(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 July 2006 (27.07.2006)

PCT

(10) International Publication Number
WO 2006/076824 A1

(51) International Patent Classification:
G01R 27/28 (2006.01)

(21) International Application Number:
PCT/CH2006/000037

(22) International Filing Date: 17 January 2006 (17.01.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
05405031.5 21 January 2005 (21.01.2005) EP

(71) Applicant (*for all designated States except US*): **ABB RESEARCH LTD** [CH/CH]; Affolternstr. 52, CH-8050 Zürich (CH).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **NIAYESH, Kaveh** [IR/IR]; Sattar Khan Ave. 1st Daryan No., IR-14557-33548 Teheran (IR). **BERTH, Matthias** [DE/CH]; Waffenplatzstr. 80, CH-8002 Zurich (CH). **DAHLQUIST, Andreas** [SE/CH]; Hofwiesenstrasse 262, CH-8050 Zürich (CH). **HEITZ, Christoph** [DE/CH]; Schulweg 2, CH-8353 Elgg/ZH (CH). **TIBERG, Martin** [SE/CH]; Kronengasse 2, CH-5400 Baden (CH).

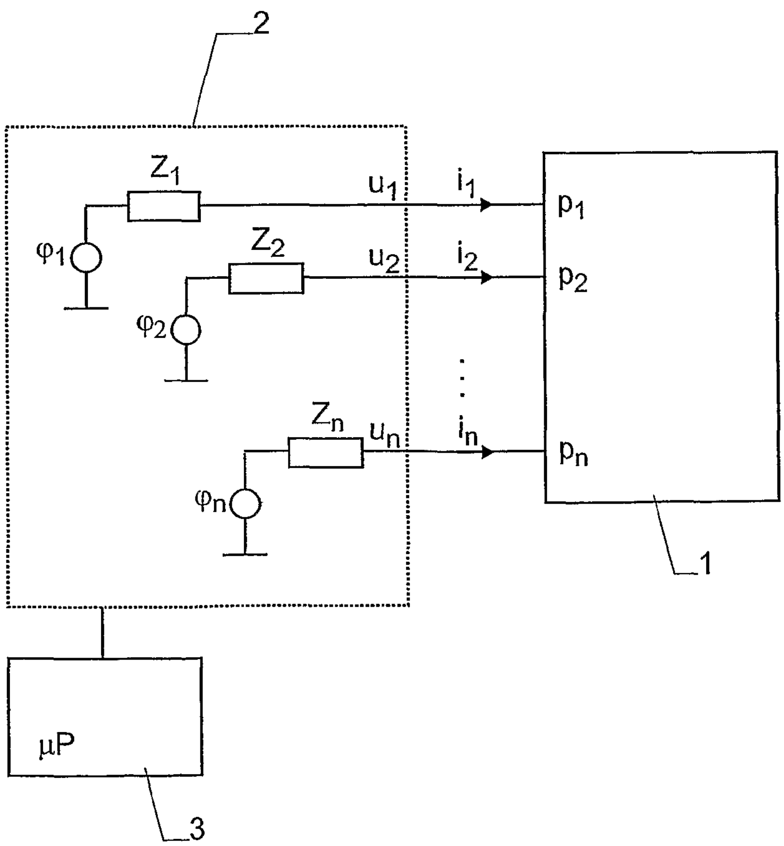
(74) Agent: **ABB SCHWEIZ AG**; Intellectual Property (CH-LC/IP), Brown Boveri Strasse 6, CH-5400 Baden (CH).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,

[Continued on next page]

(54) Title: METHOD AND DEVICE FOR CHARACTERIZING THE LINEAR PROPERTIES OF AN ELECTRICAL COMPONENT



(57) Abstract: A method and device for determining the linear response of an electrical multi-port component (1) has an "estimation procedure" in which an estimated admittance matrix is determined by applying voltages to the ports of the component and measuring the response of the component. The estimation procedure can e.g. consist of a conventional measurement of the admittance matrix. The method further has a "measurement procedure" in which several voltage patterns are applied to the port. The voltage patterns correspond to the eigenvectors of the estimated admittance matrix. For each applied voltage pattern, the response of the component is measured. This allows to measure the linear response of the component accurately even if the eigenvalues of the admittance matrix differ by several orders of magnitude.

