DEVELOPMENT OF SHOCK AND VIBRATION TEST SPECIFICATIONS FOR TELECOMMUNICATION EQUIPMENT IN AUTOMOTIVE ENVIRONMENTS

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Biography

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Abstract

Results from the development of shock and vibration test specifications for telecommunication equipment on the basis of field measurements are presented. Telecommunication products can be installed into various locations in vehicles. Thus, the measurements were conducted from several possible mounting locations. Five different telecommunication equipment was studied. In addition, various road types and situations giving different impact loads were studied. On the basis of the provided life cycle profiles the measured environmental conditions were combined and test acceleration was used in order to obtain the final shock and vibration test requirements.

Keywords

Test specification, telecommunication equipment, field measurements, vibration and shock, life cycle profile, environmental condition, shock and vibration test requirements, test tailoring.

Introduction

Telecommunication equipment is exposed to significant shock and vibration loads in automotive environment. Examples for representative test levels can be found in handbooks and standards (IEC 60721-3-5 (1997), ETS 300-019-1-5 (1992)). In addition, vehicle manufacturers may provide more specific test requirements. However, telecommunication products may be installed into different locations with different mounting systems in vehicles and therefore vibration and shock environmental conditions can – change significantly for even similar products. Therefore, it may be necessary to study the shock and vibration levels in actual field conditions and to use this knowledge for the generation of more accurate and optimized test procedures. This process is often called environmental test tailoring. At the same time, in addition to improve testing, the measured data can be used for improving equipment and mounting system design [1, 2].

In this work the main objective is to generate shock and vibration test specifications for telecommunication equipment in automotive environment with the use of field measurements and environmental test tailoring. In addition, the test tailoring process itself is studied. The produced test requirements represent the estimated total life cycle load, i.e. amount of shock and vibration loads that the product experiences during its life time. Furthermore, the tests are accelerated in order to reduce testing time and costs.

The conducted work is connected to research program MERA (Mechanical Stresses in Equipment Design) which is part of Finnish National Research Program ETX.

Test tailoring procedure

The used test tailoring process was realized with the use of the LMS Mission Synthesis software [3]. The main features of the process are presented in **Figure 1**. The given life cycle of an equipment was divided into environments and each environment was divided into situations and further into samples. In addition, each co-ordinate axis was analyzed separately. In this work, only the user environments of equipment life cycle were studied. Manufacturing, storage and package transportation environments were not considered critical.

