (I) 24 (II)

The chosen level adopted are from level IV of the ISO 7637-2 standard, with 2 exceptions. The first exception is the use of 100V for the pulse 2b to meet all but the Ford requirements. The ISO 7637 level IV setting for pulse 2b is 50V (as specified in the VAG and GM standards), this is relatively benign and even 100V is not especially onerous to meet. The other difference is the load dump (pulse 5) lower level for group II application circuits at 24V, in line with PSA and Porsche and close to the GM level.

Another difference is that the VM's usually change the majority of the pulse test parameters; rise times, pulse duration, etc. These deviations create the impression of a greater difference than really exist in these VM specifications and these are one test type that is often accepted by other VM's. The tests here use the mean of most of these additional test parameters and will be fully listed in the test specification document.

Electrostatic Discharge

ESD is considered the easiest EMC test method to get a reasonable consensus on across automotive VM's, however, there is still some significant discrepancies with some of the VM specifications. Notably DC and BMW use the standard derived for systems primarily connected to a domestic power supply (commercial EMC standard IEC 61000-4-2) rather than the ISO 10605 ESD standard that was derived specifically for the automotive environment.

There are many similarities in the 2 standards; they use the same type of ESD generator, the same voltage waveform and the same discharge tips. The differences are in the human body model (HBM) where the commercial standard uses a resistance of 330Ω compared to 2000Ω for the automotive standard. The HBM capacitance values are the same in each standard at 150pF and 330pF for air and contact discharge respectively, although some of the VM specify the same capacitance for both discharge methods. The resistance value is quite a significant difference and it should be remembered that the commercial standard is for a system that has an earth reference conductive discharge path (i.e. a path to the reference against which the static is measured), whereas in the automotive environment the discharge is really a charge transfer between two systems essentially isolated from the earth reference (body-to-vehicle). Not only do I feel the ISO 10605 standard is better for the automotive environment as a representative test, but for non-powered handling tests I would even encourage commercial testing to adopt ISO 10605 where the discharge is again charge transfer between isolated systems.

Table 5: VM Standards ESD Parameters

Vehicle Manufacturer	Handling (kV)		In-Vehicle (kV)		Human Body Model	Standard Referenced
	Contact	Air	Contact	Air		
BMW			±8	±15	150pF/330Ω	IEC 61000-4-2
DCX	±4	±8	±8	±25	150pF/330Ω	IEC 61000-4-2
Ford	±6	±8	±8	±25	330pF/2000Ω	ISO 10605
GM	±6	±8	±8	±25	150pF/2000Ω	ISO 10605
Porsche	±8	±25	±15	±25	150pF/2000Ω	ISO 10605
PSA	±4	±30	±8	±15	150/330Ω & 330pF/2000Ω	IEC 61000-4-2 & ISO 10605
Renault			±8	±15	330pF/2000Ω	ISO 10605
VAG	±8	±15		±25	150pF/330Ω	IEC 61000-4-2

The main differences therefore between VM standards are the levels at which tests are applied, and sometimes the number of pulses (between 3 and 10) and tests types (e.g. air, contact, powered and unpowered/handling). Here I have used both test scenarios and discharge methods and set the limits at a relatively high level to satisfy the majority of VM test requirements. The 2 application categories are treated the same since the powertrain and safety critical products are not directly accessible by the vehicle occupants. Consequently, although they tend to have a higher test requirement, the powertrain and safety critical products are unlikely to see any direct ESD during functional operation. Conversely the comfort and convenience functions are usually in the cabin and have directly accessible controls and as such are more likely to suffer a direct discharge during operation.

Table 6: Generic ESD Test Parameters

Test	Discharge	Network	Test Severity Level	No. of Discharges	Functional State
Unpowered or Handling	Contact	150pF/2kΩ	±8kV	5	A (I) C (II)
	Air	330pF/2kΩ	±15kV		
Powered	Contact	150pF/2kΩ	±8kV		
	Air	330pF/2kΩ	±25kV		

Tests may gradually be raised to the values shown in the above table in steps suggested in ISO 10605.

Although only 5 discharges are required (in both positive and negative polarities), this is for any single pin or any discharge point. The higher requirement of 10 used by some VM's can result in an excessively long tests where there are multiple pins to discharge to (30 pins is not uncommon) and retest after each discharge or even series of discharges will add to the overall test costs. A period of between 1s and 10s between discharges, as per ISO 10605, should be observed.

Other Test Possibilities

The tests presented here are the most common ones used throughout the automotive industry, however, they do not include some of the common test methods such as TEM cell and stripline testing. These may be introduced at a later stage should the cost prove prohibitive for radiated immunity in particular, however, part of the purpose of this work was to reduce the number of test methods to a manageable common set, in that respect adding more tests is counter productive.

