

# **Author's Guidelines for the Transactions of the Institute of Electrical Engineers of Japan**

## **Table of Contents**

### **Preface**

#### **[1] Rules for Submission**

1. Qualifications of the Authors
2. Categories and Scope of IEEJ Transactions
3. Types of Submission and Requirements
  - 3.1 Requirements of Paper
  - 3.2 Requirements of Technical Note
  - 3.3 Requirements of Letter
  - 3.4 Requirements of Discussion
4. Receipt, Review, Evaluation and Deadline of Resubmission
5. URL for Paper Submission
6. Copyrights
7. Publication in the Electronic Journal

#### **[2] Guideline for Manuscript Preparation**

1. General Remarks
2. Preparation of Manuscript and Documents to be Submitted
  - 2.1 Preparation of Manuscript
  - 2.2 Documents to be Submitted
3. Language and Page Limitations
4. Manuscript Format
  - 4.1 Manuscript Format in Style File and Template
5. Guidelines for Manuscript Preparation
  - 5.1 Paper and Technical Note
  - 5.2 Letter
  - 5.3 Discussion
6. Procedures Following Acceptance

#### **[3] Publishing Fee**

1. Publishing Fee including Reprints
2. Support for Submission from Outside of Japan
3. Color Charges

**Table 1: IEEJ Transactions, Topical Categories and Scope**

**Table 2: Types of Submission and Forms to be Submitted (initial submission)**

**Table 3: Types of Submission and Forms to be submitted (revised submission)**

**Table 4: Publishing Fee including Reprints**

**Appendix 1: Sample of Paper and Technical Note**

**Appendix 2: Sample of Extended Summary**

(This guideline came into force on April 2000, and revised on September 2009)

# **Author's Guidelines for the Transactions of the Institute of Electric Engineers of Japan**

## **Preface**

Transactions of the Institute of Electric Engineers of Japan (IEEJ) are important source of information delivered monthly to the society members directly. The authors are advised to read the guidelines before submission as all papers and articles submitted to the IEEJ Transactions are processed according to these guidelines. As a general rule, Papers, Technical Notes, Letters and Discussions to be published in the IEEJ Transactions will be printed from the manuscript in style file submitted by the authors.

Papers, Technical Notes, and Letters to be published in the IEEJ Transactions will also be published in an electronic journal that is built on the "J-Stage" of the Japan Science and Technology Agency. IEEJ Transactions on Electrical and Electronic Engineering (Hereinafter referred to as "TEEE") will be published in Inter Science of John Wiley & Sons, Inc.

These Guidelines are an abridged translation of the guidelines in Japanese, and designed to help the authors who wish to submit papers or articles in English.

## **[1] Rules for Submission**

### **1. Qualifications of the Authors**

As a general rule, the authors should be a member of the IEEJ. However, a paper or an article submitted by only non-member authors will be accepted. In the case of the submission by only non-member authors, the applicable Publishing Fee including reprints is indicated in the Table 4-3 and 4-4.

### **2. Categories and Scope of IEEJ Transactions**

Attached Table 1 indicates the IEEJ Transactions their categories and scopes.

### **3. Types of Submission and Requirements**

There are four types of submission: Paper, Technical Note, Letter and Discussion. Other than these four types of submission, articles deemed appropriate by the Editorial Committee will be accepted for publication. (Hereinafter they will be referred to as Papers and Articles.)

#### **3.1 Requirements of Paper**

Papers published in the IEEJ Transactions should have the contents that contribute to the scientific research or technology in the electrical engineering, and should satisfy at least one of the following requirements (1) through (3), and the two essential requirements (4) and (5), below.

- (1) The paper is objectively judged to have creativity. (Creativity)
- (2) The paper is objectively judged to have originality. (Originality)
- (3) The paper is useful to the development of the scientific research or the technology. (Usefulness)
- (4) The paper contains no obvious error.
- (5) The paper should not be published in the other publications prior to submission to

IEEJ. The publications refer to the books and journals printed in Japan or elsewhere, and the in-house publication of the government, public institutions and the universities. However, in the following cases, the author may still submit the paper as a new paper.