WO 2006/076824 A1

FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Method and device for characterizing the linear properties of an electrical component

Technical Field

The invention relates to a method and a device for characterizing the linear properties of an electrical multi-port component. It also relates to a method for modeling an electrical system with at least one component characterized in this manner.

Background

The linear properties of electrical components with multiple ports are generally characterized by one of the characteristics matrices, e.g. the impedance or transmittance matrix. These matrices can be measured using suitable circuitry.

In general, all elements of the characteristics matrices are frequency dependent, and therefore the measurements must be carried out for different frequencies.

It has been found that conventional methods of measurement may provide poor results because limited precision of the measurement devices and electric noise, in particular if different elements or eigenvalues of the characteristics matrices strongly differ in magnitude. In these cases, information may be lost. On the other hand, the interactions between different electrical components or subsystems in a system can only be described precisely if the properties of the characteristics matrices are well known.

Summary of the invention

Hence, the problem to be solved by the present invention is to provide an improved method and device for characterizing the linear properties of an electrical multi-port component. This problem is solved by the method and device according to the independent claims.

Accordingly, the method for characterizing a component having $n > 1$ ports contains an "estimation procedure" in which an estimated admittance matrix $\mathbf{Y}'$ is determined by applying voltages to the ports of the component and measuring the response of the component. The estimation procedure can e.g. consist of a conventional measurement of the admittance matrix $\mathbf{Y}'$ by applying a voltage to one port, grounding all other ports, measuring the current at each port, and repeating this procedure for all ports.

The method further comprises a "measurement procedure" in which several voltage patterns $\mathbf{u}_k$ are applied to the port. The voltage patterns correspond to the eigenvectors $\mathbf{v}_k$ of the estimated admittance matrix $\mathbf{Y}'$, wherein "correspond" is to express that the pattern $\mathbf{u}_k$ is substantially (but not necessarily exactly) parallel to the (normalized) eigenvector $\mathbf{v}_k$ and its corresponding eigenvalue λ_k. For each applied voltage pattern $\mathbf{u}_k$, the response of the component is measured.

As it has been found, applying voltage patterns $\mathbf{u}_k$ corresponding to the eigenvectors of the admittance matrix allows to obtain a more accurate description of the component, even if the eigenvalues of the admittance matrix differ substantially from each other.

The response of the device is advantageously measured by measuring, for each applied voltage pattern $\mathbf{u}_k$, the current pattern $\mathbf{i}_k$ at the ports.

The device according to the invention is able to carry out this type of measurement automatically on a device having $n > 1$ ports.

In another aspect, the invention is directed to a device that is able to automatically determine the linear response of a component having $n > 2$ ports by means of n voltage generators for generating a voltage for each port, and n current sensors for sensing the current at each port, either using conventional methods or the method described here.

Note: Throughout this text, bold face upper case letters, such as $\mathbf{Y}$, are used to denote matrices, bold face lower case letters, such as $\mathbf{u}$ or $\mathbf{u}_k$, are used to denote vectors, and non-bold letters, such as λ_k, are used to denote scalars or components of matrices or vectors.

When talking about "linear properties" of the component, this term is to be understood as encompassing any property that is exactly or close to linear as long as the property fulfils the mathematical relations outlined below with sufficient accuracy within the range of currents and voltages of interest.

Short description of the figures

Further embodiments, advantages and applications of the invention are given in the dependent claims as well as in the now following detailed description with reference to the figures:

Fig. 1 is a schematic illustration of a component to be characterized,

Fig. 2 is a block circuit diagram for a measuring device for characterizing the component,

Fig. 3 is a first embodiment of a measuring device, and

Fig. 4 is a second embodiment of a measuring device.

Detailed description

General measurement principle:

Fig. 1 shows a multi-port component 1 having $n > 1$ ports p_1 through p_n. When linear voltages u_1 through u_n are applied to the ports p_1 through p_n, currents i_1 through i_n will flow. The linear electrical response of component 1 are characterized by its admittance matrix **Y** or, equivalently, by its impedance matrix. In admittance notation, applying the voltage vector $\mathbf{u} = (u_1 \ldots u_n)$ of voltages at the ports p_1 through p_n generates a current vector $\mathbf{i} = (i_1 \ldots i_n)$ as follows:

$$\mathbf{i} = \mathbf{Y} \cdot \mathbf{u}. \tag{1}$$

The general principle of measurement according to the present invention is based on an estimation procedure and a measurement procedure. In the estimation procedure, an estimated admittance matrix $\mathbf{Y}'$ is determined, in the measurement procedure a more accurate measurement is carried out.

