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EMC IC modelling –
Part 3: Models of integrated circuits for EMI behavioural simulation – Radiated emissions modelling (ICEM-RE)

Modèles de circuits intégrés pour la CEM –
Partie 3: Modèles de circuits intégrés pour la simulation du comportement lors de perturbations électromagnétiques – Modélisation des émissions rayonnées (ICEM-RE)

IEC 62433-3:2017-01(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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EMC IC MODELLING –

Part 3: Models of integrated circuits for EMI behavioural simulation – Radiated emissions modelling (ICEM-RE)

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The text of this standard is based on the following documents:

FDIS	Report on voting
47A/1000/FDIS	47A/1008/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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EMC IC MODELLING –

Part 3: Models of integrated circuits for EMI behavioural simulation – Radiated emissions modelling (ICEM-RE)

1 Scope

This part of IEC 62433 provides a method for deriving a macro-model to allow the simulation of the radiated emission levels of an Integrated Circuit (IC). This model is commonly called Integrated Circuit Emission Model – Radiated Emission, ICEM-RE. The model is intended to be used for modelling a complete IC, with or without its associated package, a functional block and an Intellectual Property (IP) block of both analogue and digital ICs (input/output pins, digital core and supply), when measured or simulated data cannot be directly imported into simulation tools.

The proposed IC macro-model will be inserted in 3D electromagnetic simulation tools so as to:

- predict the near-radiated emissions from the IC
- evaluate the effect of the radiated emissions on neighbouring ICs, cables, transmission lines, etc.

This part of IEC 62433 has two main parts:

- the first is the electrical description of ICEM-RE macro-model elements,
- the second part proposes a universal data exchange format called REML based on XML. This format allows encoding the ICEM-RE in a more useable and generic form for emission simulation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TS 62433-1, *EMC IC modelling – Part 1: General modelling framework*

IEC 62433-2, *EMC IC modelling – Part 2: Models of integrated circuits for EMI behavioural simulation – Conducted emissions modelling (ICEM-CE)*

IEC 61967-1, *Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 1: General conditions and definitions*

IEC TS 61967-3, *Integrated circuits – Measurement of electromagnetic emissions – Part 3: Measurement of radiated emissions – Surface scan method*

ANSI INCITS 4:1986, *Information Systems – Coded Character Sets – 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII)*

3 Terms, definitions, abbreviations and conventions

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
electric dipole
linear current-carrying element or wire that is always of finite length

3.1.2
current loop
closed current-carrying element or wire that is always of finite radius

3.1.3
magnetic dipole
linear "magnetic current" carrying element or wire that is of finite length

Note 1 to entry: A magnetic dipole is an equivalent magnetic source counterpart of an electric dipole that is used for mathematical formulations. This quantity is purely mathematical and not physical in nature.

Note 2 to entry: This term is used in an abstract manner to explain the motion of magnetic charges giving rise to magnetic currents, when compared to their dual quantities of moving electrical charges giving rise to electrical currents.

3.1.4

PDN
Passive Distribution Network
component of an IC model that represents the geometrical base within which equivalent radiating sources would be positioned.

3.1.5
IA
Internal Activity
component of an IC model represented by a current or voltage source, which originates in activity of active devices in an IC or in a portion of the IC

Note 1 to entry: In this part of IEC 62433, a current source is commonly used to excite the elements of the PDN.

[SOURCE: IEC TS 62433-1:2011, 3.3, modified — Note 1 to entry has been added]

3.1.6
$model_{Hman}$
radiated magnetic emission model with manual sources

3.1.7
$model_{H}$
radiated magnetic emission model with automatic source detection

3.1.8
$model_{EM\_Inv}$
radiated electric and magnetic emission model based on automatic source detection, using the matrix inverse method for problem solving

3.1.9
$model_{EM\_Iter}$
radiated electric and magnetic emission model based on automatic source detection, using an iterative method for problem solving

3.1.10
model$_{EMTD}$
time-harmonic radiated electric and magnetic emission model based on automatic source detection, using an iterative method for problem solving

3.1.11
section
XML element placed one level below the root element or within another section and that contains one or more XML elements, but no value

[SOURCE: IEC 62433-4:—, 3.1.1]

3.1.12
parent
keyword which is one level above another keyword

[SOURCE: IEC 62433-4:—, 3.1.2]

3.1.13
child
keyword which is one level below another keyword

[SOURCE: IEC 62433-4:—, 3.1.3]

3.1.14
parser
tool for syntactic analysis of data that is encoded in a specified format

[SOURCE: IEC 62433-4:—, 3.1.6]

3.1.15
Radiated Emissions Markup Language
REML
data exchange format for ICEM-RE macro-model

Note 1 to entry: This note applies to the French language only.

