Conversor WAV a MIDI de muestras monofónicas

[[1]](#footnote-1)

Matías A. Larroque, Lucero G. Fernández, Manuel F. Mollon, Tomas G. Orlando y Ezequiel Vijande

*Abstract*— En el trabajo se implementaron varios métodos de detección de tono, métodos de obtención de tempo y método de obtención de onset-offset de audios (formato .wav) con el fin de procesar cada resultado individual y crear un archivo MIDI a partir del audio original. La conversión es de un solo musical de cualquier instrumento compuesto de solo notas individuales, es decir una muestra monofónica. De los varios métodos implementados se analizo su eficiencia y se presentaron mejoras posibles a realizar en el futuro.

*Index Terms*—Procesamiento de señales, audio, tono, tempo.

# INTRODUCCION

E

L esquema elemental en el cual se basa este trabajo se puede ver en la figura (?). A lo largo del trabajo se explica en detalle la implementación de los diferentes algoritmos desarrollados para cada bloque, así como su eficiencia. Tras un trabajo de investigación y desarrollo de estos algoritmos, se implementaron en un programa principal los más eficientes con el fin de realizar con la menor cantidad de error la conversión WAV a MIDI.

La primera etapa corresponde a la detección de el onset y offset de las notas musicales (Onset/Offset Detection). El onset se determina al inicio de una nota musical y el offset se refiere al fin de la misma. Los algoritmos implementados detectan el inicio y el final de las notas con el fin de usar esa información para separar notas individuales que luego son procesadas por el detector de tonos (referenciado como pitch en adelante) y también para procesar el inicio y fin de las notas en el archivo MIDI.

La segunda etapa, en paralelo con la primera, es la detección del tempo en el audio (Tempo Detection). En esta etapa se calcula el tempo del audio medido en bpm (beats per minute) para luego usar esta información para la creación del MIDI.

De la primera etapa se usa la separación de notas para aplicar el algoritmo de detección de pitch como se menciono anteriormente. Este pitch de cada nota es usado luego para la conversión a MIDI.

# Deteccion de Onset y Offset

## Review Stage

Please check with your editor on whether to submit your manuscript as hard copy or electronically for review. If hard copy, submit photocopies such that only one column appears per page. This will give your referees plenty of room to write comments. Send the number of copies specified by your editor (typically four). If submitted electronically, find out if your editor prefers submissions on disk or as e-mail attachments.

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.

## Final Stage

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* or CD-ROM disks 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 information will be used to send each author a complimentary copy of the journal in which the paper appears. In addition, designate one author as the “corresponding author.” This is the author to whom proofs of the paper will be sent. Proofs are sent to the corresponding author only.

## Figures

Format and save your graphic images using a suitable graphics processing program that will allow you to create the images as PostScript (PS), Encapsulated PostScript (EPS), or Tagged Image File Format (TIFF), sizes them, and adjusts the resolution settings. If you created your source files in one of the following you will be able to submit the graphics without converting to a PS, EPS, or TIFF file: Microsoft Word, Microsoft PowerPoint, Microsoft Excel, or Portable Document Format (PDF).

## Electronic Image Files (Optional)

Import your source files in one of the following: Microsoft Word, Microsoft PowerPoint, Microsoft Excel, or Portable Document Format (PDF); you will be able to submit the graphics without converting to a PS, EPS, or TIFF files. Image quality is very important to how yours graphics will reproduce. Even though we can accept graphics in many formats, we cannot improve your graphics if they are poor quality when we receive them. If your graphic looks low in quality on your printer or monitor, please keep in mind that cannot improve the quality after submission.

If you are importing your graphics into this Word template, please use the following steps:

Under the option EDIT select PASTE SPECIAL. A dialog box will open, select paste picture, then click OK. Your figure should now be in the Word Document.

If you are preparing images in TIFF, EPS, or PS format, note the following. High-contrast line figures and tables should be prepared with 600 dpi resolution and saved with no compression, 1 bit per pixel (monochrome), with file names in the form of “fig3.tif” or “table1.tif.”

Photographs and grayscale figures should be prepared with 300 dpi resolution and saved with no compression, 8 bits per pixel (grayscale).

*Sizing of Graphics*

Most charts graphs and tables are one column wide (3 1/2 inches or 21 picas) or two-column width (7 1/16 inches, 43 picas wide). We recommend that you avoid sizing figures less than one column wide, as extreme enlargements may distort your images and result in poor reproduction. Therefore, it is better if the image is slightly larger, as a minor reduction in size should not have an adverse affect the quality of the image.