In the estimation procedure, the elements of the estimated admittance matrix $\mathbf{Y}'$ can e.g. be measured directly using conventional methods. The diagonal elements Y'_{ii} can e.g. by measured by applying a voltage u_i to port p_i and measure the current i_i at the same port while all other ports are short-circuited to zero volt, i.e. $Y'_{ii} = i_i/u_i$ while $u_j = 0$ for $i \neq j$. The other elements Y'_{ij} of the matrix can be measured by applying a voltage u_i at port p_i while setting all other ports to zero volt and measuring the current i_j at port p_j, $Y'_{ij} = i_j/u_i$ while $u_j = 0$ for $i \neq j$.

Other conventional methods for measuring the estimated impedance matrix $\mathbf{Y}'$ in the estimation procedure can be used as well.

In general, the estimated admittance matrix $\mathbf{Y}'$ has n eigenvalues $\lambda_1 \ldots \lambda_n$ and n corresponding (normalized) eigenvectors $\mathbf{v}_1 \ldots \mathbf{v}_n$ for which

$$\mathbf{Y}' \cdot \mathbf{v}_k = \lambda_k \cdot \mathbf{v}_k. \qquad (2)$$

Once the estimated admittance matrix is known, its eigenvectors $\mathbf{v}_k$ can be calculated.

In a measurement procedure following the estimation procedure, several (in general n) voltage patterns $\mathbf{u}_k = (u_{1k} \ldots u_{nk})$ are applied to ports $p_1 \ldots p_n$ of component 1. Each voltage pattern $\mathbf{u}_k$ corresponds to one of the eigenvectors $\mathbf{v}_k$. For each applied voltage pattern $\mathbf{u}_k$, a response of the component is measured, in particular by measuring the induced current pattern $\mathbf{i}_k$.

As mentioned above, voltage pattern $\mathbf{u}_k$ corresponds to (normalized) eigenvector $\mathbf{v}_k$ (which is one of the n normalized eigenvectors of the admittance matrix), namely in the sense that the voltage pattern $\mathbf{u}_k$ is substantially parallel to the eigenvector $\mathbf{v}_k$ corresponding to eigenvalue λ_k. Theoretically, using $\mathbf{u}_k \propto \mathbf{v}_k$ would be the best solution, but a device generating the voltage patterns $\mathbf{u}_k$ will, in general, not be able to generate voltage patterns matching the eigenvectors exactly due to discretization errors. Methods for handling devices with limited resolution for generating the voltage patterns will be addressed below.

Once the measurement procedure is complete, the voltage patterns $\mathbf{u}_k$ and the corresponding current patterns $\mathbf{i}_k$ fully characterize the linear response of component 1.

In general, the admittance matrix $\mathbf{Y}$ is frequency dependent. For fully modeling the behavior of component 1 in a network, the linear response of component 1 should be known for an extended frequency range, e.g. from 50 Hz to several MHz. For this reason, the estimation procedure is carried out at a plurality of frequencies ω_i in the given range.

Advantageously, for each estimation procedure, the eigenvalues $\lambda_k(\omega_i)$ at the given frequency ω_i are calculated. Then, the most critical frequencies are determined, which are those frequencies where the eigenvalues reach a local maximum or minimum or, in particular, where the absolute ratio between the largest and smallest eigenvalue has a maximum or exceeds a given threshold. These critical frequencies are of particular interest, either because they are indicative of a resonance of component 1 or because they show that some of the estimated eigenvalues may be of poor accuracy and the described measurement procedure is required to increase the accuracy.

It is principally possible to divide the desired frequency range in a number of frequency windows and to calculate the most critical frequencies in each frequency window.

For each or at least some of the critical frequencies, the measurement procedure described above is carried out to refine the measurement. In addition or alternatively thereto, the measurement procedure can be carried out at other points within the frequency range of interest.

The frequencies ω_i where measurements are carried out can be distributed linearly or logarithmically over the range of frequencies of interest. In an advantageous embodiment, though, the density of measurement frequencies ω_i close to the critical frequencies as mentioned above is larger than the density of measurement frequencies ω_i in spectral regions far away from the critical frequencies. This allows to obtain a more reliable characterization of the component.

