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► **To cite this version:**

Romain Coulon, Jonathan Nicolas Dumazert, Vladimir Kondrasovs, Emmanuel Rohée, Stéphane Normand. Estimation of nuclear counting by a nonlinear filter based on a hypothesis test and a double exponential smoothing. IEEE Transactions on Nuclear Science, 2016, 63 (5), pp.2671 - 2676. 10.1109/TNS.2016.2601785 . hal-01867859

**HAL Id: hal-01867859**

**<https://hal.science/hal-01867859v1>**

Submitted on 3 Jul 2023

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# Estimation of nuclear counting by a nonlinear filter based on a hypothesis test and a double exponential smoothing

Romain Coulon, Jonathan Dumazert, Vladimir Kondrasovs, Emmanuel Rohée, and Stephane Normand

**Abstract**— Online nuclear counting represents a challenge due to the stochastic nature of radioactivity. The counting data have to be filtered in order to provide a precise and accurate estimation of the count rate, while ensuring a response time compatible with the application in view.

An innovative filter is presented in this paper to address this issue. The filter is nonlinear and based on a Centered Significance Test (CST) providing a local maximum likelihood estimation of the signal. This nonlinear approach allows enables to smooth the counting signal while maintaining a fast response when brutal change in activity occurs. The filter is then improved by the implementation of a Brown's double Exponential Smoothing (BES).

The filter has been validated and compared to other state-of-the-art smoothing filters. The CST\* filter shows a significant improvement compared to all tested smoothing filters.

**Index Terms**— Algorithms, Filters, Radiation detectors, Signal Processing.

## I. INTRODUCTION

N UCLEAR counting signal can be considered as a time-dependent random variable  $N^t$  taking its value into a Poisson distribution  $\mathcal{P}$  with a parameter  $\lambda^t$  (see Eq. 1) [1]. In a ratemeter, the expected count number  $\lambda^t$  has to be estimated at each time  $t$ .

document is a template for Microsoft *Word* versions 6.0 or later. If you are reading a paper or PDF version of this document, please download the electronic file, TRANS-JOUR.DOC, from the IEEE Web site at <http://www.ieee.org/web/publications/authors/transjnl/index.html> so you can use it to prepare your manuscript. If you would prefer to use LATEX, download IEEE's LATEX style and sample files from the same Web page. Use these LATEX files for formatting, but please follow the instructions in TRANS-JOUR.DOC or TRANS-JOUR.PDF.

If your paper is intended for a conference, please contact your conference editor concerning acceptable word processor formats for your particular conference.

Romain Coulon is with the French Alternative Energies and Atomic Energy Commission, CEA, LIST, Laboratoire Capteurs et Architectures Electroniques, F-91191 Gif-sur-Yvette, France (e-mail: romain.coulon@cea.fr).

## II. GUIDELINES FOR MANUSCRIPT PREPARATION

When you open TRANS-JOUR.DOC, select "Page Layout" from the "View" menu in the menu bar (View | Page Layout), (these instructions assume MS 6.0. Some versions may have alternate ways to access the same functionalities noted here). Then, type over sections of TRANS-JOUR.DOC or cut and paste from another document and use markup styles. The pull-down style menu is at the left of the Formatting Toolbar at the top of your *Word* window (for example, the style at this point in the document is "Text"). Highlight a section that you want to designate with a certain style, then select the appropriate name on the style menu. The style will adjust your fonts and line spacing. Do not change the font sizes or line spacing to squeeze more text into a limited number of pages. Use italics for emphasis; do not underline.

To insert images in *Word*, position the cursor at the insertion point and either use Insert | Picture | From File or copy the image to the Windows clipboard and then Edit | Paste Special | Picture (with "float over text" unchecked).

IEEE will do the final formatting of your paper. If your paper is intended for a conference, please observe the conference page limits.

### A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have already been defined in the abstract. Abbreviations such as IEEE, SI, ac, and dc do not have to be defined. Abbreviations that incorporate periods should not have spaces: write "C.N.R.S.," not "C. N. R. S." Do not use abbreviations in the title unless they are unavoidable (for example, "IEEE" in the title of this article).

### B. Other Recommendations

Use one space after periods and colons. Hyphenate complex modifiers: "zero-field-cooled magnetization." Avoid dangling participles, such as, "Using (1), the potential was calculated." [It is not clear who or what used (1).] Write instead, "The potential was calculated by using (1)," or "Using (1), we calculated the potential."