*Size of Author Photographs*

The final printed size of an author photograph is exactly  
1 inch wide by 1 1/4 inches long (6 picas × 7 1/2 picas). Please ensure that the author photographs you submit are proportioned similarly. If the author’s photograph does not appear at the end of the paper, then please size it so that it is proportional to the standard size of 1 9/16 inches wide by  
2 inches long (9 1/2 picas × 12 picas). JPEG files are only accepted for author photos.

*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](http://www.adobe.com/support/downloads/) (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.

*Print Color Graphics Requirements*

IEEE accepts color graphics in the following formats: EPS, PS, TIFF, Word, PowerPoint, Excel, and PDF. The resolution of a RGB color TIFF file should be 400 dpi.

When sending color graphics, please supply a high quality hard copy or PDF proof of each image. If we cannot achieve a satisfactory color match using the electronic version of your files, we will have your hard copy scanned. Any of the files types you provide will be converted to RGB color EPS files.

*Web Color Graphics*

IEEE accepts color graphics in the following formats: EPS, PS, TIFF, Word, PowerPoint, Excel, and PDF. The resolution of a RGB color TIFF file should be at least 400 dpi.

Your color graphic will be converted to grayscale if no separate grayscale file is provided. If a graphic is to appear in print as black and white, it should be saved and submitted as a black and white file. If a graphic is to appear in print or on IEEE Xplore in color, it should be submitted as RGB color.

*Graphics Checker Tool*

The IEEE Graphics Checker Tool enables users to check graphic files. The tool will check journal article graphic files against a set of rules for compliance with IEEE requirements. These requirements are designed to ensure sufficient image quality so they will look acceptable in print. After receiving a graphic or a set of graphics, the tool will check the files against a set of rules. A report will then be e-mailed listing each graphic and whether it met or failed to meet the requirements. If the file fails, a description of why and instructions on how to correct the problem will be sent. The IEEE Graphics Checker Tool is available at <http://graphicsqc.ieee.org/>

For more Information, contact the IEEE Graphics H-E-L-P Desk by e-mail at [graphics@ieee.org](mailto:graphics@ieee.org). You will then receive an e-mail response and sometimes a request for a sample graphic for us to check.



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.

## Copyright Form

An IEEE copyright form should accompany your final submission. You can get a .pdf, .html, or .doc version at <http://www.ieee.org/copyright>*.* Authors are responsible for obtaining any security clearances.

# Deteccion de Pitch

## Definicion

El tono (pitch) de una nota musical se refiere a la frecuencia percibida por el oído al escucharla. Esta misma coincide con la separación entre armónicos, la cual es la misma para todas.

Por lo que, si se computa la FFT, la frecuencia fundamental puede no estar presente, ya que, si los armónicos están espaciados una frecuencia f, esta será la fundamental y la percibida, sin que esta se encuentre presente en la señal. Esto trae problemas a la hora de encontrar la frecuencia fundamental, ya que esta puede no estar presente, y si lo está, no necesariamente es el máximo pico. Ya que hay instrumentos donde los armónicos son mas potentes que la fundamental en el sentido de densidad espectral. Por lo que para hacer una detección correcta se necesitan algoritmos más sofisticados. Algunos de estos fueron implementados y son explicados a continuación. Luego hay un análisis de resultados a partir de la implementación de los mismos en notas individuales de varios instrumentos.

## Algoritmo de Autocorrelacion

El algoritmo se basa en la función de autocorrelación de la nota en cuestión. La autocorrelación es definida de la siguiente manera:

Se puede probar que, si la función original es periódica de periodo tau, la autocorrelación también es periódica del mismo periodo. Se puede observar también como la autocorrelación debe dar un máximo en el corrimiento , ya que es la comparación de dos señales idénticas sin desfasaje. Por lo que si se encuentra el primer máximo de la función tras el origen, se encuentra el periodo de la función original, ya que se cumple:

Como la señal no es completamente periódica, encontrar el primer máximo no es sencillo ya que puede haber falsos picos que se aproximan al verdadero. Mas adelante en resultados se puede ver como este algoritmo falla en algunas ocasiones.