The measurement device:

A general measuring device 2 for carrying out the invention is disclosed in Fig. 2. In a most general case, measuring device 2 comprises n adjustable voltage sources generating voltages φ_1 to φ_n, which are fed to the ports p_1 to p_n through impedances Z_1 to Z_n. The voltages φ_1 to φ_n all have equal frequency and known phase relationship. The impedances Z_1 through Z_n may be practically zero or, as described below, they may be adjustable and potentially non-zero. A control unit 3 is provided for automatically adjusting the voltage sources and, where applicable, the impedances Z_1 to Z_n.

For the device of Fig. 2 we have

$$\boldsymbol{\varphi} = \mathbf{u} + \mathbf{Z}\cdot\mathbf{i}, \qquad (3)$$

where $\boldsymbol{\varphi} = (\varphi_1 \ldots \varphi_n)$ are the voltages of the voltage sources, $\mathbf{u} = (u_1 \ldots u_n)$ the input voltages at the ports, and $\mathbf{Z}$ is a diagonal matrix with the diagonal elements Z_1 to Z_n.

Combining equations (1) and (3) gives the following relationship between the input voltages and the applied voltages:

$$\mathbf{u} = (\mathbf{I} + \mathbf{Z}\cdot\mathbf{Y})^{-1}\cdot\boldsymbol{\varphi}. \qquad (4)$$

where $\mathbf{I}$ is the $n \times n$ identity matrix.

As mentioned above, the applied voltages $\mathbf{u}$ should correspond to the eigenvalues $\mathbf{v}_k$ of the estimated admittance matrix $\mathbf{Y'}$. In general, however, it will not be possible to match this condition exactly because the voltage sources will not be able to generate any arbitrary voltage values but only a discrete set of values. If the number of voltage values that can be generated is small, the impedances Z_1 to Z_n can be designed to be adjustable as well in order to obtain a larger number of different input voltages $\mathbf{u}$.

The input voltage vector $\mathbf{u}_k$ can be expressed as a linear combination of the eigenvalues $\mathbf{v}_i$, i.e.

$$\mathbf{u}_k = \sum_{i=1}^{n} \alpha_i \mathbf{v}_i \, . \qquad (5)$$

Combining equations (5), (1) and (2) yields

$$\mathbf{i} = \sum_{i=1}^{n} \lambda_i \alpha_i \mathbf{v}_i \, . \qquad (5)$$

Hence, to maximize the influence of the k-th eigenvalue on the input current vector $\mathbf{i}$ in proportion to the other eigenvalues, the following error function must be minimized

$$\frac{\sum_{i=1}^{n} (\lambda_i \alpha_i)^2 - (\lambda_k \alpha_k)^2}{(\lambda_k \alpha_k)^2} \, . \qquad (6)$$

In other words, for each eigenvalue λ_k, the coefficients $\alpha_1 \ldots \alpha_n$ must be found (among the set of possible coefficients, which is a finite set due to the discretization inherent to measuring device 2) for which the term of equation (6) is smallest.

If measuring device 2 has adjustable voltage sources and impedances as shown in Fig. 2, we have

$$\alpha = [\mathbf{v}_1 \ \ . \ \ . \ \ \mathbf{v}_n]^{-1} \cdot (\mathrm{I} + \mathrm{Z} \cdot \mathrm{Y}')^{-1} \cdot \varphi \qquad (7)$$

A measuring device for carrying out the above method should, in general, comprise n voltage generators that are programmable to apply the voltage pattern $\mathbf{u}$ to the n ports of device 1. Further, it should comprise n current sensors to measure the currents $\mathbf{i}$. It should be adapted to apply at least n suitable voltage patterns to the ports consecutively for measuring the linear response of the component automatically. This is especially advantageous for components 1 having more than two ports because using this kind of automatic measurement on components with $n > 2$ ports provides substantial gains in speed and accuracy while reducing the costs.

Advantageously, the measuring device should comprise a control unit for carrying out the measurement using the estimation and measurement procedures outlined above.

One possible embodiment of a measuring device 2 is shown in Fig. 3. In this device, a voltage generator 10 for generating an individual voltage φ_i of adjustable amplitude and phase is provided for each input port. It also comprises n current sensors 11, one for measuring the current to/from each port. Control unit 3 is able to set the applied input voltage directly by controlling the voltage generators 10. If the number of voltage values that can be generated by each voltage generator is small, an optimum voltage for a given eigenvector can be calculated by minimizing the term of equation (6). For each applied voltage pattern, control unit 3 measures the currents $\mathbf{i}$ through the ports by means of the current sensors 11.