Use a zero before decimal points: "0.25," not ".25." Use "cm<sup>3</sup>," not "cc." Indicate sample dimensions as "0.1 cm × 0.2 cm," not "0.1 × 0.2 cm<sup>2</sup>." The abbreviation for "seconds" is

“s,” not “sec.” Use “Wb/m<sup>2</sup>” or “webers per square meter,” not “webers/m<sup>2</sup>.” When expressing a range of values, write “7 to 9” or “7-9,” not “7~9.”

A parenthetical statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.) In American English, periods and commas are within quotation marks, like “this period.” Other punctuation is “outside”! Avoid contractions; for example, write “do not” instead of “don’t.” The serial comma is preferred: “A, B, and C” instead of “A, B and C.”

If you wish, you may write in the first person singular or plural and use the active voice (“I observed that ...” or “We observed that ...” instead of “It was observed that ...”). Remember to check spelling. If your native language is not English, please get a native English-speaking colleague to carefully proofread your paper.

### C. How to Create a PostScript File

First, download a PostScript printer driver from <http://www.adobe.com/support/downloads/pdrvwin.htm> (for Windows) or from <http://www.adobe.com/support/downloads/pdrvmac.htm> (for Macintosh) and install the “Generic PostScript Printer” definition. In *Word*, paste your figure into a new document. Print to a file using the PostScript printer driver. File names should be of the form “fig5.ps.” Use Open Type fonts when creating your figures, if possible. A listing of the acceptable fonts are as follows: Open Type Fonts: Times Roman, Helvetica, Helvetica Narrow, Courier, Symbol, Palatino, Avant Garde, Bookman, Zapf Chancery, Zapf Dingbats, and New Century Schoolbook.

## III. MATH

If you are using *Word*, use either the Microsoft Equation Editor or the *MathType* add-on (<http://www.mathtype.com>) for equations in your paper (Insert | Object | Create New | Microsoft Equation or MathType Equation). “Float over text” should *not* be selected.

### A. Equations

Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). First use the equation editor to create the equation. Then select the “Equation” markup style. Press the tab key and write the equation number in parentheses. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Use parentheses to avoid ambiguities in denominators. Punctuate equations when they are part of a sentence, as in

$$\int_0^{r_2} F(r, \varphi) dr d\varphi = [\sigma r_2 / (2\mu_0)] \cdot \int_0^\infty \exp(-\lambda |z_j - z_i|) \lambda^{-1} J_1(\lambda r_2) J_0(\lambda r_i) d\lambda. \quad (1)$$

Be sure that the symbols in your equation have been defined

before the equation appears or immediately following. Italicize symbols (*T* might refer to temperature, but *T* is the unit tesla). Refer to “(1),” not “Eq. (1)” or “equation (1),” except at the beginning of a sentence: “Equation (1) is ... .”

## IV. UNITS

Use either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.) English units may be used as secondary units (in parentheses). This applies to papers in data storage. For example, write “15 Gb/cm<sup>2</sup> (100 Gb/in<sup>2</sup>).” An exception is when English units are used as identifiers in trade, such as “3½-in disk drive.” Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.

The SI unit for magnetic field strength *H* is A/m. However, if you wish to use units of T, either refer to magnetic flux density *B* or magnetic field strength symbolized as  $\mu_0 H$ . Use the center dot to separate compound units, e.g., “A·m<sup>2</sup>.”

## V. SOME COMMON MISTAKES

The word “data” is plural, not singular. The subscript for the permeability of vacuum  $\mu_0$  is zero, not a lowercase letter “o.” The term for residual magnetization is “remanence”; the adjective is “remanent”; do not write “remnance” or “remnant.” Use the word “micrometer” instead of “micron.” A graph within a graph is an “inset,” not an “insert.” The word “alternatively” is preferred to the word “alternately” (unless you really mean something that alternates). Use the word “whereas” instead of “while” (unless you are referring to simultaneous events). Do not use the word “essentially” to mean “approximately” or “effectively.” Do not use the word “issue” as a euphemism for “problem.” When compositions are not specified, separate chemical symbols by en-dashes; for example, “NiMn” indicates the intermetallic compound Ni<sub>0.5</sub>Mn<sub>0.5</sub> whereas “Ni–Mn” indicates an alloy of some composition Ni<sub>x</sub>Mn<sub>1-x</sub>.

Be aware of the different meanings of the homophones “affect” (usually a verb) and “effect” (usually a noun), “complement” and “compliment,” “discreet” and “discrete,” “principal” (e.g., “principal investigator”) and “principle” (e.g., “principle of measurement”). Do not confuse “imply” and “infer.”

