Developing a Universal Exchange Format for Near-Field Scan Data

John Shepherd [1], Atsushi Nakamura [2], Frederic Lafon [3], Etienne Sicard [4], Mohamed Ramdani [5], David Pommerenke [6], Giorgi Muchaidze [7], Sebastien Serpaud [8]

[1] *Freescale Semiconductor*
Toulouse, France
john.shepherd@freescale.com
[2] *Renesas Technology Corp*
Tokyo, Japan
nakamura.atsushi@renesas.com
[3] *Valeo*
Creteil, France
frederic.lafon@valeo.com
[4] *INSA*
Toulouse, France
etienne.sicard@insa-toulouse.fr
[5] *ESEO*
Angers, France
mohamed.ramdani@eseo.fr
[6] *Missouri University of Science and Technology*
ROLLA, MO 65409, USA
davidjp@mst.edu
[7] *Amber Precision Instruments*
Santa Clara, CA 95954, USA
giorgi@amberpi.com
[8] *Nexio*
Toulouse, France
sebastien.serpaud@nexio.fr

***Abstract*—Near-field scan measurements and simulations generate a large amount of data. The format of the data is closely linked to the supplier of the acquisition or simulation software, rendering extremely difficult its exchange between suppliers, customers, EDA tool vendors, academics, etc. The paper describes how a universal exchange format for near-field scan data has been developed. The format caters for various coordinate systems and is suited to emission and immunity testing both in the frequency and time domains.**

I. Introduction

Near-field scan (NFS) measurements, as described for example in [1], and simulations generate a large amount of data. Many different formats are used for storing the data, thereby rendering extremely difficult its exchange and comparison between measurements and simulations from various sources. Data from NFS measurements may be used to generate models such as ICEM and ICIM [2] and such data should therefore be readily available and easily accessible.

The proposed format is intended to facilitate exchange of near-field scan data between industrials, academics, EDA tool vendors and end customers. It is based on the well-known XML (eXtensible Markup Language) format [3], which is both machine and human readable. Its structure allows the files to be generated and processed on any operating system. In order to limit file size, it is possible to store the information and data in a single file or multiple files. Moreover, the ASCII-based XML format allows the files to be compressed to a very high level with readily available compression software. A first version of the XML exchange format, limited to the Cartesian coordinate system and fixed field orientation, has been presented in [4]. The present version has been submitted to the International Electrotechnical Commission (IEC) as a Draft Technical Report [5]

II. Features

The techniques used for NFS are constantly evolving and the universal exchange format must allow future techniques to be included without the need for complete remodeling. The format should also be portable between operating systems, as well as both human and machine readable. The XML format meets these requirements perfectly. The use of keywords allows information to be included only as required. Additional keywords can be added to cater for new techniques, although they may not be interpreted by older software versions.

The ASCII representation of XML allows the files to be created modified and merged either manually, for example with text processors, or with simple scripts. Expensive specific software is not required for managing the files.

NFS techniques are used for measuring radiated emission and radiated immunity levels. The exchange format allows for both of these cases, but not in the same document, by enclosing all the information in a root XML element whose "Scantype" keyword may be either "EmissionScan" or ImmunityScan". A simple exchange file is shown in Fig. 1.

```
<?xml version="1.0" encoding="UTF-8"?>
<EmissionScan>
        <Nfs_ver>1.0</Nfs_ver>
        <Filename>Minimum_NFS_file.xml</Filename>
        <File_ver>1</File_ver>
        <Data>
                <Measurement>
                        <List>
26e-3 29e-3 2e-3 -58
                        </List>
                </Measurement>
        </Data>
</EmissionScan>
```

Fig. 1. Example file for emission scan

In order to ensure portability and compressibility, only relative paths can be used to define a path name. An absolute path is not exportable. All XML files concerning the NFS project must be placed in the same directory and other files containing data, pictures, documentation, etc must be placed in the same directory or in subdirectories.

The XML file is divided into sections concerning:

- Header information (filename, date, version, etc).
- Information about the component being scanned.
- Details of the measurement setup.
- Information on the probe (field, performance factor, etc).
- Data including the coordinate system used, frequencies or times and the data values.

Each section may be present, or not, and may include specific keywords allowing various parameters to be specified. In order to accommodate a large variety of measurements and simulations, keywords specify the format of data (magnitude only, magnitude and phase or real and imaginary), the coordinate systems (Cartesian, cylindrical or spherical) and whether the data are measured in the frequency or time domains. Both linear and logarithmic units are acceptable.

