

Folded patch design

Blasi Luca¹, Mastrofini Alessandro², and Mucenica Stefan³,

¹National Institute of Standards and Technology, Boulder, CO 80305 USA (e-mail: author@boulder.nist.gov)

²Department of Physics, Colorado State University, Fort Collins, CO 80523 USA (e-mail: author@lamar.colostate.edu)

³Electrical Engineering Department, University of Colorado, Boulder, CO 80309 USA

This work was developed for the Wireless Electromagnetic Technologies course held by Prof. G. Marrocco

ABSTRACT These instructions give you guidelines for preparing papers for IEEE Open Journal of the Industrial Electronics Society. Use this document as a template if you are using L^AT_EX. Otherwise, use this document as an instruction set. The electronic file of your paper will be formatted further at IEEE. Paper titles should be written in uppercase and lowercase letters, not all uppercase. Avoid writing long formulas with subscripts in the title; short formulas that identify the elements are fine (e.g., "Nd-Fe-B"). Do not write "(Invited)" in the title. Full names of authors are preferred in the author field, but are not required. Put a space between authors' initials. The abstract must be a concise yet comprehensive reflection of what is in your article. In particular, the abstract must be self-contained, without abbreviations, footnotes, or references. It should be a microcosm of the full article. The abstract must be between 150–250 words. Be sure that you adhere to these limits; otherwise, you will need to edit your abstract accordingly. The abstract must be written as one paragraph, and should not contain displayed mathematical equations or tabular material. The abstract should include three or four different keywords or phrases, as this will help readers to find it. It is important to avoid over-repetition of such phrases as this can result in a page being rejected by search engines. Ensure that your abstract reads well and is grammatically correct.

INDEX TERMS antenna, antenna design, patch, folded patch, resonance, radiation, microwave

I. INTRODUCTION

WRITE INTRODUCTION

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturi-

ent montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta

Parameter	Value
Feed coefficients $[A]$	$\begin{bmatrix} C_{-2} \\ C_{-1} \\ C_0 \\ C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} 9.6 \\ 29.8 \\ 41.2 \\ 29.8 \\ 9.6 \end{bmatrix}$
Tapering efficiency	$\eta_T = 79\%$
Beamwidth	<div style="display: flex; justify-content: space-around;"> Tchebyshev 50.6° Uniform 34.8° </div>

TABLE 1: Parametri materiali

vehicula.

II. TCHEBYSHEV ARRAY FACTOR DESIGN

The design of the Tchebyshev array factor will be made with five elements and a lobe/side lobe ratio of $R = 41.58 \text{ dB}$. In order to minimize the beamwidth, let's look for the optimal inter-spacing:

$$d_{\max} = \lambda \left[1 - \frac{1}{2\pi} \arccos \left(\frac{3 - x_1}{1 + x_1} \right) \right] \quad (1)$$

with $d_{\max} \in \left[\frac{\lambda}{2}, \lambda \right]$

III. RECTANGULAR FOLDED PATCH DESIGN

A. MESH DENSITY REFINEMENT

A FR4 substrate thickness of $h_{\text{sub}} = 0.8 \text{ mm}$ has been selected so it could be considered as a thin one:

$$\lambda_{\text{sub}} = 0.0652 \text{ m} \rightsquigarrow \frac{h_{\text{sub}}}{\lambda_{\text{sub}}} \cong \frac{1}{81}$$

In case of thin substrates ($h/\lambda \leq 1/50$), the Antenna Toolbox suggests to mesh the antenna using dielectric in auto mode. The other two available substrate thicknesses (1.0 mm and 1.6 mm) have not been adopted because the Antenna Toolbox reference doesn't give any information about accuracy of the results in case of $h_{\text{sub}} \in \left(\frac{\lambda}{50}, \frac{\lambda}{10} \right)$.

B. PATCH PARAMETERS

$$L + W - w_{SC} = \frac{\lambda}{4} + h_{\text{sub}} \quad (2a)$$

$$W = \frac{\lambda_0}{2} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (2b)$$

$$BW_E = 2 \arccos \sqrt{\frac{7.03 \lambda_0^2}{4(3L_e^2 + h^2)\pi^2}} \quad (3a)$$

$$BW_H = 2 \arccos \sqrt{\frac{1}{2 + k_0 W}} \quad (3b)$$

$$\ell_{\text{feed}} = \frac{L}{\pi} \arccos \sqrt{\frac{R_{\text{in}}}{R_r}} \quad (4)$$