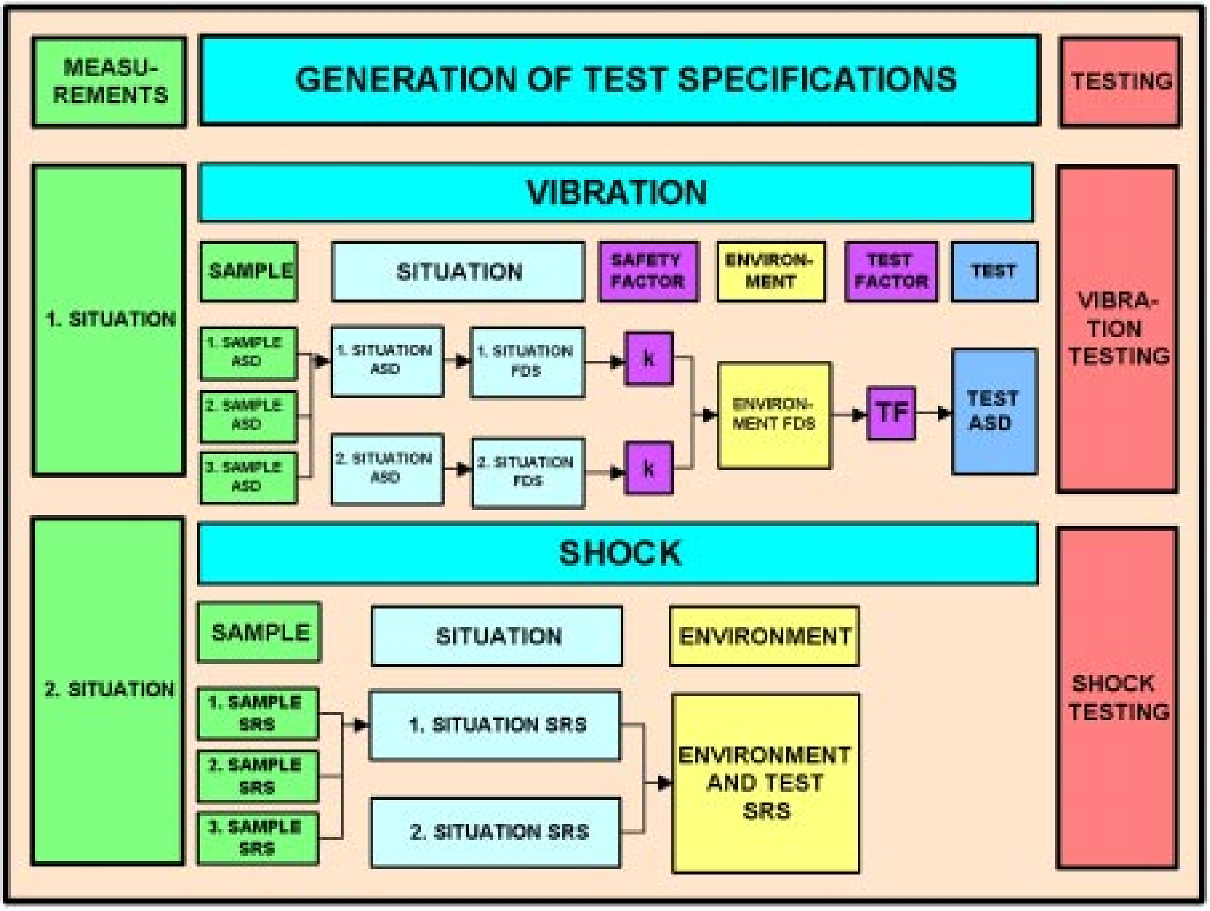

Figure 1. Environmental test tailoring process for shocks and vibrations.

Determination of environmental conditions

Introduction

Electronic devices can be installed into vehicles permanently (e.g. radios, CD-players) or temporarily (e.g. mobile phone). Installation place and usage profile vary depending on vehicle type, usage environment and user.

In this work, four places were considered as the most probable installation locations for telecommunication products such as smart traffic products, radio and control units and mobile phones. Measurements were carried out in three perpendicular directions at 6 measurement points. The selected measurement locations were dashboard, middle console, back rest of the back seat and boot. For reference and to ensure the correct results measurements were also done from front chassis of the car and from mobile phone. A Ford Mondeo passenger car shown in **Figure 2**. was used for the measurements. Measurement points are presented in **Figures 3 - 7**. Selected road types, driving speeds and shock sources are listed in **Table 1**.

Figure 2. Ford Mondeo passenger car used in measurements.

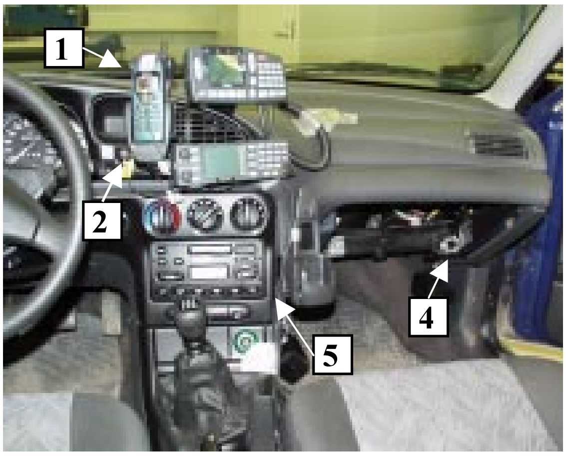

Figure 3. Acceleration measurement points 1,2,4 and 5.