It is possible to place, anywhere in the file, notes and links to external documents, in order to better describe complex test environments.

III. Development of the Exchange Format

The determination of the features and keywords required to make the exchange format as universal as possible results from requirements and the experience of many industrials and academics, and in particular the co-authors of this paper. A complete list and description of the valid keywords may be found in [5].

The starting point for the development of the present exchange format was the simple version [4], limited to the Cartesian coordinate system, fixed field orientation and frequency domain data. The following sections describe the development of the exchange format and the philosophy behind the new features.

A. Coordinate Systems and Field Orientation

Today the majority of scans and simulations are defined in Cartesian coordinates. The probe is moved horizontally in the XY-plane and at one or more altitudes (Z-coordinate). However, if the exchange format is to be universal, cylindrical and spherical coordinates must also be included. Fig. 2 compares the three coordinate systems.

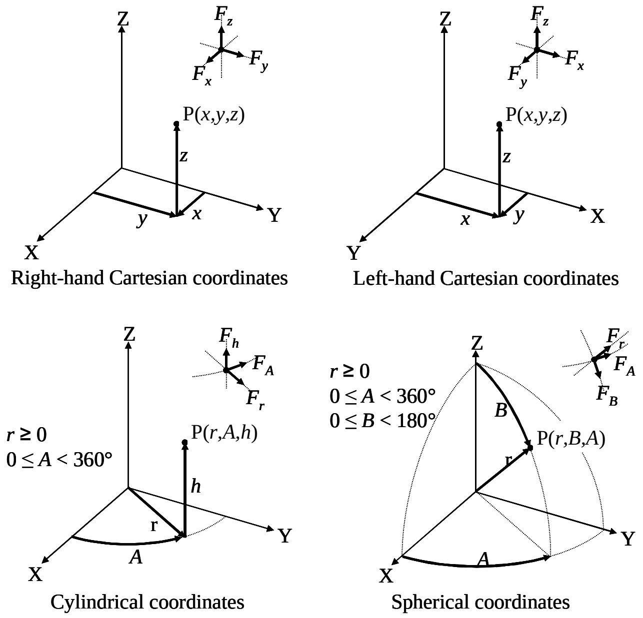

Fig. 2. Coordinate systems

When Cartesian coordinates are used, right-hand Cartesian coordinates are preferred. Left-hand Cartesian coordinates are included only to accommodate older systems. The cylindrical coordinate system is shown with the h-axis parallel to the Z-axis. In practice the cylinder may be parallel to the XY-plane. It is usual to use the symbols (r, θ, ϕ) for spherical coordinates and (ρ, ϕ, z) for cylindrical coordinates [6]. However, these symbols are not available in the character set for XML documents and have therefore been replaced by (r, B, A) and (r, A, h). The angle A represents the "azimuth" angle and varies between 0° and 360°. The angle B is the "zenith" angle referenced from the Z-axis, rather than the more common "elevation" angle referenced from the XY-plane. In this way, the angle B varies from 0° and 180° and never takes negative values. In the cylindrical and spherical coordinate systems, the R-axis represents the altitude at which the measurement or simulation data are acquired. In the Cartesian coordinate system, the altitude of the probe may be in the X, Y or Z directions.

Fig. 2 also indicates for each coordinate system the three directions of the field, which can be electric (E) or magnetic (H). These three directions are simply parallel to the X-, Y- and Z-axes in the Cartesian coordinate system. For the cylindrical coordinate system Fr and Fh are parallel to the R- and H-directions and FA is tangential to the R-axis in the A-direction. In the spherical coordinate system Fr is parallel to the R-axis and FA and FB are tangential to the r-vector in the A- and B-directions, respectively.

In many cases the measured field will not lie exactly on one of the three field directions. It is therefore necessary to define a set of two angles, which specify perfectly the field orientation. Fig. 3 shows the relation between the field orientation angles (C and D) for each of the coordinate systems. The three axes for each coordinate system in Fig. 3 correspond to the field axes represented in Fig. 2. Table I shows the relation between the azimuth, zenith angles and the field for each coordinate system when the field lies on an axis. If the zenith angle is omitted, it takes the default value of 90°, which sets the two-dimensional orientation in the XY, AH or BA plane, depending on the coordinate system.