C. OVERALL ARRAY PERFORMANCE EVALUATION

IV. REFERENCE EXAMPLES

- Basic format for books:
J. K. Author, "Title of chapter in the book," in Title of His Published Book, xth ed. City of Publisher, (only U.S. State), Country: Abbrev. of Publisher, year, ch. x , sec. x , pp. xxx–xxx.
See [2], [3].
- Basic format for periodicals:
J. K. Author, "Name of paper," Abbrev. Title of Periodical, vol. x , no. x , pp. xxx–xxx, Abbrev. Month, year, DOI. 10.1109.XXX.123456.
See [1]–[4].
- Basic format for reports:
J. K. Author, "Title of report," Abbrev. Name of Co., City of Co., Abbrev. State, Country, Rep. xxx, year.
See [5], [6].
- Basic format for handbooks:
Name of Manual/Handbook, x ed., Abbrev. Name of Co., City of Co., Abbrev. State, Country, year, pp. xxx–xxx.
See [7], [8].
- Basic format for books (when available online):
J. K. Author, "Title of chapter in the book," in Title of Published Book, x th ed. City of Publisher, State, Country: Abbrev. of Publisher, year, ch. x , sec. x , pp. xxx–xxx. [Online]. Available: <http://www.web.com>
See [9]–[10].
- Basic format for journals (when available online):
J. K. Author, "Name of paper," Abbrev. Title of Periodical, vol. x , no. x , pp. xxx–xxx, Abbrev. Month, year, Accessed on: Month, Day, year, DOI: 10.1109.XXX.123456, [Online].
See [11]–[12].
- Basic format for papers presented at conferences (when available online):
J.K. Author. (year, month). Title. presented at abbrev. conference title. [Type of Medium]. Available: site/path/file
See [13].
- Basic format for reports and handbooks (when available online):
J. K. Author. "Title of report," Company. City, State, Country. Rep. no., (optional: vol./issue), Date. [Online] Available: site/path/file
See [14], [15].
- Basic format for computer programs and electronic documents (when available online):
Legislative body. Number of Congress, Session. (year, month day). Number of bill or resolution, Title. [Type of medium]. Available: site/path/file
NOTE: ISO recommends that capitalization follow the accepted practice for the language or script in which the information is given.
See [16].