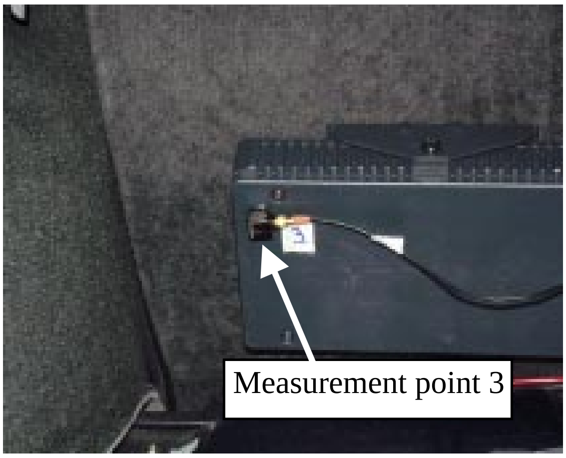

Figure 4. Acceleration measurement point 3 on back rest of back seat

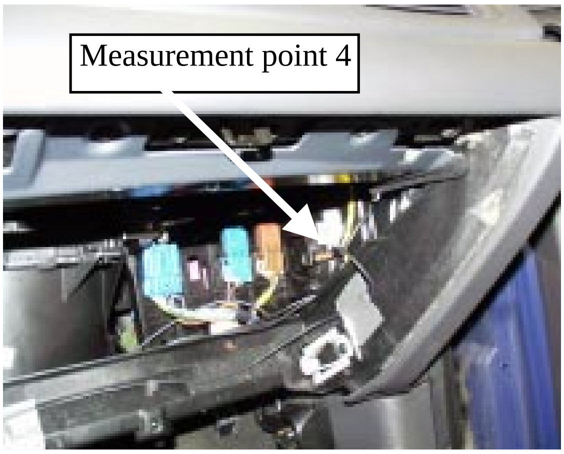

Figure 5. Measurement point on the front chassis of car.

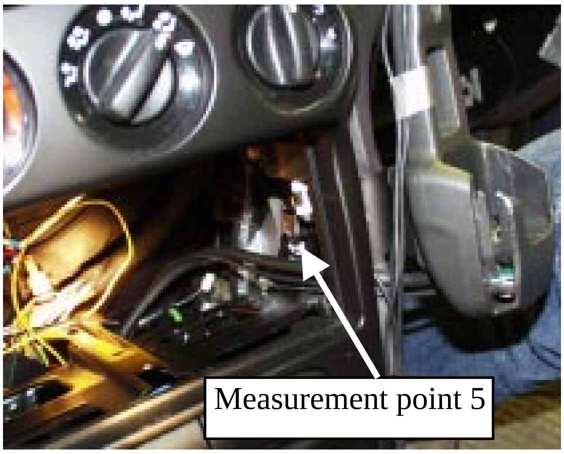

Figure 6. Accelerometer mounted near the car radio.

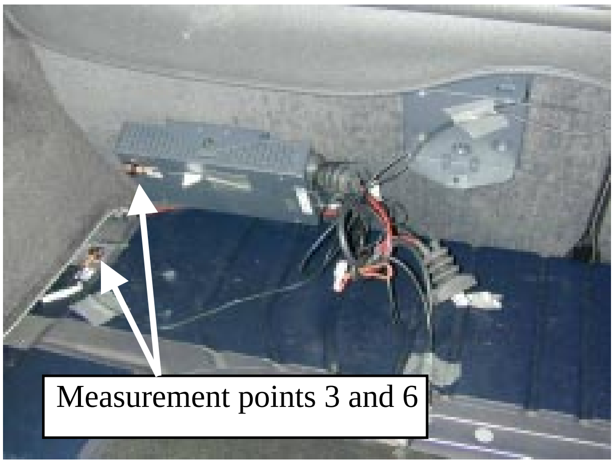

Figure 7. Acceleration measurement points on the back chassis of the car and on the radio unit.