- (a) Paper that had been previously published in the meetings or symposia or any such similar meetings, sponsored or co-sponsored by IEEJ prior to submission in the Transactions. This paper should also be non-problematic in the copyright law.
- (b) Paper that expands the Letter previously published as recent news in the Transactions.

### **3.2 Requirements of Technical Note**

Technical Notes to be published in the IEEJ Transactions must not be published in the other publications prior to submission to the IEEJ, and must meet one of the following criteria.

- (1) Systematic analysis of the existing theories.
- (2) Test results, test criteria, numerical tables and technical practice with universal interest.
- (3) Comprehensive report of scientific or technical topic that is worth specific attention at the time.
- (4) Other topics that are deemed to have scientific or technical contributions.

Authors may submit the contents, as a Technical Note, which had been previously published in the meetings or symposia or any such similar meetings, sponsored or co-sponsored by IEEJ prior to submission in the Transactions. This Technical Note should also be non-problematic in the copyright law.

### **3.3 Requirements of Letter**

Letters to be published in the IEEJ Transactions must not be published in the other publications prior to submission to IEEJ, and must meet one of the following criteria.

- (1) Recent News on a creative new research or technical developments.
- (2) Recent News on an original scientific study or technology.

Authors may submit the contents, as a Letter, which had been previously published in the meetings or symposia or any such similar meetings, sponsored or co-sponsored by IEEJ prior to submission in the Transactions. This Letter should also be non-problematic in the copyright law.

### **3.4 Requirements of Discussion**

Discussion of Paper, Technical Note and Letter and the responses from the author constitute Discussion. Authors should directly state the point of argument with only a short preamble. Objective of Discussion should be to help the authors to discover the truth. Discussion should state only what is relevant to the original article and should not touch upon items not relevant to the paper.

## **4. Receipt, Review, Evaluation and Deadline of Resubmission**

- (1) The papers and articles submitted are received by the IEEJ Editorial & Publishing Section, and the authors will receive acknowledgment of receipt with a paper number and the date of receipt. (Resubmitted papers and articles are treated in the same manner.) However when a paper or an article deviates significantly from the instructions described in these guidelines, the said paper or the article will not be accepted. And, any replacement of the papers and articles would be rejected once they submitted. Any

change and addition of the authors would be also rejected once they submitted.

- (2) The paper or article submitted will be reviewed in accordance with the “Rules for Paper Screening” by one or two or more referees who is a member of the Program Committee. Based on the comments of the referees, the editor in chief evaluates the paper and reports the results to the chairperson of the Editorial Affairs Committee. The chairperson of the Editorial Affairs Committee, based on this evaluation report, decides acceptance or rejection as categorized below, and then notify the author accordingly.

The Extended Summary will be read from a viewpoint of whether or not it has been prepared in such a manner that the outline of the paper is understandable. However, it will not be used for evaluation in things like deciding on whether to accept or reject the paper.

- (a) Publish as it is.
  - (b) Publish with minor revision. (Accept with change)
  - (c) Refer back to the authors for clarifications before decision on acceptance.  
(Reevaluation after Referral)
  - (d) Not to be published. (Reject)
- (3) When no response is received after 90 days of the paper being returned to the author for revision or clarification as described in the items (b) and (c) above, the submission will be erased from the data of IEEJ Paper Management System. Resubmission after 90 days will be considered as a new submission.
  - (4) Authors who wish to submit the papers and articles under submission to another journal must withdraw the submission from IEEJ Transactions before submitting to another journal.
  - (5) Paper screening procedure follows the steps described above and the IEEJ Editorial Affairs Committee shall not be held responsible for any liabilities incurred.

## **5. URL for Paper Submission**

Papers and articles should be submitted only through the IEEJ Paper Management System on the Web. For details, please visit the following website of the IEEJ;  
<http://www2.iee.or.jp/ver2/honbu/90-eng/14-magazine/index030.html>

## **6. Copyrights**

Copyrights of all papers and articles, appearing in the IEEJ Transactions shall be transferred to IEEJ. The authors should understand that the following applies to the copyright transfer. Completion of submission through the IEEJ Paper Management System on the Web will be considered that all the authors have read and understood the Copyright and Publishing rights in the Author’s Guidelines for the Transactions of IEEJ, and agree to all the items.

