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Alternative (Ecological) Method for Measuring  
Electronic Product Immunity to External Electromagnetic Fields

## RATIONALE

This technical report covers technology, products, or processes which are mature and not likely to change in the foreseeable future.

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## INTRODUCTION

At present, there are some standards such as SAE ARP1972, IEC 61000-4, CISPR Publication 24, etc. that regulate methods for measuring the immunity of radio and electronic products to external electromagnetic fields. The same idea is in the basis of these methods: generation of an electromagnetic field of a given strength, using a generator and radiating equipment (antenna, TEM-cell, etc.), within some volume where the equipment under test is placed. The immunity of the product to external electromagnetic fields is evaluated on the product response to the effect generated.

The methods defined in these standards have an inherent shortcoming: to realize them, the anechoic chambers (very often of large volume) or the open test sites (polygons) that are specially equipped and organized in special areas. Also, the powerful generating equipment and radiating systems are required. The method described herein is an alternative to these methods. It can be practically considered ecological, as its utilization needs no powerful radiating systems and generation equipment. In addition, this method can be easily utilized outside anechoic chambers.

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## 1. SCOPE:

This method is used to define the immunity of electric and electronic apparatus and equipment (products) to radiated electromagnetic (EM) energy.

This method is based on injecting the calibrated radio frequency currents (voltages) into external conductors and/or internal circuits of the product under test, measuring the strength of the EM field generated by this product and evaluating its immunity to the external EM field on the basis of the data obtained.

The method can be utilized only when it is physically possible to connect the injector to the conductors and/or circuits mentioned before.

The method allows:

- Evaluating immunity of the product under test to external EM fields of the strength equal to a normalized one;

- Calculating the level of external EM field strength at which the given (including maximum permissible) induced currents or voltages are generated in the equipment under test, or solving the “opposite” task;

- Finding potentially “weak” points of the product design (housing, shield, etc.), through which EM energy can enter inside the product.

The method capabilities mentioned above define the sphere of its application:

- Measurements of electronic product immunity to external EM fields at different conditions (polygons, laboratories, in-situ) as an alternative to direct test methods;

- Operating instruments for a designer working out the product of a given immunity to external EM fields.

This method can't be directly applied to evaluate the immunity of the equipment under test to the pulse electromagnetic fields. But it can be used to get the initial data necessary to solve this task.

## 2. NORMATIVE REFERENCES:

The text of this document includes references to the following normative documents:

SAE ARP1972 – Procedure of immunity measurement

IEC 60050-161:1990 – International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility

IEC 61000-4-3: 1995 – Electromagnetic compatibility (EMC) – Part 4: Test and measurement technology – Clause 3: Tests on immunity to radiated EM field

Amendment A1 to IEC 61000-4-3:1998

## 3. DEFINITIONS:

The terms and definitions defined in IEC 61050-161 are used in this document.

## 4. GENERAL:

Electromagnetic emissions generated while operating stationary radio transmitting equipment, handheld radio stations, RF devices, industrial electric equipment and other sources affect the conductors connected to electronic products and internal electric circuits. Therefore the necessity to evaluate their immunity to such effects appears.

The direct method of evaluation of the electronic product immunity to the external electromagnetic fields is the following. Using a generator and radiating equipment, the radio frequency field of the given strength is generated. The equipment under test is placed into this field. The products' response to the RF field is defined by objective (measuring the induced currents and voltages) or subjective methods. This product response served for evaluation of the product immunity to the external effect of the given level.

To realize the direct evaluation method the special polygons, where electromagnetic fields of high strength can be generated, or anechoic chambers are required.

Moreover, powerful generating and radiating equipment is required. Therefore the expense to carry out the direct evaluation methods are essential, and only specialized test centers can afford such tests.

The suggested method for the evaluation of electronic product immunity to the external RF field is the alternative method towards the direct one.

#### 4. (Continued):

The essence of this method is that the product under test is not exposed in the external electromagnetic field. The product itself under the influence of the exciting signal generates the relatively low electromagnetic field. The product immunity to the external electromagnetic field which level is defined in the direct method is evaluated on the basis of this exciting signal and the level of the field generated.

According to this alternative method, the calibrated low-level signals are injected into the accessible external product conductors and/or its internal circuits. The level of this field is measured using a small antenna and measuring receiver. Using this data for the given (in the direct method) electromagnetic field level, the current and/or voltage induced while such effects are calculated and also the opposite operation (definition of the effect level that generates the given current and/or voltage) is solved.

The reciprocal theorem is the theoretical basis of the alternative method. This theorem is correct not only for the usual quadrapole, but for the case when the input circuit of the measuring receiver is the output ports of the quadrapole, and the circuit where the current and/or voltage is injected is the quadrapole input circuit. The connection between input and output ports is provided by electromagnetic fields and the parameters of the medium between the mentioned ports can change arbitrarily from point to point.

To realize the alternative method of evaluation of electronic product immunity to the external RF field, a low-noise generator, a measuring receiver and a small antenna are required. At this, the tests can be satisfied not only in the anechoic chamber or at the polygon, but also at the open test site and in the laboratory. These advantages made the alternative method easy to use. In addition, it can be a working instrument for a designer of electronic products.

The theoretical basis for the measuring method defined in this document and the formula derivation are described in Appendix A.

According to this method the immunity of electronic products to the external RF EM fields is measured as follows:

1. If e.m.f.  $U_0$  is injected into any circuit of the equipment under test then the current  $I$  that will be induced by the external electromagnetic field in the same circuit is calculated.
2. If the current  $I_0$  is injected into any circuit of the equipment under test then the voltage  $U$  that will be induced by the external electromagnetic field in the same circuit is calculated.

#### 4.1 Definition of the Currents Induced and the Equipment-Under-Test Immunity:

The evaluation of the current  $I$  that will be induced by the external electromagnetic field in any circuit is satisfied as follows:

- a. A calibrated sine-wave voltage of a proper (low) amplitude  $U_0$  at the frequency  $F$  is injected into one of the conductors connected to the equipment under test or into one of its electric circuits;
- b. Using an antenna and a measuring device, the EM field strength generated by the equipment under test into the external environment is measured over each of the equipment coordinate surfaces. Maximum value  $E_{m \max}$  and also maximum voltage at the input of the measuring receiver  $U_{0 \max}$  or maximum current  $I_{0 \max}$  at the input circuit of the measuring receiver (input impedance  $R_{in}$ ) are defined ( $U_{0 \max} = I_{0 \max} R_{in}$ ).

If a dipole is used as the measuring antenna the measurement are made for both horizontal and vertical antenna polarization. Then, using the data received ( $E_{m \max}$ ,  $U_{0 \max}$  or  $I_{0 \max}$ ), the necessary calculations for the product circuit where the e.m.f.  $U_0$  was injected are made.

##### 4.1.1 Evaluation of the Equipment-Under-Test Immunity to the External Electromagnetic Field of a Given Strength: The evaluation of the product-under-test immunity at the frequency $F$ to the external EM fields of normalized strength $E_{norm}$ is satisfied using the following:

If technical documentation on the product to be tested includes permissible values of the current  $I_{\max}$  induced in the circuit, into which the test effect  $U_0$  was injected, then the product is considered resistive (having immunity) to external EM fields  $E_{norm}$  when

$$I'_{\max} > \frac{U_{0 \max}}{\beta^2 R_{in}} \cdot \frac{E_{norm}}{E_{m \max}} \cdot \alpha_1 \quad (\text{Eq.1})$$

where:

$$\alpha_1 = U_{0 \max}/U_0$$

$\beta$  = the height of the measuring antenna used, normalized to about 1 m