Chosen situations

In practice, for field measurements one have to limit the study for the most important excitation sources and situations for shocks and vibrations. Thus, vibration measurements were carried out by measuring vibration levels at different car speeds on different road types. Chosen vibration situations are listed in **Table 1**. For shocks and transients there are numerous possible sources of excitations such as ramps, speed bumps, potholes, tram/rail tracks, cobblestones, collisions, closing of doors etc. The ramps and closing of doors were selected to be the most important and to give the essential characteristics the possible shocks and transients. These shock and transient measurements are listed in **Table 2**. Each door was closed forcefully five times and the accelerations were measured. The car was driven to the ramp shown in **Figure 8** at speeds listed in **Table 2**.

Table 1. Measured vibration environments.

	Highway	City drive	Cobblestone	Country road	Concrete road
Measured situations	1. 80 km/h 2. 100 km/h 3. 120 km/h 4. 140 km/h	1. 50 km/h	1. 50 km/h	1. 60 km/h	1. 120 km/h 2. 140 km/h

Table 2. Measured shocks and transients.

	Ramps	Closing of doors
Measured situations	20 km/h 30 km/h 40 km/h	Front left Front right Back right Back left Boot

Figure 8. The ramp for the shock and transient measurements. The height of the ramp was about 5 cm.

Measurement arrangements

Used Data Acquisition Equipment

Vibrations and shocks were measured in three perpendicular directions (**Figure 9**) by using tri-axial piezoelectric Endevco E 63B-100 accelerometers Measured signals were recorded by using Heim DATaREC A-160 digital tape recorder.

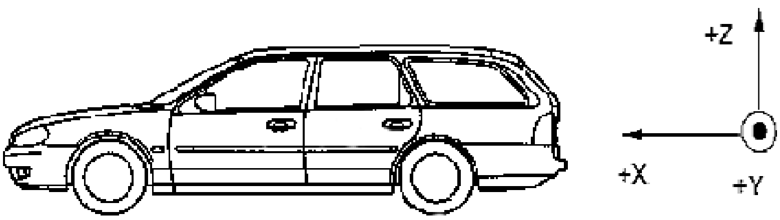

Figure 9. Global co-ordinate axes of vehicle.

Parameters used in field measurements

The frequency band in field measurements was 0 - 4000 Hz and sampling rate was 12000 Hz. The recorded amplitude range was set to either ±100 m/s^2 or ±500 m/s^2 depending on the vibration levels expected from each measured situation.

Environment description

Introduction

The goal was to produce such test requirements that have the same damage potential as actual environmental conditions which product encounters during its life cycle. In addition, test requirements should be able to be conducted with standard test machines and with reasonable costs. Thus, shock and random vibration tests were selected. Product resistance to shocks and transients can be ensured by shock testing and resistance to vibration and cycle fatigue can be ensured by random vibration testing.

Shocks

The most significant shocks were expected while closing the doors and driving over ramps. In the situation of closing the doors, each door and trunk were closed 5 times. In ramp tests, car was driven over ramp at three different speeds. From each situation 4-5 samples were selected. Sample time length was 2-3 s and the samples were visually inspected before shock response spectra were calculated.

The situation Shock Response Spectrum (SRS) was obtained by forming an envelope from the corresponding calculated sample SRS curves. The parameters used in calculation of SRS are listed in **Table 3**. Furthermore, the test SRS was obtained with the envelope of situation SRS curves (**Figure 10**).