When the paper is rejected for publication, the copyright transfer becomes invalid from the moment the decision is made to reject the paper.

- (1) Copyrights (all of the rights stipulated in the provisions from Article 21 to Article 28 in the Japanese Copyright Law) are hereby transferred to the IEEJ.  
However, the authors reserves the following rights :
  - \*All proprietary rights other than copyright, such as patent rights
  - \*Re-use of all or part of the paper for their curriculum vitae
  - \*To make copies for his/her own purposes other than for commercial purposes

\*To use without violating the Japanese Copyright Law

(2) IEEJ agrees under the contract with John Wiley & Sons, Inc. (USA) to translate and publish in English journals “Electrical Engineering in Japan” or “Electronics and Communications in Japan” the papers and articles appeared in the IEEJ Transactions excluding “TEEE”. Authors may hear directly from John Wiley & Sons, Inc. about the publication in the said journals.

(3) Authors should be noted the following items in copyright transferring.

\*Authors should not submit the articles containing the same contents to multiple publications.

\*Authors should take full cautions in quoting articles from another work to avoid any infringement of copyrights.

\*All the persons who have made substantial contributions to the work shall appear as authors.

\*An agreement for publication shall be obtained in cases where it is necessary from a person having appropriate authority in any organization to which authors belongs.

As described above, IEEJ makes efforts to publicize the papers and articles by requesting the authors to transfer copyrights, without diminishing the author’s proprietary rights.

## **7. Publication in the Electronic Journal**

Papers, Technical Notes and Letters to be published in the IEEJ Transactions (excluding “TEEE”) will also be published in the electronic journal that is built on the “J-Stage” of the Japan Science and Technology Agency (JST). An Extended Summary will appear on the first page of these Papers and Technical Notes.

“TEEE” will be published in the form of an electronic journal on the website (Inter Science) of John Wiley & Sons, Inc..

## **[2] Guideline for Manuscript Preparation**

### **1. General Remarks**

IEEJ Transactions are public forum for communicating expeditiously and extensively to the members, the results of new research, development and applications that contribute to the scientific research and technology in the electric engineering. Therefore the authors should keep in mind to communicate effectively the information valuable and interesting to the members. Furthermore, to ensure that the paper is published in the Transactions promptly, it is necessary to reduce the time required for review, therefore, the authors should keep in mind the following points, when writing a manuscript.

(1) Ensure that the significance of the subject to be published and the results are understandable to the readers who are the specialists in the field as well as the non-specialists. Special attention should be taken when writing the abstract and the introduction.

(2) Express clearly, omitting the subjects irrelevant to the theme. Check elaborately for any spelling errors or typographical errors. We recommend the manuscript to be read by a reliable third person.

(3) Summarise the current status of study in the related field, and explicitly define the position of the content to be published.

- (4) Express clearly the creative, original or useful aspects of the paper to be published. For example, illuminate the points how theory, experimental methods or the results differ from the existing theories, methods or results.
- (5) Contents of the paper should be presented in a logical order and there should not be any leap of logic in the explanation.
- (6) A paper with a leap of logic in part will not be credible. Propriety of the hypothesis or the conditions which form the premise of the paper should be considered carefully and the universality should be illuminated.

## **2. Preparation of Manuscript and Documents to be Submitted**

### **2.1 Preparation of Manuscript**

As a general rule, a style file or a template submitted by the author for Paper, Technical Note, Letter and Discussion, will be used to print IEEJ Transactions. In this procedure, the electronic data as submitted by the author will be printed as it is, and the author should prepare the manuscript according to the paper format described in section “4. Manuscript Format.”

Manuscript should be prepared following the method indicated below.

(a) Manuscript prepared in style file or template

Please refer to the section “4.1 Manuscript Format in Style File and Template.” For instruction for downloading the LaTeX style file and MS-Word Template, please also refer to section 4.1

Authors, when preparing a manuscript, should be careful with the format and layout of manuscript, including the figures and tables, to ensure clarity and legibility.

### **2.2 Documents to be Submitted**

(1) Paper, Technical Note and Letter

For submission, please visit the IEEJ Paper Management System on the Web and complete the required information. All documents should be uploaded in PDF format to the IEEJ Paper Management System.