Prefixes such as “non,” “sub,” “micro,” “multi,” and “ultra” are not independent words; they should be joined to the words they modify, usually without a hyphen. There is no period after the “et” in the Latin abbreviation “*et al.*” (it is also italicized). The abbreviation “i.e.,” means “that is,” and the abbreviation “e.g.,” means “for example” (these abbreviations are not italicized).

A general IEEE styleguide is available at <http://www.ieee.org/web/publications/authors/transjnl/index.html>

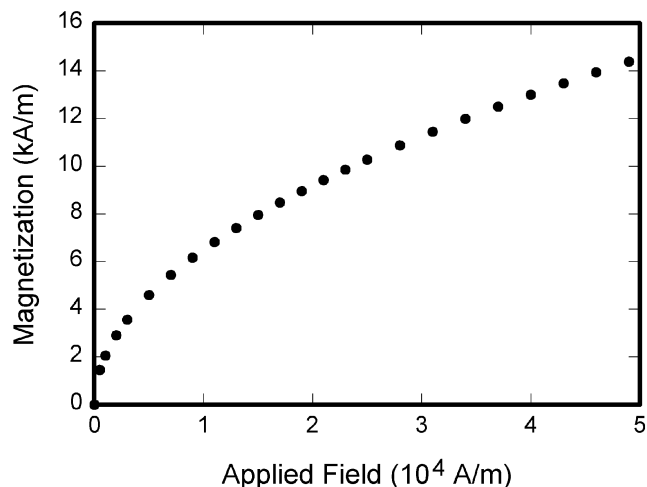


Fig. 1. Magnetization as a function of applied field. Note that “Fig.” is abbreviated. There is a period after the figure number, followed by two spaces. It is good practice to explain the significance of the figure in the caption.

## VI. GUIDELINES FOR GRAPHICS PREPARATION AND SUBMISSION

### A. Types of Graphics

The following list outlines the different types of graphics published in IEEE journals. They are categorized based on their construction, and use of color / shades of gray:

#### 1) Color/Grayscale figures

Figures that are meant to appear in color, or shades of black/gray. Such figures may include photographs, illustrations, multicolor graphs, and flowcharts.

#### 2) Lineart figures

Figures that are composed of only black lines and shapes. These figures should have no shades or half-tones of gray. Only black and white.

#### 3) Author photos

Head and shoulders shots of authors which appear at the end of our papers.

#### 4) Tables

Data charts which are typically black and white, but sometimes include color.

### B. Multipart figures

Figures compiled of more than one sub-figure presented side-by-side, or stacked. If a multipart figure is made up of multiple figure types (one part is lineart, and another is grayscale or color) the figure should meet the stricter guidelines.

### C. File Formats For Graphics

Format and save your graphics using a suitable graphics processing program that will allow you to create the images as PostScript (PS), Encapsulated PostScript (.EPS), Tagged Image File Format (.TIFF), Portable Document Format (.PDF), or Portable Network Graphics (.PNG) sizes them, and adjusts the resolution settings. If you created your source files

TABLE I  
UNITS FOR MAGNETIC PROPERTIES

| Symbol         | Quantity                                  | Conversion from Gaussian and CGS EMU to SI <sup>a</sup>                                     |
|----------------|---|---|
| $\Phi$         | magnetic flux                             | 1 Mx $\rightarrow$ $10^{-8}$ Wb = $10^{-8}$ V·s   |
| $B$            | magnetic flux density, magnetic induction | 1 G $\rightarrow$ $10^{-4}$ T = $10^{-4}$ Wb/m <sup>2</sup>                                 |
| $H$            | magnetic field strength                   | 1 Oe $\rightarrow$ $10^3/(4\pi)$ A/m  |
| $m$            | magnetic moment                           | 1 erg/G = 1 emu<br>$\rightarrow$ $10^{-3}$ A·m <sup>2</sup> = $10^{-3}$ J/T                 |
| $M$            | magnetization                             | 1 erg/(G·cm <sup>3</sup> ) = 1 emu/cm <sup>3</sup><br>$\rightarrow$ $10^3$ A/m              |
| $4\pi M$       | magnetization                             | 1 G $\rightarrow$ $10^3/(4\pi)$ A/m   |
| $\sigma$       | specific magnetization                    | 1 erg/(G·g) = 1 emu/g $\rightarrow$ $1$ A·m <sup>2</sup> /kg                                |
| $j$            | magnetic dipole moment                    | 1 erg/G = 1 emu<br>$\rightarrow$ $4\pi \times 10^{-10}$ Wb·m                                |
| $J$            | magnetic polarization                     | 1 erg/(G·cm <sup>3</sup> ) = 1 emu/cm <sup>3</sup><br>$\rightarrow$ $4\pi \times 10^{-4}$ T |
| $\chi, \kappa$ | susceptibility                            | 1 $\rightarrow$ $4\pi$  |
| $\chi_p$       | mass susceptibility                       | 1 cm <sup>3</sup> /g $\rightarrow$ $4\pi \times 10^{-3}$ m <sup>3</sup> /kg                 |
| $\mu$          | permeability                              | 1 $\rightarrow$ $4\pi \times 10^{-7}$ H/m<br>= $4\pi \times 10^{-7}$ Wb/(A·m)               |
| $\mu_r$        | relative permeability                     | $\mu \rightarrow \mu_r$   |
| $w, W$         | energy density                            | 1 erg/cm <sup>3</sup> $\rightarrow$ $10^{-1}$ J/m <sup>3</sup>                              |
| $N, D$         | demagnetizing factor                      | 1 $\rightarrow$ $1/(4\pi)$  |