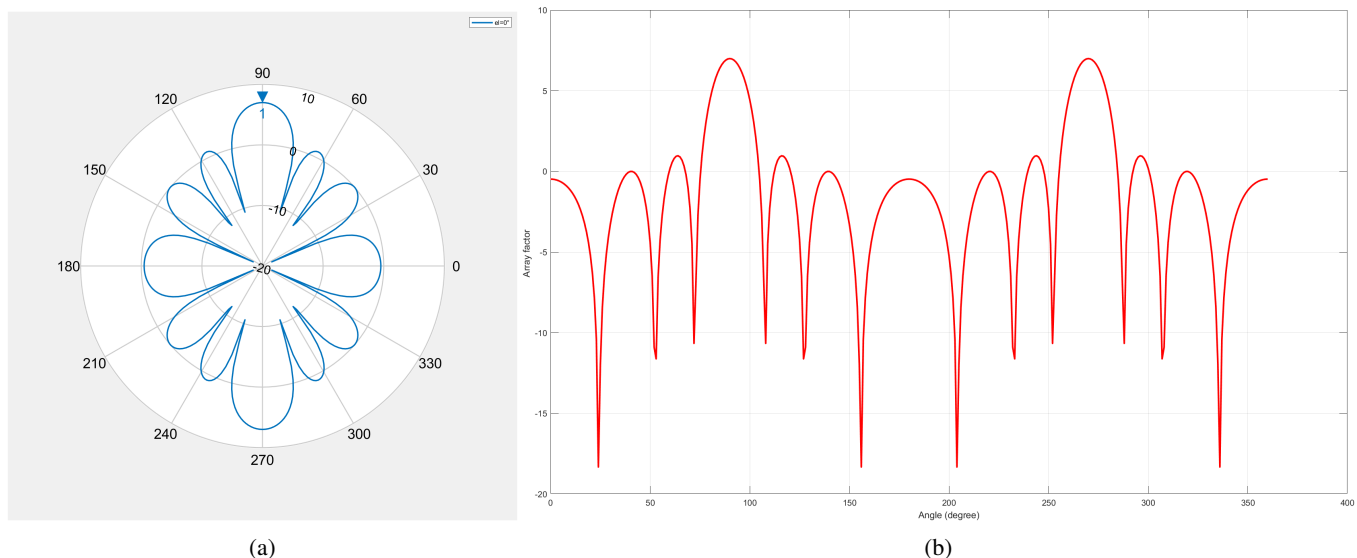


FIGURE 1: Array factor polar (a) and rectangular (b) diagrams

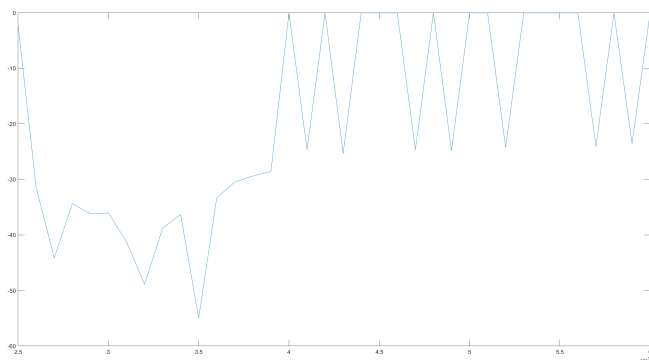


FIGURE 2: Minimum of the reflection coefficient Γ [dB] in the frequency range $2.0 \div 2.2$ GHz depending on the varying mesh density level

- Basic format for patents (when available online):
Name of the invention, by inventor's name. (year, month day). Patent Number [Type of medium]. Available: site/path/file
See [17].
- Basic format for conference proceedings (published):
J. K. Author, "Title of paper," in Abbreviated Name of Conf., City of Conf., Abbrev. State (if given), Country, year, pp. xxxxxx.
See [18].
- Example for papers presented at conferences (unpublished):
See [19].
- Basic format for patents:
J. K. Author, "Title of patent," U.S. Patent x xxx xxx, Abbrev. Month, day, year.
See [20].
- Basic format for theses (M.S.) and dissertations (Ph.D.):

- 1) J. K. Author, "Title of thesis," M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.
- 2) J. K. Author, "Title of dissertation," Ph.D. dissertation, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

See [21], [22].

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

- 1) J. K. Author, private communication, Abbrev. Month, year.
- 2) J. K. Author, "Title of paper," unpublished.
- 3) J. K. Author, "Title of paper," to be published.

See [23]–[24].

- Basic formats for standards:

- 1) Title of Standard, Standard number, date.
- 2) Title of Standard, Standard number, Corporate author, location, date.

See [25], [26].

- Article number in reference examples:

See [27], [28].

- Example when using et al.:

See [29].

REFERENCES

- [1] F. N. Author, The title of the online book, ser. Example series. P. Name, Apr. 2003. [Online]. Available: <http://books.google.es>
- [2] F. N. Author, Title of the book, 3rd ed., ser. series 1, vol. 4, ch. 8, pp. 201–213. The address of the publisher: The name of the publisher, Apr. 1993, an optional note.
- [3] F. N. Author, Title of the book, 3rd ed., ser. 10, vol. 4. Country: The name of the publisher, Apr. 1993, an optional note.
- [4] F. N. Author1, "The title of the article," Journal title, vol. 56, DOI XX/XXXX/ZZZ.XXXX.XXXXXXXX, no. 2, pp. 581–588, Feb. 2009.
- [5] F. N. Author1 and F. N. Author2, "The title of the conference," in Title of the Proceeding, vol. 3, DOI XX/XXXX/ZZZ.XXXX.XXXXXXXX, pp. 1–6, Apr. 2003.

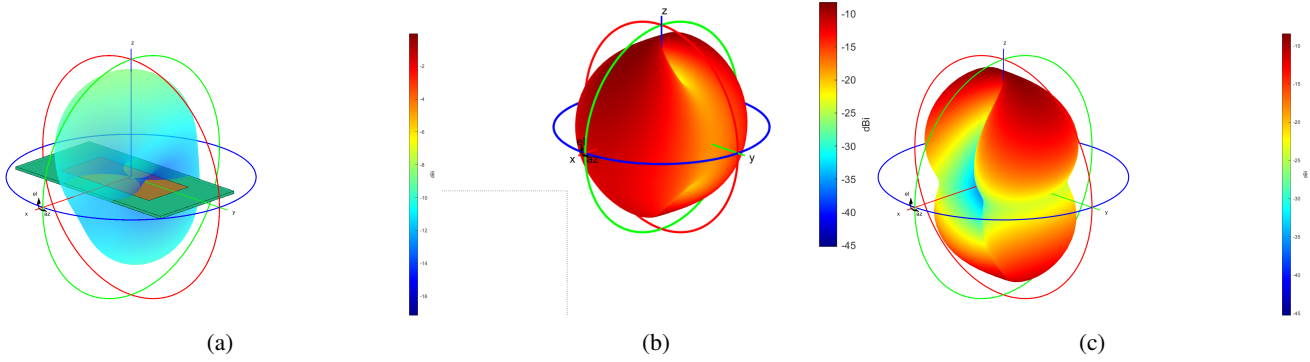


FIGURE 3: Gain pattern (a), gain pattern with vertical polarization (b) and with the horizontal one (c)