Another possible embodiment of a measuring device is shown in Fig. 4. This device comprises a single voltage source 4 only. The voltage φ from the voltage source is fed to n voltage converters 5 controlled by control unit 3, the voltage source and 4 and voltage converters 5 being used instead of the voltage generators 10 of the previous embodiment. Each voltage converter 5 selectively connects one port to either the voltage φ directly, to the voltage φ through a damping circuitry 6, to ground via an impedance 7, to ground directly, or leaves the port open (infinite impedance). This measuring circuit has the advantage that it requires a single voltage source only. Suitable settings of the voltage converters for each value can be calculated form equations (6) and (7).

Further processing of the results:

As mentioned above, the described measurement procedure yields, for a given frequency, a set of voltage patterns $\mathbf{u}_k$ and the corresponding current patterns $\mathbf{i}_k$, which fully characterize the linear response of component 1 at the given frequency.

The values $\mathbf{u}_k$ and $\mathbf{i}_k$ for k = 1 ... n can, in principle, be converted into a more accurate estimate of the admittance matrix **Y** or the corresponding impedance matrix. However, if the smallest and largest eigenvalues of admittance matrix **Y** differ by several orders of magnitude, such a matrix is difficult to process numerically with floating point calculations due to rounding errors and limited accuracy of the numerical algorithms. Hence, in an advantageous embodiment of the present invention, the values $\mathbf{u}_k$ and $\mathbf{i}_k$ are used directly for further processing, without prior conversion to an admittance or impedance matrix **Y**.

For example, the results of the measurement procedure can e.g. be used for modeling the electrical properties of the component 1 or of a network that component 1 is part of. Such a model can e.g. be used to analyze the stability of the network in general or its response to given events in particular.

The method described here can be used for characterizing a variety of components, such as electrical motors, transformers, switches, transmission lines, etc.

<u>List of reference numerals</u>

1 component under test
2 measuring device
3 control unit
4 single voltage source
5 voltage converter
6 damping circuit
7 impedance
10 voltage generator
11 current sensor

CLAIMS

1. A method for characterizing the linear properties of an electrical component having $n > 1$ ports, said method including

an estimation procedure comprising the step of determining an estimated admittance matrix $\mathbf{Y}'$ of said component by applying voltages to said ports and measuring a response of said component,

said method further being characterized by a measurement procedure comprising the step of applying several voltage patterns $\mathbf{u}_k$ to the ports of said component, each voltage pattern $\mathbf{u}_k$ corresponding to an eigenvector $\mathbf{v}_k$ of said estimated admittance matrix $\mathbf{Y}'$, and determining, for each applied voltage pattern $\mathbf{u}_k$, a response of said component.

2. The method of claim 1 wherein said measurement procedure comprises the step of measuring, for each voltage pattern $\mathbf{u}_k$ applied to said ports, a current pattern $\mathbf{i}_k$ at said ports.

3. The method of any of the preceding claims wherein said admittance matrix $\mathbf{Y}'$ has n eigenvectors and wherein each voltage pattern $\mathbf{u}_k$ corresponds to a different eigenvector.

4. The method of any of the preceding claims wherein said voltage patterns $\mathbf{u}_k$ are generated by means of a test device capable of applying a discrete set of different voltage patterns to said ports, wherein each voltage pattern $\mathbf{u}_k$ corresponds to that member of said set that has the property that the term

$$\frac{\sum_{i=1}^{n} (\lambda_i \alpha_i)^2 - (\lambda_k \alpha_k)^2}{(\lambda_k \alpha_k)^2}$$

is minimal, wherein

$$\mathbf{u}_k = \sum_{i=1}^{n} \alpha_i \mathbf{v}_i$$

with coefficients α_i.

5. The method of claim 4 wherein said test device has n voltage generators generating n different voltages φ_k, which voltages are applied through n selectable impedances Z_k to said ports, wherein

$$\alpha = [\mathbf{v}_1 \; . \; . \; \mathbf{v}_n]^{-1} \cdot (\mathbf{I} + \mathbf{Z} \cdot \mathbf{Y}')^{-1} \cdot \varphi$$

where α is a vector of the coefficients α_1 to α_n, $\mathbf{Z}$ is a diagonal matrix with diagonal elements Z_k and φ is a vector with elements φ_1 to φ_k.