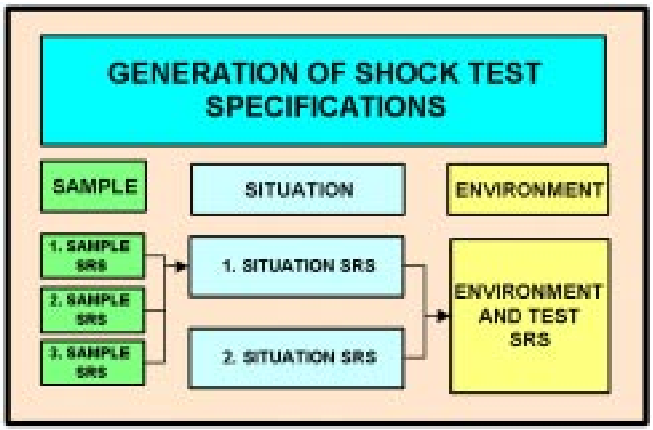

Figure 10. Diagram of generation of shock test specifications.

Table 3. Parameters used in calculation of SRS.

PARAMETER	VALUE
Q factor	10
Frequency axis	Octave
Frequency range [Hz]	1-1000
Points per octave	12

In addition to field measurement signals, SRS was calculated from different classical half-sine test pulses. A half sine pulse giving approximately similar SRS as the actual generated test SRS is useful if test equipment available can not use SRS as test specification input.

Vibrations

Introduction

The procedure for test Acceleration Spectral Density (ASD) is presented in **Figure 11**. Sample ASD were combined into situation ASD. Situation Fatigue Damage Spectra (FDS) were calculated from situation ASD and multiplied by safety factor (k) before combining into an Environment FDS. The obtained Environment FDS was further multiplied by test factor (TF) before the final Test ASD was calculated from it. The parameter selection was based on the recommendations of the LMS software and its supporting research material [3, 4] combined with engineering judgement.

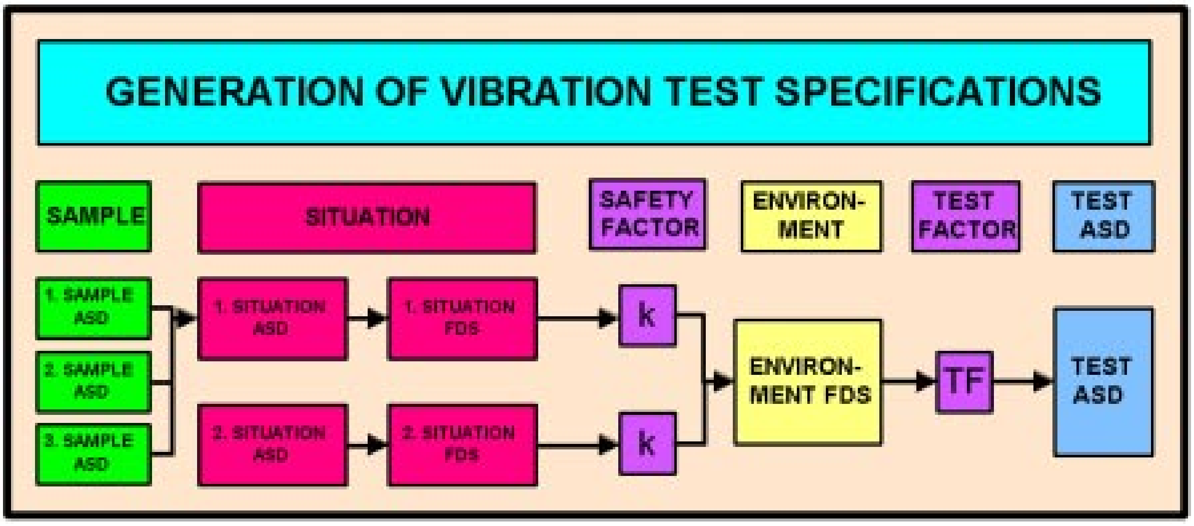

Figure 11. Generation of vibration test specifications.

Calculation of Acceleration Spectral Density from time histories

Total number of 3-8 sample time histories from the recorded field tests were selected for further analysis. Length of the time samples was 20 s and the selected samples were visually inspected before calculation of the ASD. ASD calculated from each selected time history sample is called here as "sample ASD". Parameters for analysis are listed in **Table 4**.