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

<sup>a</sup>Gaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

in one of the following programs you will be able to submit the graphics without converting to a PS, EPS, TIFF, PDF, or PNG file: Microsoft Word, Microsoft PowerPoint, or Microsoft Excel. Though it is not required, it is recommended that these files be saved in PDF format rather than DOC, XLS, or PPT. Doing so will protect your figures from common font and arrow stroke issues that occur when working on the files across multiple platforms. When submitting your final paper, your graphics should all be submitted individually in one of these formats along with the manuscript.

### D. Sizing of Graphics

Most charts, graphs, and tables are one column wide (3.5 inches / 88 millimeters / 21 picas) or page wide (7.16 inches / 181 millimeters / 43 picas). The maximum depth a graphic can be is 8.5 inches (216 millimeters / 54 picas). When choosing the depth of a graphic, please allow space for a caption. Figures can be sized between column and page widths if the author chooses, however it is recommended that figures are not sized less than column width unless when necessary.

There is currently one publication with column measurements that don't coincide with those listed above. PROCEEDINGS OF THE IEEE has a column measurement of 3.25 inches (82.5 millimeters / 19.5 picas).

The final printed size of author photographs is exactly 1 inch wide by 1.25 inches tall (25.4 millimeters x 31.75 millimeters / 6 picas x 7.5 picas). Author photos printed in editorials measure 1.59 inches wide by 2 inches tall (40 millimeters x 50 millimeters / 9.5 picas x 12 picas).

### E. Resolution

The proper resolution of your figures will depend on the type of figure it is as defined in the “Types of Figures” section. Author photographs, color, and grayscale figures should be at least 300dpi. Lineart, including tables should be a minimum of 600dpi.

### F. Vector Art

While IEEE does accept, and even recommends that authors submit artwork in vector format, it is our policy is to rasterize all figures for publication. This is done in order to preserve the figures’ integrity across multiple computer platforms.

### G. Color Space

The term color space refers to the entire sum of colors that can be represented within the said medium. For our purposes, the three main color spaces are Grayscale, RGB (red/green/blue) and CMYK (cyan/magenta/yellow/black). RGB is generally used with on-screen graphics, whereas CMYK is used for printing purposes.

All color figures should be generated in RGB or CMYK color space. Grayscale images should be submitted in Grayscale color space. Line art may be provided in grayscale OR bitmap colorspace. Note that “bitmap colorspace” and “bitmap file format” are not the same thing. When bitmap color space is selected, .TIF/.TIFF is the recommended file format.

### H. Accepted Fonts Within Figures

When preparing your graphics IEEE suggests that you use of one of the following Open Type fonts: Times New Roman, Helvetica, Arial, Cambria, and Symbol. If you are supplying EPS, PS, or PDF files all fonts must be embedded. Some fonts may only be native to your operating system; without the fonts embedded, parts of the graphic may be distorted or missing.

A safe option when finalizing your figures is to strip out the fonts before you save the files, creating “outline” type. This converts fonts to artwork what will appear uniformly on any screen.

### I. Using Labels Within Figures

#### 1) Figure Axis labels

Figure axis labels are often a source of confusion. Use words rather than symbols. As an example, write the quantity “Magnetization,” or “Magnetization  $M$ ,” not just “ $M$ .” Put units in parentheses. Do not label axes only with units. As in Fig. 1, for example, write “Magnetization (A/m)” or “Magnetization ( $A \cdot m^{-1}$ ),” not just “A/m.” Do not label axes with a ratio of quantities and units. For example, write “Temperature (K),” not “Temperature/K.”