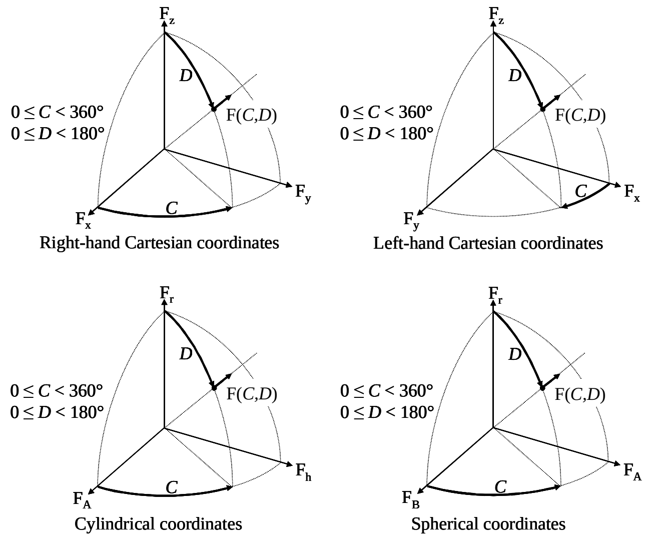

Fig. 3. Field orientation

TABLE I
RELATIONSHIP BETWEEN AZIMUTH, ZENITH ANGLES AND FIELD COMPONENT

Coordinates	**C (°)**	**D (°)**	**Field**
Cartesian	-	0	z
	0	90	x
	90	90	y
Cylindrical	-	0	r
	0	90	a
	90	90	h
Polar	-	0	r
	0	90	b
	90	90	a

B. Data Formats

The earlier versions of the exchange format could only accommodate Cartesian coordinates without the possibility of including field orientation information. Also, only magnitude could be included in the data values. The data is organized in lines, each line corresponding to a scanned point. The first three values are the x,y and z coordinates followed by a data value for each frequency measured:

x y z data1 data2 ……… datan

In the present version of the exchange format the same basic data format is retained (with one exception described later), but with the possibility to use any of the three coordinate systems and to add field orientation values and complex data values (magnitude and phase or real and imaginary). The basic format without field orientation is:

axis1 axis2 axis3 data1 data2 ……… datan

where:

- axis1, axis2 and axis3 depend on the coordinate system
- datax may be magnitude data only (one value), magnitude and phase data (two values) or real and imaginary data (two values) at each frequency or time.

When field information is included there are two cases:

- The same azimuth or azimuth-zenith angles are valid for all frequencies or times. Azimuth or azimuth-zenith values are then only required once in the data line. The data line is:

  axis1 axis2 axis3 C data1 data2 .……..datan
  or
  axis1 axis2 axis3 C D data1 data2 ……..datan

  where C and D are the azimuth and zenith angles.

- The azimuth or azimuth-zenith angles are frequency or time dependent. Azimuth or azimuth-zenith values are required for each frequency or time in the data line. The data line is:

  axis1 axis2 axis3 C1 data1 C2 data2 … Cn datan
  or
  axis1 axis2 axis3 C1 D1 data1 … Cn Dn datan

In the first case the measured or simulated field is orientated in the same direction for all frequencies or times. In the second case the field is orientated, for example, to find the maximum value of the field and thus may vary with frequency or time.

As the coordinates and field orientation angles are stored for each scanned point, it is possible to store data in the file for several predefined zones. Simulation software often outputs data for electrical or magnetic field strength on the surface of a rectangular box placed around the radiating object. Using Cartesian coordinates and the azimuth and zenith field orientation angles, it is possible with the exchange format to store and exchange such data.