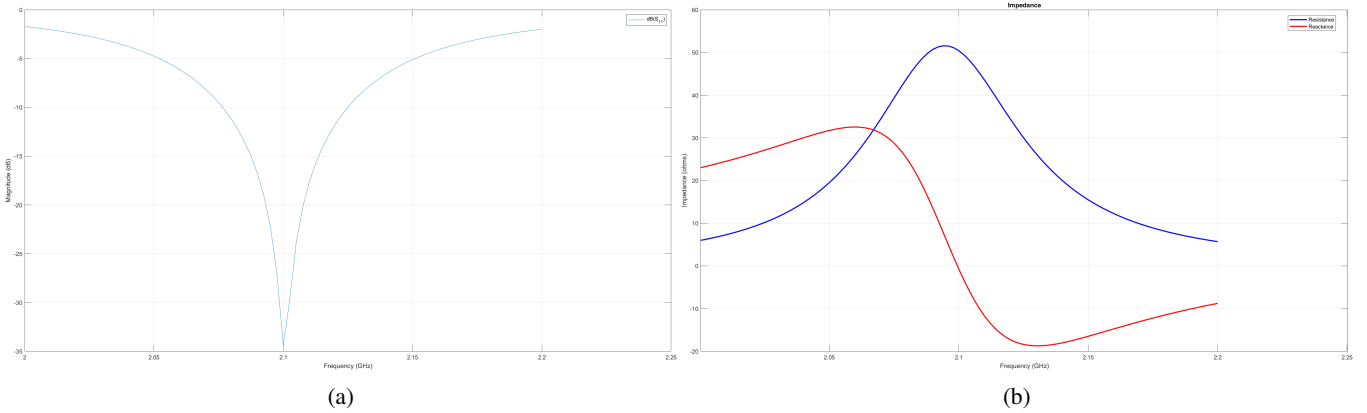


FIGURE 4: Reflection coefficient (left) and impedances (right) plots depending on $f \in 2.0 \div 2.1$ GHz