Multipliers can be especially confusing. Write “Magnetization (kA/m)” or “Magnetization ( $10^3$  A/m).” Do not write “Magnetization (A/m)  $\times$  1000” because the reader would not know whether the top axis label in Fig. 1 meant 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8 to 10 point type.

### 2) Subfigure Labels in Multipart Figures and Tables

Multipart figures should be combined and labeled before final submission. Labels should appear centered below each subfigure in 8 point Times New Roman font in the format of (a) (b) (c).

### J. File Naming

Figures (line artwork or photographs) should be named starting with the first 5 letters of the author’s last name. The next characters in the filename should be the number that represents the sequential location of this image in your article. For example, in author “Anderson’s” paper, the first three figures would be named *ander1.tif*, *ander2.tif*, and *ander3.ps*.

Tables should contain only the body of the table (not the caption) and should be named similarly to figures, except that ‘.t’ is inserted in-between the author’s name and the table number. For example, author Anderson’s first three tables would be named *ander.t1.tif*, *ander.t2.ps*, and *ander.t3.eps*.

Author photographs should be named using the first five characters of the pictured author’s last name. For example, four author photographs for a paper may be named: *oppen.ps*, *moshc.tif*, *chen.eps*, and *durand.pdf*.

If two authors or more have the same last name, their first initial(s) can be substituted for the fifth, fourth, third... letters of their surname until the degree where there is differentiation. For example, two authors Michael and Monica Oppenheimer’s photos would be named *oppmi.tif*, and *oppmo.eps*.

### K. Referencing a Figure or Table Within Your Paper

When referencing your figures and tables within your paper, use the abbreviation “Fig.” even at the beginning of a sentence. Do not abbreviate “Table.” Tables should be numbered with Roman Numerals.

### L. Checking Your Figures: The IEEE Graphics Checker

The IEEE Graphics Checker Tool enables authors to pre-screen their graphics for compliance with IEEE Transactions and Journals standards before submission. The online tool, located at <http://graphicsqc.ieee.org/>, allows authors to upload their graphics in order to check that each file is the correct file format, resolution, size and colorspace; that no fonts are missing or corrupt; that figures are not compiled in layers or have transparency, and that they are named according to the IEEE Transactions and Journals naming convention. At the end of this automated process, authors are provided with a detailed report on each graphic within the web applet, as well as by email.

For more information on using the Graphics Checker Tool or any other graphics related topic, contact the IEEE Graphics Help Desk by e-mail at [graphics@ieee.org](mailto:graphics@ieee.org).

### M. Submitting Your Graphics

Because IEEE will do the final formatting of your paper, you do not need to position figures and tables at the top and bottom of each column. In fact, all figures, figure captions, and tables can be placed at the end of your paper. In addition to, or even in lieu of submitting figures within your final manuscript, figures should be submitted individually, separate

from the manuscript in one of the file formats listed above in section VI-J. Place figure captions below the figures; place table titles above the tables. Please do not include captions as part of the figures, or put them in “text boxes” linked to the figures. Also, do not place borders around the outside of your figures.

#### N. Color Processing / Printing in IEEE Journals

All IEEE Transactions, Journals, and Letters allow an author to publish color figures on IEEE *Xplore*<sup>®</sup> at no charge, and automatically convert them to grayscale for print versions. In most journals, figures and tables may alternatively be printed in color if an author chooses to do so. Please note that this service comes at an extra expense to the author. If you intend to have print color graphics, include a note with your final paper indicating which figures or tables you would like to be handled that way, and stating that you are willing to pay the additional fee.

#### VII. CONCLUSION

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

#### APPENDIX

Appendixes, if needed, appear before the acknowledgment.

#### ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ... .” In most cases, sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page, not here.

#### REFERENCES AND FOOTNOTES

##### A. References

References need not be cited in text. When they are, number citations on the line, in square brackets inside the punctuation. Multiple references are each numbered with separate brackets. When citing a section in a book, please give the relevant page numbers. In text, refer simply to the reference number. Do not use “Ref.” or “reference” except at the beginning of a sentence: “Reference [3] shows ... .” Please do not use automatic endnotes in *Word*, rather, type the reference list at the end of the paper using the “References” style.