The exchange format also allows data values to be included without the coordinate information. This allows a "matrix" representation. When coordinate information is included, as described above, the order of the data lines and the spacing between data points in not important. However, when coordinate information is not included, the data points must be uniformly spaced and the data values must be inserted in the correct order. Minimum, maximum and step values are specified for each axis. These values, as well as the number of frequencies or times, allow the coordinates of each value to be determined. Fig. 4 shows an example of a file with no coordinate information in the data. The X-coordinates range from 10mm to 13mm in 1mm steps (four points) and the Y-coordinates range from 20mm to 24mm in 2mm steps (three points). The Z-coordinate is 2mm. The data is arranged in a 4 by 3 matrix and is then easily readable. When data is given at several frequencies, the readability of data, when coordinate information is not included, is lost. For this same reason, field orientation information is also not permitted in files where coordinate information is not included.

```
<?xml version="1.0" encoding="UTF-8"?>
<EmissionScan>
       <Nfs_ver>0.5</Nfs_ver>
       <Filename>No_coordinates.xml</Filename>
       <File_ver>1</File_ver>
       <Data>
              <Coordinates>none</Coordinates>
              <X0>10mm</X0>
              <Xstep>1mm</Xstep>
              <Xmax>13mm</Xmax>
              <Y0>20mm</Y0>
              <Ystep>2mm</Ystep>
              <Ymax>24mm</Ymax>
              <Z0>2mm</Z0>
              <Measurement>
                     <List>
-58 -60 -61 -60
-59 -57 -58 -57
-60 -55 -57 -56
                     </List>
              </Measurement>
       </Data>
</EmissionScan>
```

Fig. 4. Example file with no coordinate information

C. Data Format Specification

At first sight the use of scalar or complex data values, three coordinate systems and field orientation all in one data line appears difficult to specify with simple keywords and easily interpretable values. The most difficult specification concerns the field orientation, which can include azimuth or azimuth-zenith angle information that is frequency or time dependent, or not. At first the use of three keywords was considered (Format, Coordinates and Orientation). These indicate clearly the concerned parameter, but concise and clear values for Coordinates and Orientation could not be found. Finally, two keywords (Format and Coordinates) were chosen.

The Format keyword specifies the format of the data values:

- "ma" for magnitude and angle complex values
- "ri" for real and imaginary complex values

The Format keyword is omitted when data values are magnitude only.

The Coordinate keyword specifies the coordinate system and the field orientation. It takes values corresponding to the axes and field orientation values present in the data lines, as shown in Table II. For example, the Cartesian coordinate system is designated by "xyz" corresponding to the three axes of the system. Left-handed Cartesian coordinates are designated by "-xyz". When field orientation angles are present, they are added to the keyword value. Thus, spherical coordinates with azimuth or azimuth-zenith field orientation are designated by "rbac" and "rbacd", respectively. Frequency or time dependent field orientation is specified by appending "f" to the end of the value. For example, cylindrical coordinates with frequency or time dependent field orientation are designated by "rbacf" or "rbacdf". The

The Coordinate keyword takes the value "none" when coordinate information is not included. In this case the coordinate system is determined by the maximum, minimum and step keywords present (i.e. Ymax, Rmax, etc).

TABLE II
PERMITTED VALUES FOR THE COORDINATES KEYWORD

Coordinate system	**Order of axes**	**Field orientation**		
		None	***Azimuth***	***Azimuth and zenith***
Right-handed Cartesian	x, y, z	xyz	xyzc or xyzcf	xyzcd or xyzcdf
Left-handed Cartesian	x, y, z	-xyz	-xyzc or -xyzcf	-xyzcd or -xyzcdf
Cylindrical	R, A, h	rah	rahc or rahcf	rahcd or rahcdf
Spherical	r, B, A	rba	rbac or rbacf	rbacd or rbacdf

D. Performance Factor

An important parameter in near-field scanning is the performance factor of the probe, which allows conversion of measured values (typically measured as a power or voltage level) into magnetic or electric field strength. The performance factor is usually obtained by calibrating the probe against a known field strength at a number of frequencies [7]. Care must be taken to specify the performance factor of the probe without any additional losses or gains due to the measurement setup (cables, amplifiers, etc).

This conversion can be achieved in one of two ways:

$$PF = M_F / F \qquad (1)$$

Or

$$PF = F / M_F \qquad (2)$$

where: M_F is the measured or applied value
F is the measured or generated field strength
PF is the performance factor

The same expressions may also be expressed in dB:

$$dB(PF) = dB(M_F) - dB(F) \quad (3)$$

or

$$dB(PF) = dB(F) - dB(M_F) \quad (4)$$

Performance factor is the ratio of the measured value and the field strength or the inverse. In decibels, it is the difference between the measured value and the field strength. The formula used can generally be recognized from the slope of the performance factor plotted against frequency as shown in Fig. 5.