3.2 Abbreviations

REM	Radiated Emission Model
XML	eXtensible Markup Language

3.3 Conventions

For the sake of clarity, but with some exceptions, the writing conventions of XML language have been used in text and tables.

The symbol “µ” is used in the text part to define micro = 1e-6. The symbol “u” is used in the XML parts to define the micro = 1e-6.

4 Philosophy

With every generation, ICs have become more and more complex and diverse with respect to integration density and functional capabilities in a reduced form-factor. ICs have also become faster more than ever with lower supply voltages. Modern ICs may contain on-chip radio frequency modules co-existing with analogue and/or digital logic cores. Printed Circuit Board (PCB) carrying these ICs has also become denser. The emissions from one IC can couple back into neighbouring components (ICs, passive components, traces, etc.) and provoke undesired system performance or even system failure. Consequently, the emissions from ICs are becoming more and more critical.

Due to this increased risk of emissions emanating from ICs, it is indispensable to use simulation tools for evaluating the emission behaviour of every module during the IC design stages. It is therefore necessary to have accurate radiated electromagnetic emission models in order to predict the radiated emission behaviour of ICs and their effects on neighbouring circuits (coupling to PCB tracks, connectors, etc.). Precise evaluation of emission risks at board level cannot be done otherwise.

IC's equivalent radiation sources integration in 3D electromagnetic solvers can be achieved using different input techniques. This part of IEC 62433 identifies and specifies a more generic, exchangeable and validated macro-model for simulating the radiated emission behaviour at IC level. For ICs with multiple operating modes, functionalities, programmable logics and conditions of the IC, its emission profile would be completely different depending on the operating mode. Consequently, ICEM-RE macro-models are valid only in the conditions in which they have been established. The models will be used to predict the radiated electromagnetic emissions at application level.

ICEM-RE macro-model data is arranged in a decipherable nested manner using XML format. The objective of this exchange format, called Radiated Emission Markup Language (REML), is to create simple and practical universal access to ICEM-RE macro-model. The preliminary definitions for XML representation is given in Annex A.

5 ICEM-RE macro-model description

5.1 General

The internal structure of an IC can be broken down into two parts:

- Passive parts, (parasitic resistance (R), inductance (L) and capacitance (C) of tracks, Electrostatic Discharge (ESD) protection components, pins and bonding) which connects the external environment to the internal IC blocks.
- Active parts, (Central Processing Unit (CPU) core, clock system, memory, analogue blocks). It is these active internal blocks that are the emission sources in an IC.

The ICEM-RE macro-model consists of a set of data describing these two parts:

– PDN: the Passive Distribution Network (PDN) represents the geometrical base within which the equivalent radiating sources would be positioned. It contains the geometrical co-ordinates of the model.

– IA: the Internal Activity (IA) represents the excitation source of the radiating elements of the PDN. It contains the amplitude and phase of the electrical current of the model.

Figure 1 presents the general ICEM-RE macro-model structure.