6. The method of any of the preceding claims comprising the steps of

repeating said estimation procedure at a plurality of frequencies over a frequency range of interest and

carrying out said measurement procedure for at least some of the frequencies.

7. The method of claim 6 wherein said measurement procedure is carried out for frequencies where an absolute ratio between maximum and a minimum eigenvalue of said estimated admittance matrix $\mathbf{Y}'$ has a local maximum or exceeds a given threshold.

8. The method of any of the claims 6 or 7 comprising the step of determining critical frequencies, wherein a density of measurements close to said critical frequencies is larger than a number of measurements away from said critical frequencies.

9. A method for modeling an electrical system with at least one component comprising the steps of

characterizing the component using the method of any of the preceding claims by determining the applied voltage patterns $\mathbf{u}_k$ and, for each voltage pattern $\mathbf{u}_k$

applied to said ports, a current pattern $\mathbf{i}_k$ at said ports, and

modeling said system using said voltage patterns $\mathbf{u}_k$ and said current patterns $\mathbf{i}_k$ without calculating an admittance or impedance matrix of said component.

10. A device for characterizing the linear properties of an electrical component having n > 1 ports, said device comprising

n voltage generators (10) for generating a voltage for each port,

n current sensors (11) for sensing the current at each port, and

a control unit (3) for automatically carrying out the method of any of the preceding claims.

11. A device for characterizing the linear properties of an electrical component, in particular of claim 10, having n > 2 ports, said device comprising

n voltage generators (10) for generating a voltage for each port,

n current sensors (11) for sensing the current at each port, and

a control unit (3) for automatically generating several voltage patterns ($\mathbf{u}_k$) at said ports and measuring the corresponding currents ($\mathbf{i}_k$) at said ports and deriving the linear response of said component therefrom.

12. The device of any of the claims 10 or 11 wherein said control unit (3) is adapted to apply at least n different voltage patterns to said ports consecutively.