Table 4. Parameters used in the calculation of ASD.

Parameter	Value
Samples	8192
Overlap [%]	50
Average type	linear
Averages	57
Window type	hanning
Weighting	original

Combination of ASD into situations and calculation of FDS from situation ASD

Envelopes of the sample ASD of each situation were calculated in order to obtain spectra that represents the situation ASD. Following main parameters were needed in calculations:.

- driven hours per time unit (e.g. week or year)
- driven road types (e.g. motor way, country road, dirt road etc.)
- number of impacts due to ramps, speed bumps, pot holes, tram/rail tracks, road construction etc.

FDS was calculated from situation ASD on the basis of usage profiles. The needed usage profile information was received from the end customers. Parameters used in the calculation of FDS are shown in **Table 5**.

Table 5. Parameters used in calculation of FDS.

Parameter	Used value
Q factor	10
Wohler exponent	8
Wohler constant	1
Stress/displacement	1
Response calculation method	Duhamel
Frequency axis	Octave
Frequency range [Hz]	1-2000
Points per octave	12

Determination of the safety factor

Since the true environmental loads and material properties of the tested equipment are not exactly known the calculated FDS spectra have to be multiplied by a safety factor k. Values used in calculation of safety factor are based on literature [4]. In order to calculate the safety factor, values of the following four parameters have to be specified:

- Distribution (Gaussian or log-normal)
- Failure probability (P_0)

- Coefficient of variation of the material (CV_R).
- Coefficient of variation of the environment (CV_E)

Log-normal distribution was chosen since it is more representative at the both tails of distribution curve. The accuracy of these curve sections is emphasized in safety factor computations. Failure probability represents the maximum permissible failure probability.

Coefficient of variation of the material represents the strength characteristics of the material involved in the equipment under test. Value of CV_R is relative for example to the size of product; larger product requires larger value [4]. Increasing of this value will increase the safety factor. Coefficient of variation of the material is defined as the ratio of the standard deviation (σ_R) and the distribution mean (E_r).

$$CV_R = \frac{\sigma_R}{\overline{E}_r}$$

Coefficient of variation of the environment represents the variation in the environmental characteristics of the test. Increasing of this value will increase safety factor. Coefficient of variation of the environment is defined as the ratio of the standard deviation (σ_E) and the distribution mean (E_m).

$$CV_E = \frac{\sigma_E}{\overline{E}_m}$$

Generation of the test specifications

In this report each environment corresponds to a particular product and thus one usage environment. The environment FDS is the sum of the situation FDS:

$$FDS_{Env} = \sum_i k * FDS_{Sit}$$

where, k is safety factor and i is number of situations.

Not all the manufactured equipment will be tested and therefore a test factor (TF) is used. Each environment FDS is multiplied by a test factor. The test factor is based upon worst case scenarios in a way that when all tests performed did not cause failure, one can be sure that the other products won't break either [3, 4].

The test ASDs for different products were calculated from environment FDS. Three test ASD envelopes (one for each co-ordinate axes direction) of each product were obtained.

Results

Vibration test specifications

Vibration spectra were determined for accelerated testing representing the total vibration load of the products lifetime. Examples of test spectra are presented in **Figure 12**. Clear difference in test spectra for dashboard and boot installed products can be seen. In addition to the different installation places of the products, difference in test spectra are e.g. due to different products, lifetimes and exposure time to vibration. Mobile phones are temporarily put in on a car kit system, but smart traffic products are normally permanently installed, hence they encounter more vibrations.