Para mejorar este algoritmo, se introduce un preprocesamiento de la señal, con el fin de reducir estos picos falsos y tener mayor planicie fuera de la región del máximo que se requiere. Este preprocesamiento introducido por [1] se puede ver en el siguiente diagrama (¿). Donde es una transformación lineal dada por:

Donde Cl es un threshold seteado experimentalmente como una fracción del máximo de la función original. Se encontró que el Cl optimo fue 0.68 para los instrumentos testeados. Luego de aplicar esta transformación y calcular la convolución, vuelve a buscarse el primer máximo, tarea simplificada por estas transformaciones. Como se puede ver en resultados, los picos falsos desaparecen y el algoritmo es mucho menos susceptible a errores de búsqueda del máximo verdadero. Este algoritmo resulto ser muy rápido y eficiente, ya que la convolución fue implementada con FFT. Al igual que todos los algoritmos descriptos en esta sección, falla para muestras de audio polifónicas, es decir, solo funciona para notas individuales y no acordes.

## Algoritmo Harmonic Product Spectrum

Este algoritmo, a diferencia del primero, no busca en el tiempo, sino que en frecuencia a través de la FFT.

El algoritmo se puede apreciar fácilmente en la siguiente imagen (¿). Consiste en generar la FFT de la señal original y de otras FFT de la señal downsampleada por un factor desde 2 a n, siendo n el número de armónicos a tener en cuenta. Al hacer el downsample, si el fundamental tiene armónicos, estos quedan alineados en la misma frecuencia. Luego de calcular todas las FFT, estas se multiplican entre si. En la frecuencia fundamental, se multiplicarán todos los armónicos generando un pico mayor al resto. Esta frecuencia donde el pico es mayor será la frecuencia fundamental, por lo que será el pitch de este. Con este algoritmo en ocasiones se puede producir un error de una octava. Un criterio introducido en [2] es TERMINAR.

El algoritmo resulto ser muy rápido y eficiente para todas las muestras testeadas, pero tuvo la desventaja ante la autocorrelación de necesitar un mayor número de muestras mínimas para estimar el pitch sin error.

## Algoritmo YIN

El ultimo algoritmo implementado es el algoritmo YIN, propuesto en [3]. El mismo se basa en la ecuación fundamental:

Donde se toma la diferencia, se eleva al cuadrado y se introduce la sumatoria:

Por lo que se computa esta función y se busca el primer cero de esta. La cual corresponde a el periodo de la frecuencia fundamental. La implementación en código de esta función es lenta, por lo que expandiendo la diferencia al cuadrado se puede usar propiedades de la convolución y de FFT para poder hacer una implementación más rápida:

Esta búsqueda puede ser difícil y poco precisa, por lo que se define una nueva función basada en esta:

Con esta nueva función, el pico correspondiente a la frecuencia fundamental queda mejor definido. Para encontrarlo, se elige el primer mínimo cercano a cero, debajo de un threshold.

## Implementación en un audio (WAV)

TABLA I

Resultados de implementacion en notas (NUMERO MIDI)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Instrumento (Nota) | Real | AC | AC  preporcesada | HPS | YIN |
| Saxo (B3) | 59.0 | 59.0 | 59.0 | 59.0 | 59.0 |
| Guitarra (G3) | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 |
| Trompeta (A4) | 69.0 | 69.0 | 69.0 | 69.0 | 69.0 |
| Violin (A4) | 69.0 | 69.0 | 69.0 | 69.0 | 69.0 |
| Cello (A#2) | 46.0 | 46.0 | 46.0 | 46.0 | 46.0 |
| Flauta (G5) | 79.0 | 79.0 | 79.0 | 79.0 | 79.0 |
| Oboe (E5) | 76.0 | 88.0 | 76.0 | 76.0 | 76.0 |
| Banjo (E6) | 88.0 | 88.0 | 88.0 | 88.0 | 88.0 |
| Clarinete (F5) | 77.0 | 85.0 | 77.0 | 77.0 | 77.0 |
| Tuba (A1) | 33.0 | 64.0 | 33.0 | 33.0 | 33.0 |
| Acorde Piano | 60.0 | 51.0 | 24.0 | 36.0 | 150.0 |
|  |

Valores en número MIDI de la nota, determinados redondeando al entero el resultado de la ecuación:

Tras implementar los algoritmos, se grabo una secuencia de varias notas y se corrió el algoritmo separando el audio en ventanas de un largo wLen y un overlap de wOverlap. En cada ventana se aplico el algoritmo y se guardo el pitch detectado. Luego de grafico esos pitches detectados conjunto con la grabación. Primero se aplicó el algoritmo sin criterio alguno, obteniendo (¿). Teniendo en cuenta que para el tamaño de la ventana no puede haber un solo pitch aislado, es decir, no puede una nota sonar tan poco tiempo, estas se cambiaban teniendo en cuenta los valores próximos. También se elegio un threshold por el cual, a menor amplitud, el audio era considerado ruido y no una nota. Tras aplicar estos criterios se obtuvo (¿) con el método de autocorrelación preprocesada. Al usar el método de HPS, como el tamaño de ventana era muy chico ara este algoritmo, se obtuvieron varios errores (¿). Estos se arreglaron agrandando el ancho de la ventana (¿). El algoritmo YIN tuvo el mejor desempeño, pero a su vez fue el que más tiempo llevo al no implementar la sumatoria con FFT. Si la sumatoria se implementa con FFT, el algoritmo YIN lleva menos tiempo de procesamiento y es el mas confiable.

## Resultados

Se creo un banco de pruebas con once instrumentos diferentes para probar los diferentes algoritmos implementados. Como se puede ver en la tabla, el algoritmo basado en la autocorrelación tuvo casos donde hay un error entre la nota real y calculada. Estos errores se arreglaron al introducir el preprocesamiento anteriormente explicado. Se puede ver esto en las figuras (¿). Ningún algoritmo tuvo éxito en la muestra polifónica, como era de esperarse.

# Deteccion de tempo

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/cm2 (100 Gb/in2).” 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 µ0*H*. Use the center dot to separate compound units, e.g., “A·m2.”

# Implementacion y resultados

## Figures and Tables

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 at the end of the paper. Large figures and tables may span both columns. Place figure captions below the figures; place table titles above the tables. If your figure has two parts, include the labels “(a)” and “(b)” as part of the artwork. Please verify that the figures and tables you mention in the text actually exist. **Please do not include captions as part of the figures. Do not put captions in “text boxes” linked to the figures. Do not put borders around the outside of your figures.** Use the abbreviation “Fig.” even at the beginning of a sentence. Do not abbreviate “Table.” Tables are numbered with Roman numerals.

Color printing of figures is available, but is billed to the authors. Include a note with your final paper indicating that you request and will pay for color printing. Do not use color unless it is necessary for the proper interpretation of your figures. If you want reprints of your color article, the reprint order should be submitted promptly. There is an additional charge for color reprints. **Please note that many IEEE journals now allow an author to publish color figures on Xplore and black and white figures in print. Contact your society representative for specific requirements.**

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 (Am−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 (103 A/m).” Do not write “Magnetization (A/m) × 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 12 point type.

## References

Number citations consecutively in square brackets [1]. The sentence punctuation follows the brackets [2]. Multiple references [2], [3] are each numbered with separate brackets [1]–[3]. When citing a section in a book, please give the relevant page numbers [2]. In sentences, refer simply to the reference number, as in [3]. Do not use “Ref. [3]” or “reference [3]” 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.

Number footnotes separately in superscripts (Insert | Footnote).[[2]](#footnote-2) 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).

Please note that the references at the end of this document are in the preferred referencing style. Give all authors’ names; do not use “*et al*.” unless there are six authors or more. Use a space after authors’ initials. Papers that have not been published should be cited as “unpublished” [4]. Papers that have been accepted for publication, but not yet specified for an issue should be cited as “to be published” [5]. Papers that have been submitted for publication should be cited as “submitted for publication” [6]. Please give affiliations and addresses for private communications [7].

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 [8].

## 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).

## 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

 (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 ... .”

## 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 “cm3,” not “cc.” Indicate sample dimensions as “0.1 cm × 0.2 cm,” not “0.1 × 0.2 cm2.” The abbreviation for “seconds” is “s,” not “sec.” Do not mix complete spellings and abbreviations of units: use “Wb/m2” or “webers per square meter,” not “webers/m2.” 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.

# conclusion y futuras mejoras

The word “data” is plural, not singular. The subscript for the permeability of vacuum µ0 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 Ni0.5Mn0.5 whereas “Ni–Mn” indicates an alloy of some composition NixMn1-x.

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).

An excellent style manual and source of information for science writers is [9]. A general IEEE style guide and an *Information for Authors* are both available at <http://www.ieee.org/web/publications/authors/transjnl/index.html>

Appendix

Appendixes, if needed, appear before the acknowledgment.