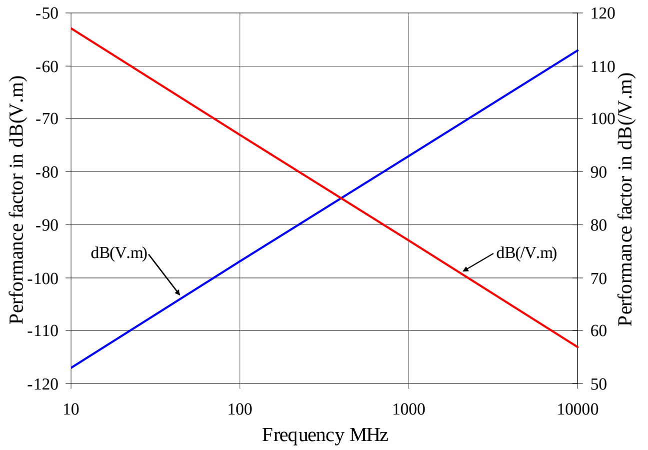

Fig. 5. Performance factor of a magnetic probe against frequency

The sensitivity of a probe usually increases with frequency. Therefore, the performance factor increases with frequency when calculated with (1) or (3) and decreases with frequency when calculated with (2) or (4). Furthermore, the units of the performance factor also indicate the expression used for its calculation. Table III compares the units of performance factor when calculated with (3) and (4).

TABLE III
PERFORMANCE FACTOR UNITS

Performance factor equation		**dB(M_F)-dB(F)**		**dB(F)-dB(M_F)**	
Field strength units (F)		***dBA/m***	***dBV/m***	***dBA/m***	***dBV/m***
Measured or applied signal units (M_F)	***dBV***	dB(Ohm.m)	dB(m)	dB(S/m)	dB(/m)
	dBA	dB(m)	dB(S.m)	dB(/m)	dB(Ohm/m)
	dBW	dB(V.m)	dB(A.m)	dB(/V.m)	dB(/A.m)

In Fig. 5 the performance factor with dB(V.m) units is calculated with (3), whereas the performance factor with dB(/V.m) units is calculated with (4). Although not shown in Table III, the exchange format also allows performance factors for power density, expressed in W/m2 or dB(W/m2). In this case the performance factor corresponds to the capture area of the probe (or antenna) or its inverse.

The performance factor is specified in the XML file as a list of values, each corresponding to a previously specified frequency. For an emission scan this is sufficient. As shown in Fig. 6, in the case of an emission scan the field strength generated by a radiating element, such as a metal track on an IC or on a PCB, will depend on the radiating element and its environment, but not on the probe. The field strength will decrease with distance, which is the altitude (a) of the probe above the scanned surface, but the probe will capture the value of the field passing through it. This is what is required. The measured value is the value of field strength at the measurement altitude. A list of performance factors at n frequencies for an emission scan may be:

PF1 PF2 PF3 PF4 …… PFn

However, for an immunity scan the field strength applied to the scanned component depends on its distance from the probe and on the probe itself. The relation between the field and the distance from a probe is not easily calculated and depends on many factors. It is therefore not easy to specify a performance factor and predict the field strength at a given distance. The exchange format allows the performance factor to be specified at a given altitude (a). The line of performance factors at a given altitude is preceded by the value of altitude:

a PF1 PF2 PF3 PF4 …… PFn

Care must be taken to include sufficient altitudes to allow acceptable interpolation.

If the units of the measurement or simulated data values are field strength, performance factor data is ignored and considered as being included only for information.

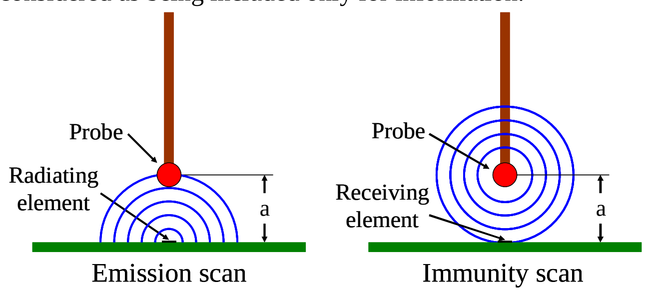

Fig. 6. Field received and radiated from a probe

E. Transducer

Many near-field scan measurement setups include a pre-amplifier for improved sensitivity and cables are often long. At low frequencies the variation of pre-amplifier gain and cable losses can be neglected. However, at higher frequencies the pre-amplifier gain may fall off and cable losses increase significantly. In the initial version of the exchange format [4] the measurement setup allowed the pre-amplifier gain to be specified by a single value which was constant over the frequency range.