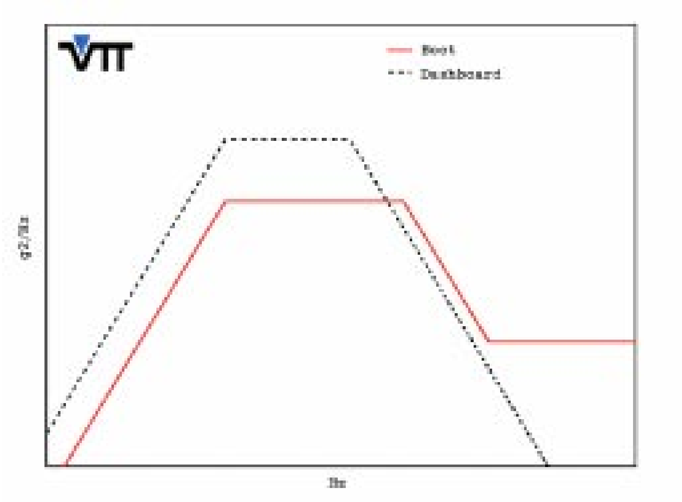

Figure 12. Vibration test spectra for products installed on boot and dashboard.

Shock test specifications

This report studies the shocks and transients caused by car door impacts and other external excitations. The high level shocks due to e.g. dropping, mishandling, accidents or direct impacts of foreign objects are not discussed in this paper.

It is not practical to do shock tests with real life time scale. Test time can be reduced with test time compression by using a sequence of shocks representing the total amount of shocks of the products lifetime. In addition, the produced shock tests may be accelerated by using an exaggeration factor. This is possible, if the critical failure can be considered to be controlled by e.g. low cycle fatigue process. Exaggeration factor for the produced half-sine test pulse was based on Wöhler´s curve and Miner´s rule. Thus, amplitude of half-sine test pulse was increased while number of pulses was decreased.

The examples of test SRS for mobile phone and other telecommunication products are presented in **Figure 13.** Furthermore, SRS was calculated from different classical half-sine pulses in order to compare the field measurement results to typical test requirements.

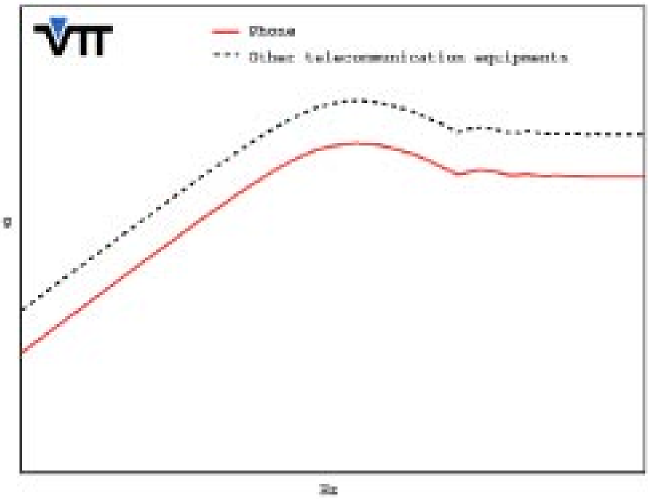

Figure 13. Test SRS for mobile phone and other telecommunication equipment.

Conclusions

Challenges of telecommunication equipment design are often due to shock and vibration loads which they are exposed to. In this work, shock and vibration test specifications have been developed for telecommunication equipment which are used or installed in automotive environment by using environmental test tailoring process and field measurement.

The studied vehicle and different environments were selected in order to obtain essential information of the actual operational loads. During the field measurements accelerations were recorded in three axes from different locations in the car.

The test tailoring process proved to give good insight into the real life user conditions and the possible design and testing criteria. The developed test specifications represent the total amount of possible shock and vibration stresses that telecommunication equipment will encounter during its lifetime. However, in this report the extreme shock loads due to e.g. dropping of equipment or direct impacts of foreign objects are not studied.

The produced tests are accelerated in order to reduce testing time. Accelerated testing allows shorter testing times but includes more uncertainties due to e.g. higher amplitudes and therefore possible change of failure modes. The test specifications can be further developed with more careful study of e.g. dynamic properties of vehicles and equipment, different failure modes and test acceleration methods.

Acknowledgements

This work was supported by Tekes, The National Technology Agency. Support from Nokia Mobile Phones is acknowledged.

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