Forms to be submitted for initial and revised submission are indicated in the Table 2 and 3, respectively.

(2) Discussion

Please inquire the IEEJ Editorial & Publishing Section for details of style format.

## **3. Language and Page Limitations**

(1) All texts should be written in Japanese or English, provided however when the Program Committee approves, this will not be the case. In the case of submitting to “TEEE”, all texts have to be written in English only.

(2) Page Limitations (See Table 2)

(2.1) Paper and Technical Note

Paper and Technical Note should be 6 pages or less. However, Author may use up to the maximum of 14 pages, this is to say that the author is allowed to use 8 additional

pages if necessary. When an author submits two articles that are deemed to be of single topic, but divided into two submissions due to the page limitations, the author will be requested to rewrite and combine the two articles.

(2.2) Letter

Letter should not exceed 2 pages.

(2.3) Discussion

Discussion should not exceed 1 page.

## 4. Manuscript Format

### 4.1 Manuscript Format in Style File and Template

LaTeX Style File and MS-Word Template are available for downloading from the IEEEJ website at:

<http://www2.iee.or.jp/ver2/honbu/90-eng/14-magazine/index030.html>

Please ensure the described below when preparing the manuscript using LaTeX style file or MS-Word Template.

- (a) Figures and photographs in EPS formats should be electronically included in the manuscript.
- (b) Style file and template distributed should not be modified.

## 5. Guidelines for Manuscript Preparation (See Appendix 1)

### 5.1 Paper and Technical Note

(1) Style for Manuscript

(1.1) Prepare according to the steps (a) to (d) below, in reference to Appendix 1.

- (a) Title, name of the author(s), membership category
- (b) Abstract (150 to 200 words.)
- (c) Keywords
- (d) Author affiliation and contact information are to be given in footnotes in the left column of page one. (See Appendix 1 for details.)

(1.2) Keywords

Select six or less keywords that represent the theme of paper and place them under the summary with a comma separating each keyword. Words should be selected following the criteria below.

- (a) Select words or phrases with specific meanings.
- (b) Use nouns.
- (c) Abbreviations should be limited to those used and understood extensively in Japan and elsewhere. (New words coined by the author should not be used.)
- (d) Compound words should be limited to commonly used terms.

(1.3) Writing the main text

Text should be organized by their importance in the following order. Double line spaces before the Chapter heading.

Chapter: 1. Heading

Article: 1.1 Sub-heading

(1.4) Typeface and style

(a) Paper and Technical Note: Text must be in English.

(b) References

- References should include not only the author's own papers but the papers written by others, and ensure that appropriate and sufficient list of bibliography is provided. The author can not attach any reference material that are related to content of the paper submitted.
- All references should be numbered and listed at the end of the main text, and the numbers should be noted in the main text with a parenthesized number in superscript, where the reference is made in the main text.
- Committee reports and in-house reports not available to public should not be included in the references.
- Papers pending acceptance should not be quoted.
- Reference should be stated in the following manner.

Name of the author(s): "Title", Name of Publication, Volume, Number, Page  
(Year and Month of Publication)

Include all the author's names in full. Try to avoid abbreviating the title.

(1.5) Figures and Photographs

- (a) Place captions for figures and photographs directly below the figure or photograph described.
- (b) Figures and photographs should be serially numbered.
- (c) The size and position of figures inserted should be clearly legible to the readers.
- (d) When a figure does not fill the full column width, do not use the remaining space for text.

(1.6) Tables

- (a) Table captions should be placed above the table.
- (b) Tables should be serially numbered as for figures.

(1.7) Color Figures

- (a) Color figures, photographs and tables can be included in the manuscript. Please refer to [3] 3 for color charges in the print version. All figures submitted electronically in color will be published in color in the electronic journal version without charges.
- (b) Authors who wish to publish in color in the electronic version only, create the manuscript data in color. The black-and-white figures for print will be derived from the color data submitted by the authors. Authors have to create the manuscript data with care after confirming the figures appear clearly in the black-and-white print.
- (c) Authors who hope the black-and-white appearance for both the electronic and print versions, create the manuscript data in black and white.

