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# SURFACE VEHICLE INFORMATION REPORT

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## Radiated Emissions (RE) Narrowband Data Analysis—Power Spectral Density (PSD)

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***Foreword***—In the context of the automotive industry, the present method of using only a limit line for determining module radiated emissions (e.g., per SAE J1113-41) acceptance is too simplistic and is not the most effective way to make competitive business decisions. The limit line approach does not address many real issues. Consider the following.

It is very difficult if not unpractical to get the same results at each frequency from different test labs for radiated emissions due to the many variables involved. However it is possible to establish correlation between different labs on a statistical basis. Some technical papers have suggested a solution (e.g., per reference 2.1.2 a, b). For example, if only the highest emission levels are compared independent of the emission frequencies a higher degree of correlation is possible. Such an approach may be justified under the assumption that the test facility design does not significantly affect the total emissions power but mainly leads to the radiated power spectrum redistribution.

The simplistic approach of being below a limit line may still result in instances of a customer concern. For example, even if the RE is all below a limit line, it is more probable that a concern would exist if there are many spectral lines close to the limit (i.e., the spectral density is high). Another situation that may result in overdesign would be to fail a module that only had a few data points slightly over the limit but otherwise showed little emissions.

There are many differences between the module test setup and the vehicle configuration (e.g., harness configuration) and it is unlikely that there is a one to one correlation between the lab and the vehicle (at each frequency). For example, even if a module was below a limit line using the bench test configuration, in the vehicle there may be an entirely different configuration so that those frequencies that were below the limit line are now connected to a system which more effectively radiates and results in a customer concern (and conversely).

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***1. Scope***—This SAE Information Report defines a procedure for indicating the severity of narrowband emissions from an electronic system-component.

## *2. References*

**2.1 Applicable Publications—**The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1113-41—Limits and Methods of Measurement of Radio Disturbance Characteristics of Components and Modules for the Protection of Receivers Used On Board Vehicles

2.1.2 OTHER PUBLICATIONS

a. 1987 IEEE Symposium - “Statistical EMC: A New Dimension in EMC of Digital Electronic Systems”
b. 1992 IEEE Symposium - “Qualification of Radiated EMI Test Sites Using Statistical Methods”
c. 1996 ITEM - “Signal Processing in Radiated EMI Measurements,” Werner Schaefer

## *3. Procedure*

**3.1 General—**This procedure uses the limit line as only one part of a decision for acceptance. Another important parameter to consider is the total amount of power available to excite the vehicle wiring. The following presents one possible concept for addressing the issues raised.

**3.2 PSD Applicability**

a. If there are narrowband (discrete peaks) emissions above a Preferred Limit and any peak does not exceed a defined level (e.g., 6 dB) over this Preferred Limit.
b. There is a high density of spectral lines near the limit (e.g., within 3 dB).

**3.3 PSD Calculation**

a. Consider the data points in terms of $(x/L)^2$ where x is the value of the data point in linear terms (microvolts/m) and L is the preferred limit at the frequency of the data point. For example, if a data point is 20 dB microvolts/m (10 microvolts/m) and the preferred limit at that frequency is 10dB microvolts/m (3.2 microvolts/m), the $(x/L)^2$ value would be $(10/3.2)^2 = 9.8$.
b. By taking $(x/L)^2$, the method can be applied even if the limit is not a constant value - i.e., it can be applied on a sloping limit line since the specific limit at a specific frequency can be used.

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c. The squaring gives exponentially more weight to data points that are high relative to a preferred limit. It also gives an indication of spectral power hence the PSD designation (receivers are sensitive to power impinging on their antenna).
d. Compute Power Spectral Density (PSD):

$$\mathrm{PSD} = \sum (x/L)^2 / (\text{Frequency Span/Resolution}) \qquad \text{(Eq. 1)}$$

A total sum of the squared ratio of the emission level to the limit at each of the sample frequencies shall be accumulated for the frequency range being evaluated. This sum shall then be scaled by dividing by the ratio of the width of the frequency range evaluated divided by the spacing of the sample frequencies.
e. For higher frequencies, the Frequency Span should be a “sliding frequency window”.
f. This concept is relatively easy to automate. A key is to properly recognize the peaks in the RE data. Reference 2.1.2 c addresses this issue.

**3.4 Implementation Examples—**The following examples are for illustrative purposes, each company will need to access the correct Frequency Span and Resolution based on their data and experience.

3.4.1 For high frequency type signal emissions (e.g., clock harmonics):

a. Sliding Frequency Window (Span) = 50 MHz, Frequency Resolution = 1 MHz, therefore Span/ Resolution = 50. Report the highest PSD.
b. The 50 MHz span is chosen since the radiating test harness is assumed to be 1.5 meters. At that length, it has a quarter wavelength resonance every 50 MHz. Therefore the 50 MHz span will encompass the emissions contained within these major resonance "humps".
c. Acceptance Criteria:

Assumption = PSD should be no worse than if all potential data points (assume data points are at 1 MHz intervals) are at x/L = 0.7 (3 dB below limit), the criteria would be:

$$\mathrm{PSD} = [(\#\text{ data points})(x/L^2)]/(\mathrm{Span/Resolution}) = [(50)(0.7^2)]/[50\text{ MHz}/1\text{ MHz}] = 0.5 \qquad \text{(Eq. 2)}$$

Since the FM band (75 - 110 MHz, includes Japan) is more critical, the sliding window concept may not be applicable - the purpose, in this case, is to reduce emissions to such a low level that even harness variations within the vehicle are not enough to cause concern.:

$$\mathrm{PSD} = [(35\text{ data points}) \times (0.5^2)]/[35\text{ MHz}/1\text{ MHz}] = 0.25 \qquad \text{(Eq. 3)}$$

3.4.2 For low frequency type signal emissions (e.g., switching power supply harmonics):

a. The sliding window concept does not apply since the harness length is short compared to the wavelength.
b. Span = 1.65 MHz (AM Band, 0.15 MHz - 1.8 MHz), Resolution = 20 kHz, therefore Span/Resolution = 83. The 20 kHz was chosen to be more representative of the emission spectral spacing in this range.
c. Acceptance Criteria:

Since the AM band is more critical, the limit should be stringent:

$$\mathrm{PSD} = [(83\text{ data points}) \times (0.5^2)]/[1.65\text{ MHz}/20\text{ kHz}] = 0.25 \qquad \text{(Eq. 4)}$$

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