The most likely new addition would be the use of reverberation chamber testing for high frequency radiated immunity (and even emission) to cover the 5GHz-18GHz range. Free-field testing in this region would be extremely expensive at high field. Similarly pulsed mode testing at specific frequencies (e.g. 24GHz and 77GHz for adaptive cruise control and collision avoidance radar) could also be a future additional test method, should a near consensus be achievable between VM's.

Further Test Information

The resulting test regime suggested here needs more information to fully be used as a test specification, there are numerous parameters such as step size for radiated emissions testing and all the pulse parameters for transient immunity that need defining, however that is beyond this papers scope, but will be included in the test document once that is completed. The tests generally meet the majority of the VM test requirements, although not all. The tests included here also meet (exceed) the requirements of the new EU automotive EMC directive (2004/104/EC), hence results can be used to submit for e-mark certification.

Summary

The "big 3" US VM's (Ford, GM and DCX) have already recognised the potential benefits of a common standard for EMC tests and have been working to align their methods over the last 3 or so years. However, there are vested interests and a speed of response that does not always meet with market demand for change. Although some progress has been made, many independent commentators, particularly from test service providers, still note significant differences between what these VM's require. On the same note Ford is still the only VM that publicly make their EMC standard freely available (www.fordemc.com). The apparent "secrecy" surrounding other VM EMC requirements continues to suggest a lack of commonality. Some EMC specifications, the Japanese VM's in particular, are difficult to obtain information from even if you are a Tier 1 supplier, hence it can be almost impossible to gain an insight into what might be required.

It was suggested by some of the reviewers of this paper that it would mainly be useful as a comparison of VM standards, but this has been done several times before and to what aim? Simply to highlight the disparities in the VM marketplace? What I wanted to provide here is a possible solution to some of these disparities, a "middle way" through the minefield of VM standards that gives the reader something other than a simple and long list of VM tests and levels. At the same time I recognise that there is no authority in this work to adopt any of the recommendations made here. It is therefore left open to the industry to determine even if such a "middle way" is required, or if the existing methods of struggling along with a plethora of different, and often difficult to obtain, test standards is adequate. Maybe my example of being asked for the mythical "Generic VM EMC Standard" was an isolated case, but I believe not and hope someone will find the output of this work useful.

Conclusion

The results presented here and the suggested test levels will not guarantee any supplier access to every VM or even any particular VM. They are presented as a best "middle way" that gives a very good indication of likelihood of VM compliance while minimising the number and cost of EMC testing required. While obviously I commend them to the Tier 1 and test service suppliers, in particular as a solution for speculative developments and/or aftermarket designs hoping to eventually obtain line-fit acceptance.

Caveat

I should stress that there has been no direct VM input to this work and that the VM's themselves do not have any vested interest in any other than their own EMC standards.

Appendix A: ISO Failure Mode Severity Classification

All classifications given below are for the total device/system functional status.

Note: The word "function" as used here concerns only the function performed by the electronic system.

Class A: all functions of a device or system perform as designed during and after exposure to interference.

Class B: all functions of a device/system perform as designed during exposure; however, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after exposure is removed. Memory functions shall remain class A.

Class C: one or more functions of a device or system do not perform as designed during exposure but return automatically to normal operation after exposure is removed.

Class D: one or more functions of a device or system do not perform as designed during exposure and do not return to normal operation until exposure is removed and the device or system is reset by a simple "operator/use" action.

Class E: one or more functions of a device or system do not perform as designed during and after exposure and cannot be returned to proper operation without repairing or replacing the device or system.

References

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Commission Directive 95/54/EC of 31 October 1995 adapting to technical progress Council Directive 72/245/EEC on the approximation of the laws of the Member States relating to the suppression of radio interference produced by spark-ignition engines fitted to motor vehicles and amending Directive 70/156/EEC on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers

Commission Directive 2004/104/EC of 14 October 2004 adapting to technical progress Council Directive 72/245/EEC on the approximation of the laws of the Member States relating to the suppression of radio interference produced by spark-ignition engines fitted to motor vehicles and amending Directive 70/156/EEC on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers

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Part 3: Vehicles with nominal 12V and 24V supply voltage – electrical transient transmission by capacitive and inductive coupling via lines other than supply lines (1995)

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Biographical Notes

Martin O'Hara is the founder of the Automotive EMC Network and the Automotive EMC Conference organiser. Author of "EMC at the Component and PCB Level" and numerous papers on EMC and circuit design. Martin has previously designed satellite navigation systems, vehicle tracking products and traffic information devices for Trafficmaster PLC and prior to that was Electronic Technologist at Motorolas' Automotive division in their European Design Centre. Now Technical Director for Danfoss Randall Ltd.