References

1. G. O. Young, “Synthetic structure of industrial plastics (Book style with paper title and editor),” in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.
2. W.-K. Chen, *Linear Networks and Systems* (Book style)*.* Belmont, CA: Wadsworth, 1993, pp. 123–135.
3. H. Poor, *An Introduction to Signal Detection and Estimation*. New York: Springer-Verlag, 1985, ch. 4.
4. B. Smith, “An approach to graphs of linear forms (Unpublished work style),” unpublished.
5. E. H. Miller, “A note on reflector arrays (Periodical style—Accepted for publication),” *IEEE Trans. Antennas Propagat.*, to be published.
6. J. Wang, “Fundamentals of erbium-doped fiber amplifiers arrays (Periodical style—Submitted for publication),” *IEEE J. Quantum Electron.*, submitted for publication.
7. C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.
8. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interfaces (Translation Journals style),” *IEEE Transl. J. Magn.Jpn.*, vol. 2, Aug. 1987, pp. 740–741 [*Dig. 9th Annu. Conf. Magnetics* Japan, 1982, p. 301].
9. M. Young, *The Techincal Writers Handbook.* Mill Valley, CA: University Science, 1989.
10. J. U. Duncombe, “Infrared navigation—Part I: An assessment of feasibility (Periodical style),” *IEEE Trans. Electron Devices*, vol. ED-11, pp. 34–39, Jan. 1959.
11. S. Chen, B. Mulgrew, and P. M. Grant, “A clustering technique for digital communications channel equalization using radial basis function networks,” *IEEE Trans. Neural Networks*, vol. 4, pp. 570–578, Jul. 1993.
12. R. W. Lucky, “Automatic equalization for digital communication,” *Bell Syst. Tech. J.*, vol. 44, no. 4, pp. 547–588, Apr. 1965.
13. S. P. Bingulac, “On the compatibility of adaptive controllers (Published Conference Proceedings style),” in *Proc. 4th Annu. Allerton Conf. Circuits and Systems Theory*, New York, 1994, pp. 8–16.
14. G. R. Faulhaber, “Design of service systems with priority reservation,” in *Conf. Rec. 1995 IEEE Int. Conf. Communications,* pp. 3–8.
15. W. D. Doyle, “Magnetization reversal in films with biaxial anisotropy,” in *1987 Proc. INTERMAG Conf.*, pp. 2.2-1–2.2-6.
16. G. W. Juette and L. E. Zeffanella, “Radio noise currents n short sections on bundle conductors (Presented Conference Paper style),” presented at the IEEE Summer power Meeting, Dallas, TX, Jun. 22–27, 1990, Paper 90 SM 690-0 PWRS.
17. J. G. Kreifeldt, “An analysis of surface-detected EMG as an amplitude-modulated noise,” presented at the 1989 Int. Conf. Medicine and Biological Engineering, Chicago, IL.
18. J. Williams, “Narrow-band analyzer (Thesis or Dissertation style),” Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.
19. N. Kawasaki, “Parametric study of thermal and chemical nonequilibrium nozzle flow,” M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.
20. J. P. Wilkinson, “Nonlinear resonant circuit devices (Patent style),” U.S. Patent 3 624 12, July 16, 1990.
21. *IEEE Criteria for Class IE Electric Systems* (Standards style)*,* IEEE Standard 308, 1969.
22. *Letter Symbols for Quantities*, ANSI Standard Y10.5-1968.
23. R. E. Haskell and C. T. Case, “Transient signal propagation in lossless isotropic plasmas (Report style),” USAF Cambridge Res. Lab., Cambridge, MA Rep. ARCRL-66-234 (II), 1994, vol. 2.
24. 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 (420-46)-3, Nov. 1988.
25. (Handbook style) *Transmission Systems for Communications,* 3rd ed., Western Electric Co., Winston-Salem, NC, 1985, pp. 44–60.
26. *Motorola Semiconductor Data Manual,* Motorola Semiconductor Products Inc., Phoenix, AZ, 1989.
27. (Basic Book/Monograph Online Sources) J. K. Author. (year, month, day). *Title* (edition) [Type of medium]. Volume (issue). Available: <http://www.(URL>)
28. J. Jones. (1991, May 10). Networks (2nd ed.) [Online]. Available: <http://www.atm.com>
29. (Journal Online Sources style) K. Author. (year, month). Title. *Journal* [Type of medium]. Volume(issue), paging if given. Available: <http://www.(URL>)
30. R. J. Vidmar. (1992, August). On the use of atmospheric plasmas as electromagnetic reflectors. *IEEE Trans. Plasma Sci.* [Online]. *21(3).* pp. 8 76–880. Available: http://www.halcyon.com/pub/journals/21ps03-vidmar

1. [↑](#footnote-ref-1)
2. 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. [↑](#footnote-ref-2)