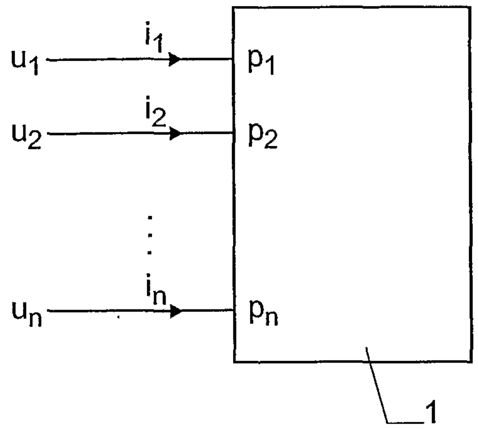

u1
i1
p1
u2
i2
p2
un
in
pn
1

Fig. 1

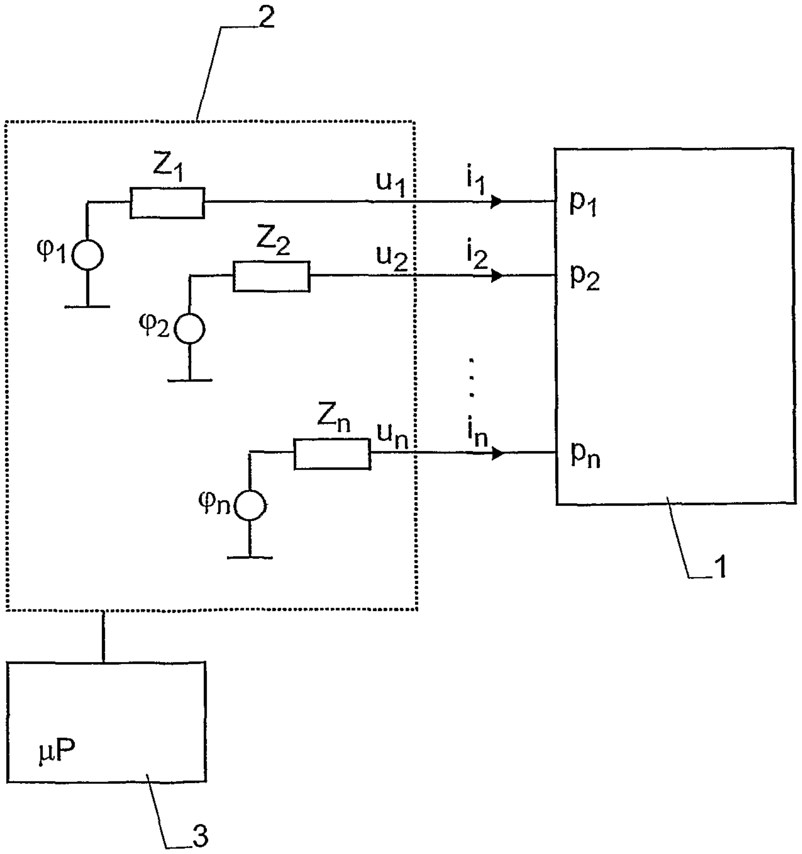

2
Z1
u1
i1
p1
φ1
Z2
u2
i2
p2
φ2
Zn
un
in
pn
φn
1
μP
3

Fig. 2

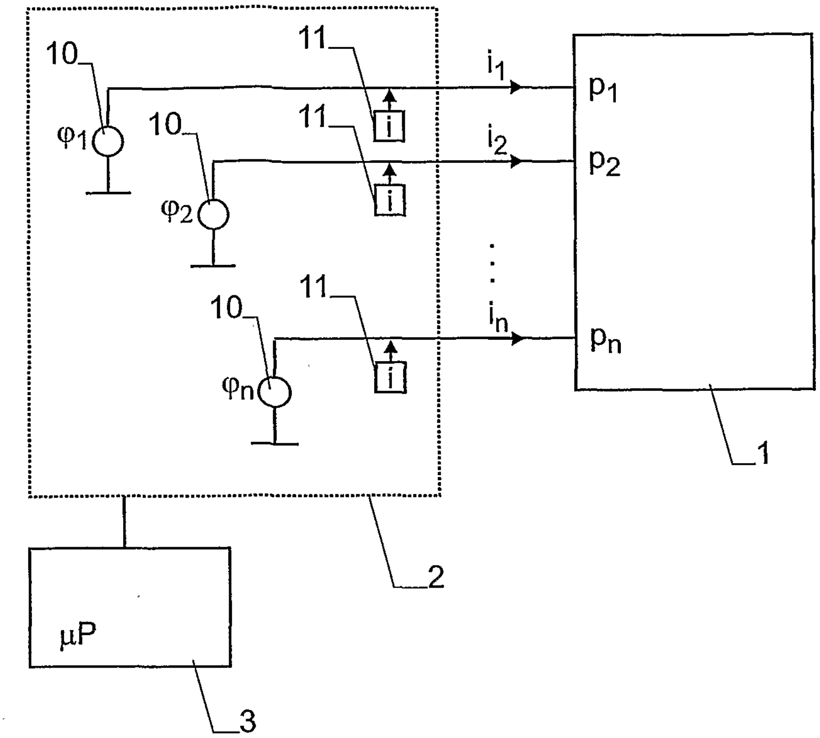

10
11
i_1
p_1
φ_1
10
11
i_2
p_2
φ_2
11
10
i_n
p_n
φ_n
i
1
2
μP
3

Fig. 3

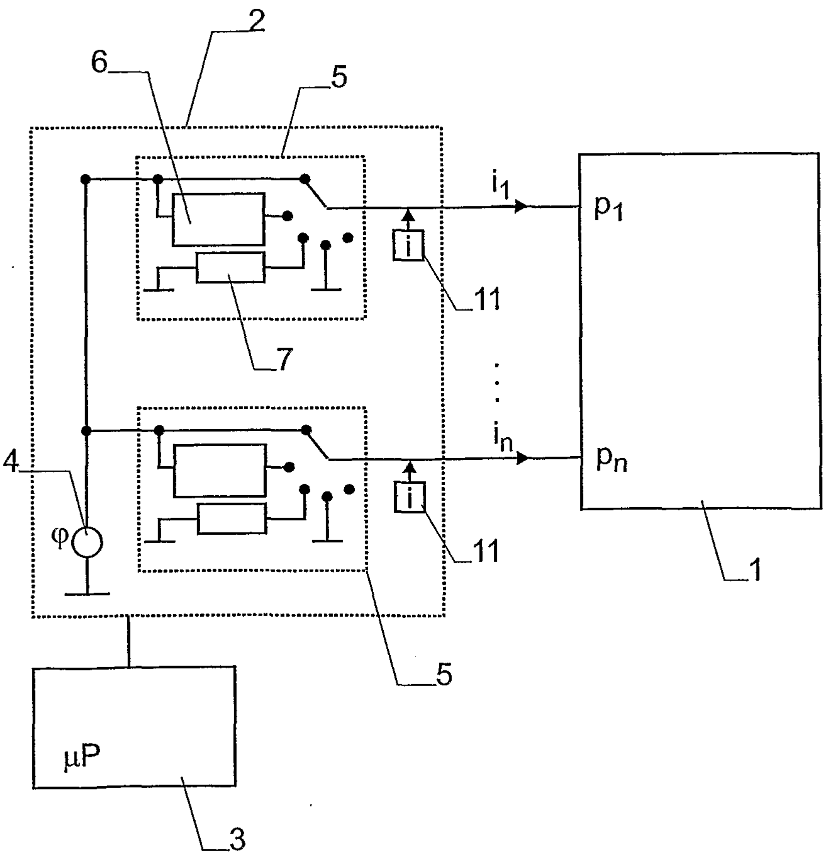

2
6
5
i_1
p_1
i
11
7
i_n
p_n
4
φ
11
1
5
μP
3

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/CH2006/000037

A. CLASSIFICATION OF SUBJECT MATTER
G01R27/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AGILENT TECHNOLOGIES: "Agilent 4155C/4156C Semiconductor Parameter Analyzer User's Guide , Edition 1" AGILENT MANUALS, vol. 1, January 2001 (2001-01), pages 1.1-1.20,2.41-2.46,4.39,4.41,7.19-7.25, XP002334387 the whole document	10-12
A		1,2,9

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 March 2006	28/03/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Höller, H

INTERNATIONAL SEARCH REPORT

International application No
PCT/CH2006/000037

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	SI. FANG: "Electrical Modeling of Main Injector Dipole Magnets" [Online] 17 March 1995 (1995-03-17), FERMI NATIONAL ACCELERATOR LABORATORY , XP002334389 Retrieved from the Internet: URL:http://www-fmi.fnal.gov/fmiinternal/MI_Notes_Pages/MI-0133.pdf> [retrieved on 2005-07-04] figures 1,2 page 1 - page 2 -----	10-12 1,2,6,9
X	US 4 156 842 A (BROOKS, JAMES L ET AL) 29 May 1979 (1979-05-29) figure 1 column 2, line 50 - column 3, line 42 column 4, line 13 - line 28 column 6, line 60 - column 7, line 13 -----	10-12