The present version allows gain values in dB to be specified at predefined frequencies. The gain values include all gains and losses between the probe and the measurement equipment, as shown in Fig. 7.

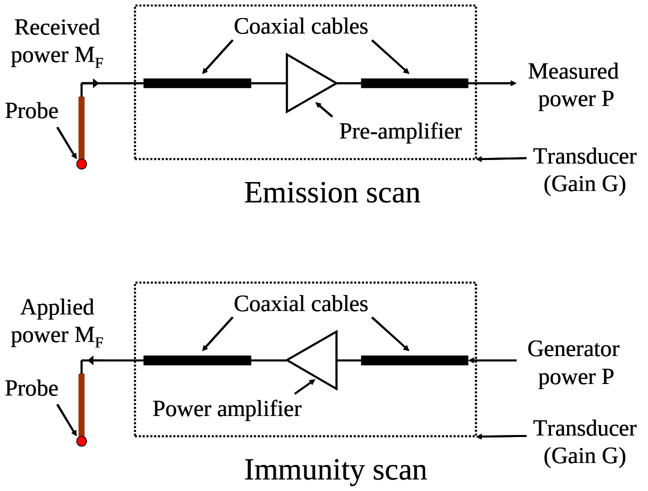

Fig. 7. Transducer examples

The gain of the transducer in dB (G) is:

- For an emission scan:

$$G = P - M_F$$

- For an immunity scan:

$$G = M_F - P$$

If the transducer gain is omitted, it is assumed that the data values are the received power or applied power at the probe.

IV. Future Developments

A concern is the size of data files, which could be come prohibitive when high resolution scans are carried out over large areas. The accuracy of the ASCII data format included in the XML file suffices when the number of significant digits is low, particularly when the file is compressed. However, when higher accuracy is required, some form of binary coding may be needed to optimize file size. Such coding is no longer human readable, but this sacrifice may be necessary. The XML file must remain ASCII and can include the path to the binary data file(s). The coding of the binary data files must also then be standardized. Nevertheless, it must be remembered that the exchange format is intended to facilitate exchange of data and not its storage.

Other types of data may also need to be accommodated. For example, it is possible to measure S-parameters at each point, and this will generate a very large quantity of data.

The exchange format allows images to be referenced. Today scans are generally two-dimensional (X-Y) at a given altitude (Z) and the scan data can be simply overlaid on a JPEG compressed picture. However, in the spherical or cylindrical coordinate systems, scans become three-dimensional and it may be desirable to overlay the data on a 3D representation of the object scanned. The exchange format can be updated to accommodate these 3-D representations as the need becomes clear.

V. Conclusion

The development of the near-field scan exchange format has involved many potential users. Academics and industrials have been consulted and their requirements integrated into the present version.

New features will be required in the future. Some features have been left open, as their use is not clearly defined. An attempt has been made to project these requirements into the future. This is a major advantage of the use of XML.

The exchange format has been developed around the near-field scan application. However, its use for other applications could be envisaged. For example, the spherical coordinate system is used for measuring and displaying antenna radiation patterns and the present format could easily be applied to their exchange.

For the exchange format to become accepted by the community, it is important that industrials and academics involved in near-field scan techniques use it now. The standardization process gives the exchange format an official and international backing, but its true acceptance and future evolution can only come from the users.

References

[1] International Electrotechnical Commission, “IEC/TS 61967-3, Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 3: Measurement of radiated emissions – Surface scan method” IEC standard, 2005, www.iec.ch.

[2] A. Boyer, S. Akue Boulingui, S. Bendhia, E. Sicard, S. Baffreau, " A Methodology for Predicting by Near Field Chip to Chip Coupling" in EMC Compo 2007

[3] Extensible Markup Language (XML) 1.0 (Fourth Edition), W3C Recommendation 16 August 2006, edited in place 29 September 2006.

[4] Sebastien Serpaud, Bertrand Vrignon, Etienne Sicard, "Common standard proposal for near-field data exchange" in EMC Compo 2007

[5] International Electrotechnical Commission, “IEC/TR 61967-x Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part x: Near-Field Scan Data Exchange Format”, www.iec.ch.

[6] International Organization for Standardization, "ISO 31-11. Quantities and units -- Part 11: Mathematical signs and symbols for use in the physical sciences and technology"

[7] J. SHI et al.: "Calibration and Compensation of Near-Field Scan Measurements", IEEE Transactions on Electromagnetic Compatibility, VOL. 47, NO. 3, August 2005