Reference numbers are set flush left and form a column of their own, hanging out beyond the body of the reference. The reference numbers are on the line, enclosed in square brackets. In all references, the given name of the author or editor is abbreviated to the initial only and precedes the last name. Use

them all; use *et al.* only if names are not given. Use commas around Jr., Sr., and III in names. Abbreviate conference titles. When citing IEEE transactions, provide the issue number, page range, volume number, year, and/or month if available. When referencing a patent, provide the day and the month of issue, or application. References may not include all information; please obtain and include relevant information. Do not combine references. There must be only one reference with each number. If there is a URL included with the print reference, it can be included at the end of the reference.

Other than books, capitalize only the first word in a paper title, except for proper nouns and element symbols. For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation. See the end of this document for formats and examples of common references. For a complete discussion of references and their formats, see “The IEEE Style Manual,” available as a PDF link off the [Author Digital Toolbox](#) main page.

##### A. Footnotes

Number footnotes separately in superscripts (Insert | Footnote).<sup>1</sup> Place the actual footnote at the bottom of the column in which it is cited; do not put footnotes in the reference list (endnotes). Use letters for table footnotes (see Table I).

#### VIII. SUBMITTING YOUR PAPER FOR REVIEW

##### A. Review Stage Using Word 6.0 or Higher

If you want to submit your file with one column electronically, please do the following:

- First, click on the View menu and choose Print Layout.
- Second, place your cursor in the first paragraph. Go to the Format menu, choose Columns, choose one column Layout, and choose “apply to whole document” from the dropdown menu.
- Third, click and drag the right margin bar to just over 4 inches in width.

The graphics will stay in the “second” column, but you can drag them to the first column. Make the graphic wider to push out any text that may try to fill in next to the graphic.

##### B. Final Stage Using Word 6.0

When you submit your final version (after your paper has been accepted), print it in two-column format, including figures and tables. You must also send your final manuscript on a disk, via e-mail, or through a Web manuscript submission system as directed by the society contact. You may use *Zip* for large files, or compress files using *Compress*, *Pkzip*, *Stuffit*, or *Gzip*.

Also, send a sheet of paper or PDF with complete contact information for all authors. Include full mailing addresses, telephone numbers, fax numbers, and e-mail addresses. This

<sup>1</sup>It is recommended that footnotes be avoided (except for the unnumbered footnote with the receipt date on the first page). Instead, try to integrate the footnote information into the text.

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### C. Review Stage Using ScholarOne® Manuscripts

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## IX. EDITORIAL POLICY

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At least two reviews are required for every paper submitted. For conference-related papers, the decision to accept or reject a paper is made by the conference editors and publications committee; the recommendations of the referees are advisory only. Indecipherable English is a valid reason for rejection. There is a service available that will help you improve your English for a fee, and the link to that service can be found at <http://www.ieee.org/web/publications/authors/transjnl/index.html>. Authors of rejected papers may revise and resubmit them as regular papers, whereupon they will be reviewed by two new referees.

## X. PUBLICATION PRINCIPLES

The two types of contents of that are published are; 1) peer-reviewed and 2) archival. The Transactions and Journals Department publishes scholarly articles of archival value as well as tutorial expositions and critical reviews of classical subjects and topics of current interest.

Authors should consider the following points:

- 1) Technical papers submitted for publication must advance the state of knowledge and must cite relevant prior work.
- 2) The length of a submitted paper should be commensurate with the importance, or appropriate to the complexity, of the work. For example, an obvious extension of previously published work might not be appropriate for publication or might be adequately treated in just a few pages.
- 3) Authors must convince both peer reviewers and the editors of the scientific and technical merit of a paper; the standards of proof are higher when extraordinary or unexpected results are reported.
- 4) Because replication is required for scientific progress,

papers submitted for publication must provide sufficient information to allow readers to perform similar experiments or calculations and use the reported results. Although not everything need be disclosed, a paper must contain new, useable, and fully described information. For example, a specimen's chemical composition need not be reported if the main purpose of a paper is to introduce a new measurement technique. Authors should expect to be challenged by reviewers if the results are not supported by adequate data and critical details.

- 5) Papers that describe ongoing work or announce the latest technical achievement, which are suitable for presentation at a professional conference, may not be appropriate for publication.

## REFERENCES

### Basic format for books:

- [1] J. K. Author, "Title of chapter in the book," in *Title of His Published Book*, xth ed. City of Publisher, Country if not  
[2] USA: Abbrev. of Publisher, year, ch. x, sec. x, pp. xxx-xxx.