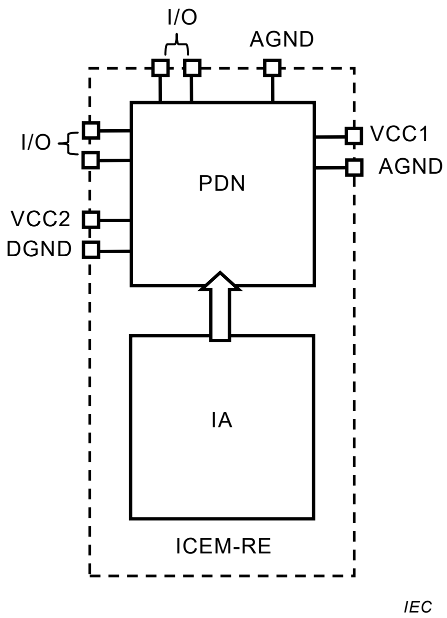


Figure 1 – General ICEM-RE model structure

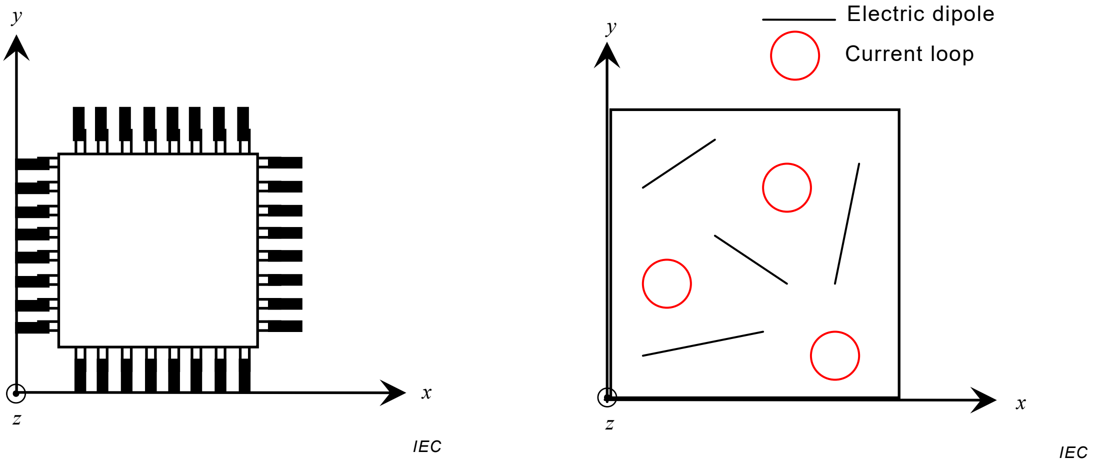
There is a direct link between the PDN block and IA block. The PDN represents a set of equivalent radiation sources such as electric dipoles or electric current loops which serves as the geometrical base for the IA. The source coordinates are defined with respect to a point in space which is called the reference point. More details of the reference point can be found in 5.2.

The IA represents the current flowing in each of the equivalent radiating element in the PDN. The current value is complex in nature, i.e., the currents through the dipole (or loop) are represented with their magnitude and phase. The phase value is relative to the EM field's phase at the reference point. By definition, each element of the PDN has a specific IA, both the PDN coordinates and IA phase values are referenced to the reference point.

The ICEM-RE macro-model is generally defined in the frequency domain. It does not inherently have a frequency limit for validity i.e. ICEM-RE structure is valid over any frequency range. However, depending on the data used for model extraction, the model's limit of validity is set by the input data used for extracting the model. Moreover, the model is defined only in the conditions in which it has been extracted: IC's operating conditions, activated functions, external components (decoupling capacitors, external oscillators, etc.) needed for IC's basic functioning, etc. Any variation from the specified conditions could necessitate a modification to the model (re-extract the model). The incorporation of the variation is not included in the current edition.

5.2 PDN description

The PDN consists of passive elements for the package, bonding and on-chip interconnections. These elements behave like radiating antennas when high-frequency signals (currents) and transients' flow through them. The PDN block of ICEM-RE can be described using a set of equivalent radiation sources such as electric dipoles or magnetic loops representing the different package/bonding/interconnection elements as shown in Figure 2.



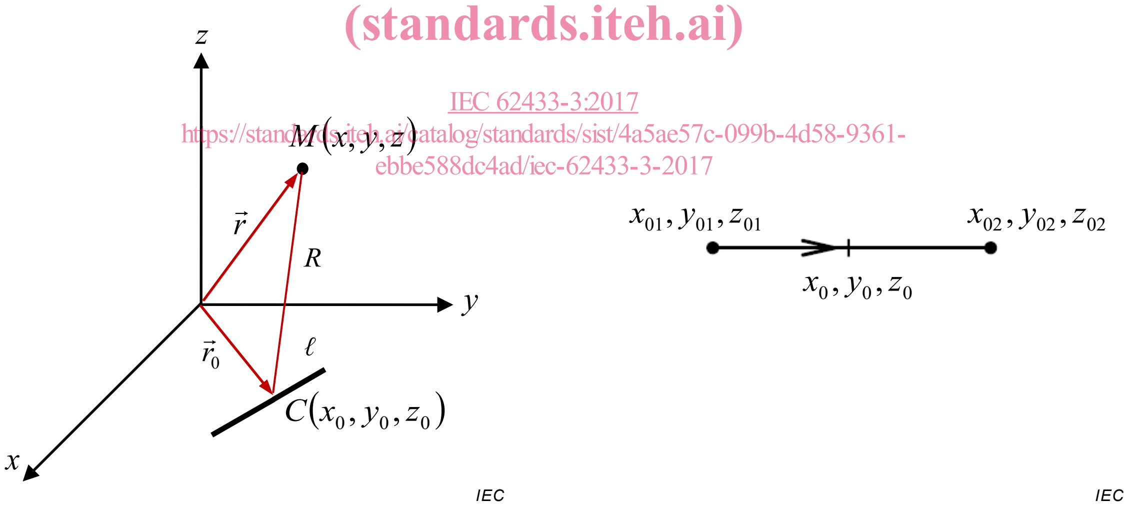
a) IC under test

b) Equivalent PDN described with a set of elementary dipole sources

Figure 2 – Geometrical representation of the ICEM-RE PDN

The dimensions of the equivalent sources shall be thin and small (normally less than one tenth of the wavelength) with respect to the wavelength.

An elementary electric dipole in 3D space, representing the PDN, is shown in Figure 3.



a) An elementary electric dipole length ℓ in 3D space

b) Parameters defining an electric dipole of the PDN

Figure 3 – Representation of an elementary dipole in the ICEM-RE PDN

Similar to an electric dipole, an elementary current loop is shown in Figure 4.