X	GUILLAUME P ET AL: "Parametric identification of two-port models in the frequency domain" INSTRUMENTATION AND MEASUREMENT TECHNOLOGY CONFERENCE. ATLANTA, MAY 14, vol. CONF. 8, 14 May 1991 (1991-05-14), pages 263-271, XP010036959 ISBN: 0-87942-579-2 figure 2 abstract page 263, paragraph I.INTRODUCTION page 267, paragraph VIII.CONCLUSIONS -----	10-12
A	SCHLAGENHAUFOR F ET AL: "Using N-port models for the analysis of radiating structures" 2002 IEEE INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY. EMC. SYMPOSIUM RECORD. MINNEAPOLIS, MN, AUG. 19 - 23, 2002, INTERNATIONL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY, NEW YORK, NY : IEEE, US, vol. VOL. 1 OF 2, 19 August 2002 (2002-08-19), pages 297-302, XP010603241 ISBN: 0-7803-7264-6 figure 1 page 297, paragraph N-PORT.BASICS-THEORY -----	1,2,9,10
A	US 6 054 867 A (WAKAMATSU ET AL) 25 April 2000 (2000-04-25) figures 2,6,8 ----- -/--	1,2,9,10

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 443 835 A (HEWLETT-PACKARD COMPANY) 28 August 1991 (1991-08-28) figures 1-7 page 2, line 36 - page 3, line 15 claims 1,6,8	1,2,9,10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/CH2006/000037

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 4156842	A	29-05-1979	NONE			
US 6054867	A	25-04-2000	DE	19731750	A1	29-01-1998
			JP	10038936	A	13-02-1998
EP 0443835	A	28-08-1991	CA	2036127	A1	22-08-1991
			DE	69115733	D1	08-02-1996
			DE	69115733	T2	15-05-1996
			JP	2975389	B2	10-11-1999
			JP	3243868	A	30-10-1991