### Examples:

- [3] G. O. Young, "Synthetic structure of industrial plastics," in *Plastics*, 2nd ed., vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15-64.  
[4] W.-K. Chen, *Linear Networks and Systems*. Belmont, CA: Wadsworth, 1993, pp. 123-135.

### Basic format for periodicals:

- [5] J. K. Author, "Name of paper," *Abbrev. Title of Periodical*, vol. x, no. x, pp. xxx-xxx, Abbrev. Month, year.

### Examples:

- [6] J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility," *IEEE Trans. Electron Devices*, vol. ED-11, no. 1, pp. 34-39, Jan. 1959.  
[7] E. P. Wigner, "Theory of traveling-wave optical laser," *Phys. Rev.*, vol. 134, pp. A635-A646, Dec. 1965.  
[8] E. H. Miller, "A note on reflector arrays," *IEEE Trans. Antennas Propagat.*, to be published.

### Basic format for reports:

- [9] J. K. Author, "Title of report," Abbrev. Name of Co., City of Co., Abbrev. State, Rep. xxx, year.

### Examples:

- [10] E. E. Reber, R. L. Michell, and C. J. Carter, "Oxygen absorption in the earth's atmosphere," Aerospace Corp., Los Angeles, CA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.  
[11] J. H. Davis and J. R. Cogdell, "Calibration program for the 16-foot antenna," Elect. Eng. Res. Lab., Univ. Texas, Austin, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

### Basic format for handbooks:

- [12] *Name of Manual/Handbook*, x ed., Abbrev. Name of Co., City of Co., Abbrev. State, year, pp. xxx-xxx.

### Examples:

- [13] *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, 1985, pp. 44-60.  
[14] *Motorola Semiconductor Data Manual*, Motorola Semiconductor Products Inc., Phoenix, AZ, 1989.

### Basic format for books (when available online):

- [15] Author. (year, month day). *Title*. (edition) [Type of medium]. *volume (issue)*. Available: site/path/file

### Example:

- [16] J. Jones. (1991, May 10). *Networks*. (2nd ed.) [Online]. Available: <http://www.atm.com>

### Basic format for journals (when available online):

- [17] Author. (year, month). Title. *Journal*. [Type of medium]. *volume (issue)*, pages. Available: site/path/file

### Example:

- [18] R. J. Vidmar. (1992, Aug.). On the use of atmospheric plasmas as electromagnetic reflectors. *IEEE Trans. Plasma Sci.* [Online]. 21(3), pp. 876-880. Available: <http://www.halcyon.com/pub/journals/21ps03-vidmar>

### Basic format for papers presented at conferences (when available online):

- [19] Author. (year, month). Title. Presented at Conference title. [Type of Medium]. Available: site/path/file

### Example:

- [20] PROCESS Corp., MA. Intranets: Internet technologies deployed behind the firewall for corporate productivity. Presented at INET96 Annual Meeting. [Online]. Available: <http://home.process.com/Intranets/wp2.http>

### Basic format for reports and handbooks (when available online):

- [21] Author. (year, month). Title. Company. City, State or Country. [Type of Medium]. Available: site/path/file

### Example:

- [22] S. L. Talleen. (1996, Apr.). The Intranet Architecture: Managing information in the new paradigm. Amdahl Corp., CA. [Online]. Available: <http://www.amdahl.com/doc/products/bsg/intra/infra/html>

### Basic format for computer programs and electronic documents (when available online): ISO recommends that capitalization follow the accepted practice for the language or script in which the information is given.

### Example:

- [23] A. Harriman. (1993, June). Compendium of genealogical software. *Humanist*. [Online]. Available e-mail: HUMANIST@NYVM.ORG Message: get GENEALOGY REPORT

### Basic format for patents (when available online):

- [24] Name of the invention, by inventor's name. (year, month day). *Patent Number* [Type of medium]. Available: site/path/file

### Example:

- [25] Musical toothbrush with adjustable neck and mirror, by L.M.R. Brooks. (1992, May 19). *Patent D 326 189* [Online]. Available: NEXIS Library: LEXPAT File: DESIGN

### Basic format for conference proceedings (published):

- [26] J. K. Author, "Title of paper," in *Abbreviated Name of Conf.*, City of Conf., Abbrev. State (if given), year, pp. xxxxx.

### Example:

- [27] D. B. Payne and J. R. Stern, "Wavelength-switched passively coupled single-mode optical network," in *Proc. IOOC-ECOC*, 1985, pp. 585-590.