- [6] F. N. Author1, F. N. Author2, and F. N. Author3, "The title of the patent," Journal Name, no. 146643245, Oct. 1990.
- [7] F. N. Author1, "The title of the article," Journal title, vol. 1, DOI XX/XXXX/ZZ.XXXX.XXXXXXXX, no. 4, pp. 58–67, Jan. 2017.
- [8] T. Hansen. The multibib.sty package. (2004, Jan.). [Online]. Available: <http://www.ctan.org/tex-archive/macros/latex/contrib/multibib/>
- [9] P. Lehman. The biblatex package. (2007, Jan.). [Online]. Available: <http://www.ctan.org/tex-archive/macros/latex/exptl/biblatex/>
- [10] R. K. Gupta and S. D. Senturia, "Pull-in time dynamics as a measure of absolute pressure," in Proc. IEEE International Workshop on Microelectromechanical Systems (MEMS'97), pp. 290–294, Nagoya, Japan, Jan. 1997.
- [11] B. D. Cullity, Introduction to Magnetic Materials. Reading, MA: Addison-Wesley, 1972.
- [12] W. V. Sorin, "Optical reflectometry for component characterization," in Fiber Optic Test and Measurement, D. Derickson, Ed. Englewood Cliffs, NJ: Prentice-Hall, 1998.
- [13] J. B. Anderson and K. Tepe, "Properties of the tailbiting BCJR decoder," in Codes, Systems and Graphical Models, ser. IMA Volumes in Mathematics and Its Applications. New York: Springer-Verlag, 2000.
- [14] P. Hedelin, P. Knagenhjelm, and M. Skoglund, "Theory for transmission of vector quantization data," in Speech Coding and Synthesis, W. B. Kleijn and K. K. Paliwal, Eds., ch. 10, pp. 347–396. Amsterdam, The Netherlands: Elsevier Science, 1995.
- [15] R. M. A. Dawson, Z. Shen, D. A. Furst, S. Connor, J. Hsu, M. G. Kane, R. G. Stewart, A. Ipi, C. N. King, P. J. Green, R. T. Flegel, S. Pearson, W. A. Barrow, E. Dickey, K. Ping, C. W. Tang, S. V. Slyke, F. Chen, J. Shi, J. C. Sturm, and M. H. Lu, "Design of an improved pixel for a polysilicon active-matrix organic LED display," in SID Tech. Dig., vol. 29, pp. 11–14, 1998.
- [16] FLEXChip Signal Processor (MC68175/D), Motorola, 1996.
- [17] FLEXChip Signal Processor, MC68175/D, Motorola, 1996.
- [18] M. S. Yee and L. Hanzo, "Radial basis function decision feedback equaliser assisted burst-by-burst adaptive modulation," in Proc. IEEE Globecom '99, pp. 2183–2187, Rio de Janeiro, Brazil, Dec. 5–9, 1999.
- [19] M. Yajnik, S. B. Moon, J. Kurose, and D. Towsley, "Measurement and modeling of the temporal dependence in packet loss," in Proc. IEEE INFOCOM'99, vol. 1, pp. 345–352, New York, NY, Mar. 1999.
- [20] M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, "High resolution fiber distributed measurements with coherent OFDR," in Proc. ECOC'00, paper 11.3.4, p. 109, 2000.
- [21] B. Mikkelsen, G. Raybon, R.-J. Essiambre, K. Dreyer, Y. Su., L. E. Nelson, J. E. Johnson, G. Shtengel, A. Bond, D. G. Moodie, and A. D. Ellis, "160 Gbit/s single-channel transmission over 300 km nonzero-dispersion fiber with semiconductor based transmitter and demultiplexer," in Proc. ECOC'99, postdeadline paper 2-3, pp. 28–29, 1999.
- [22] S. G. Finn, M. Médard, and R. A. Barry, "A novel approach to automatic protection switching using trees," presented at the Proc. Int. Conf. Commun., 1997.
- [23] N. C. Loh, "High-resolution micromachined interferometric accelerometer," Master's thesis, Massachusetts Institute of Technology, Cambridge, 1992.
- [24] Q. Li, "Delay characterization and performance control of wide-area networks," Ph.D. dissertation, Univ. of Delaware, Newark, May. 2000. [Online]. Available: <http://www.ece.udel.edu/qli>
- [25] R. Jain, K. K. Ramakrishnan, and D. M. Chiu, "Congestion avoidance in computer networks with a connectionless network layer," Digital Equipment Corporation, MA, Tech. Rep. DEC-TR-506, Aug. 1987.
- [26] J. Padhye, V. Firoiu, and D. Towsley, "A stochastic model of TCP Reno congestion avoidance and control," Univ. of Massachusetts, Amherst, MA, CMPSCI Tech. Rep. 99-02, 1999.
- [27] D. Middleton and A. D. Spaulding, "A tutorial review of elements of weak signal detection in non-Gaussian EMI environments," National Telecommunications and Information Administration (NTIA), U.S. Dept. of Commerce, NTIA Report 86-194, May. 1986.
- [28] T. J. Ott and N. Aggarwal, "TCP over ATM: ABR or UBR," unpublished.

[29] V. Jacobson. Modified TCP congestion avoidance algorithm. end2end-interest mailing list. (1990, Apr.). [Online]. Available: <ftp://ftp.isi.edu/end2end/end2end-interest-1990.mail>



FIRST A. AUTHOR (M'76–SM'81–F'87) and all authors may include biographies. 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 (publisher name, year) similar to a reference. Current and previous research interests end the paragraph. The third paragraph begins with the author's title and last name (e.g., Dr. Smith, Prof. Jones, Mr. Kajor, Ms. Hunter). List any memberships in professional societies other than the IEEE. Finally, list any awards and work for IEEE committees and publications. If a photograph is provided, it should be of good quality, and professional-looking. Following are two examples of an author's biography.



SECOND B. AUTHOR was born in Greenwich Village, New York, NY, USA in 1977. He received the B.S. and M.S. degrees in aerospace engineering from the University of Virginia, Charlottesville, in 2001.

Since 2009, he has been an Assistant Professor with the Mechanical Engineering Department, Texas A&M University, College Station. He is the author of more than 150 articles. His research interests include high-pressure and high-density nonthermal plasma discharge processes and applications, plasma propulsion, and innovation plasma applications.

Dr. Author was a recipient of the International Association of Geomagnetism and Aeronomy Young Scientist Award for Excellence in 2008, and the IEEE Electromagnetic Compatibility Society Best Symposium Paper Award in 2011.



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, TX, USA.

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.

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).