### Example for papers presented at conferences (unpublished):

- [28] D. Ebehard and E. Voges, "Digital single sideband detection for interferometric sensors," presented at the 2nd Int. Conf. Optical Fiber Sensors, Stuttgart, Germany, Jan. 2-5, 1984.

### Basic format for patents:

- [29] J. K. Author, "Title of patent," U.S. Patent x xxx xxx, Abbrev. Month, day, year.

### Example:

- [30] G. Brandli and M. Dick, "Alternating current fed power supply," U.S. Patent 4 084 217, Nov. 4, 1978.

### Basic format for theses (M.S.) and dissertations (Ph.D.):



- [31] J. K. Author, "Title of thesis," M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.
- [32] J. K. Author, "Title of dissertation," Ph.D. dissertation, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

*Examples:*

- [33] J. O. Williams, "Narrow-band analyzer," Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.
- [34] N. Kawasaki, "Parametric study of thermal and chemical nonequilibrium nozzle flow," M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

*Basic format for the most common types of unpublished references:*

- [35] J. K. Author, private communication, Abbrev. Month, year.
- [36] J. K. Author, "Title of paper," unpublished.
- [37] J. K. Author, "Title of paper," to be published.

*Examples:*

- [38] A. Harrison, private communication, May 1995.
- [39] B. Smith, "An approach to graphs of linear forms," unpublished.
- [40] A. Brahms, "Representation error for real numbers in binary computer arithmetic," IEEE Computer Group Repository, Paper R-67-85.

*Basic format for standards:*

- [41] *Title of Standard*, Standard number, date.

*Examples:*

- [42] IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.
- [43] Letter Symbols for Quantities, ANSI Standard Y10.5-1968.



**First A. Author** (M'76–SM'81–F'87) and the other authors may include biographies at the end of regular papers. Biographies are often not included in conference-related papers. This author became a Member (M) of IEEE in 1976, a Senior Member (SM) in 1981, and a Fellow (F) in 1987. The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author's educational background is listed. The degrees should be listed with type of degree in what field, which institution, city, state, and country, and year the degree was earned. The author's major field of study should be lower-cased.

The second paragraph uses the pronoun of the person (he or she) and not the author's last name. It lists military and work experience, including summer and fellowship jobs. Job titles are capitalized. The current job must have a location; previous positions may be listed without one. Information concerning previous publications may be included. Try not to list more than three books or published articles. The format for listing publishers of a book within the biography is: title of book (city, state: publisher name, year) similar to a reference. Current and previous research interests end the paragraph.

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**Second B. Author** was born in Greenwich Village, New York City, in 1977. He received the B.S. and M.S. degrees in aerospace engineering from the University of Virginia, Charlottesville, in 2001 and the Ph.D. degree in mechanical engineering from Drexel University, Philadelphia, PA, in 2008.

From 2001 to 2004, he was a Research Assistant with the Princeton Plasma Physics Laboratory. Since 2009, he has been an Assistant Professor with the Mechanical Engineering Department, Texas A&M University, College Station. He is the author of three books, more than 150 articles, and more than 70 inventions. His research interests include high-pressure and high-density nonthermal plasma discharge processes and applications, microscale plasma discharges, discharges in liquids, spectroscopic diagnostics, plasma propulsion, and innovation plasma applications. He is an Associate Editor of the journal *Earth, Moon, Planets*, and holds two patents.

Mr. Author was a recipient of the International Association of Geomagnetism and Aeronomy Young Scientist Award for Excellence in 2008, the IEEE Electromagnetic Compatibility Society Best Symposium Paper Award in 2011, and the American Geophysical Union Outstanding Student Paper Award in Fall 2005.



**Third C. Author, Jr. (M'87)** received the B.S. degree in mechanical engineering from National Chung Cheng University, Chiayi, Taiwan, in 2004 and the M.S. degree in mechanical engineering from

National Tsing Hua University, Hsinchu, Taiwan, in 2006. He is currently pursuing the Ph.D. degree in mechanical engineering at Texas A&M University, College Station.

From 2008 to 2009, he was a Research Assistant with the Institute of Physics, Academia Sinica, Tapei, Taiwan. His research interest includes the development of surface processing and biological/medical treatment techniques using nonthermal atmospheric pressure plasmas, fundamental study of plasma sources, and fabrication of micro- or nanostructured surfaces.

Mr. Author's awards and honors include the Frew Fellowship (Australian Academy of Science), the I. I. Rabi Prize (APS), the European Frequency and Time Forum Award, the Carl Zeiss Research Award, the William F. Meggers Award and the Adolph Lomb Medal (OSA).