(2) Author Introduction

Use the last seven lines of the text for author introduction. In principle, place a facial photo (28 mm (height) by 22 mm (width)) flush left under the name of the author. Following the membership category, write the short introduction. (See page 2 of Appendix 1)

(3) Extended Summary (Not applicable for submission of "TEEE")

Extended Summary should be prepared according to Appendix 2 so that it provides by itself an understandable outline of the paper, and it is also possible to include the figures and tables. The Extended Summary submitted will be published after formatting it on the

first page of the electronic journal that is built on the “J-Stage” of the Japan Science and Technology Agency (JST) and on the page next to the contents of the IEEJ Transactions.

LaTeX Style File and MS-Word Template are available for downloading from the IEEJ website at:

<http://www2.iee.or.jp/ver2/honbu/90-eng/14-magazine/index030.html>

(3.1) An Extended Summary on a single A4 page should be prepared for each Paper and Technical Note submitted. Outline of the paper should be understandable in the Extended Summary.

(3.2) Title, names, membership category and affiliation should be indicated at the top of page according to 5.1 (1) (a). When an E-mail address is provided, place the address with the affiliation in the parentheses as (Affiliation, E-mail address)

## **5.2 Letter**

### (1) Text

Follow (1) of 5.1 “Paper and Technical Note”. Abstract should be about 100 words.

### (2) Author Introduction

Author may include author introduction, but if an author introduction is included, the instruction in 5.1 (2) must be followed and it should be included within the page and/or word limitations. Author may omit facial photo.

## **5.3 Discussion**

Inquire the IEEJ Editorial & Publishing Section about the details.

## **6. Procedures Following Acceptance**

### (1) Submission of final manuscript

Author upon receiving the letter of acceptance, must submit the final manuscript following the instructions on the website.

### (2) Proofreading by the author

As a general rule, author will proof-read the final copy once.

## **[3] Publishing Fee**

### **1. Publishing Fee including Reprints**

When the paper or article is accepted for publication, the author will have to purchase 50 or more copies of the reprint at a fee. The publishing fee including reprints for Transactions A to E for members and non-members are indicated in the Table 4-1 and 4-3, respectively. As for “TEEE”, the publishing fee including reprints will be the half or less of the regular fee for Transactions A to E, in principle. For details, please refer to Table 4-2 for members and 4-4 for non-members. In the case of the submission by only non-Japanese authors from outside Japan, however, the applicable Publishing Fee including reprints is indicated in the Table 4-1 and 4-2.

If the payment is not received within one year after the publication, please note that we will reject any new submissions for all authors of the unpaid appropriate paper until the

outstanding payment is confirmed.

## **2. Support for Submission from Outside of Japan (Not applicable to “TEEE”)**

Non-Japanese authors submitting from outside of Japan who may have difficulties in paying the Publishing Fee including reprints indicated above, may apply for partial waiver of payment by submitting a letter of request at the initial submission. There is no special format for this letter of request. Please note that this support does not apply to “TEEE”.

## **3. Color Charges**

Presenting color figures, photographs and tables in print version can be done at the author's request and all charges for color are the responsibility of the author.

**Table 1: IEEJ Transactions, Topical Categories and Scope**

Society Transaction	Scope	
Transactions A (Fundamentals and Materials)	<p>(Common Interests)            Education and Research            Electromagnetic Theory            Electromagnetic Environment            Instrument and Measurement            Light Applications and Visual Science            History of Electrical Engineering</p> <p>(Fundamentals)            Discharges and Plasma            Pulsed Power</p>	<p>(Materials)            Dielectric Materials            Electrical, Electronics, and Insulating Materials            Metals and Ceramics            Magnetics</p>
Transactions B (Power and Energy)	<p>(Power System)            Power System Planning and Operation            Power System Control            Power System Analysis and Simulation            Power System Protection            Power System monitoring and Control            Energy System</p>	<p>(Energy Conversion and Transmission)            Transmission and Distribution Lines and Cables            Transmission and Distribution Apparatus, Insulators            Switchgear and Protective Devices, Lightning Protection, Arc Phenomena            Substation Apparatus and Devices            Superconducting Devices            High Voltage, Lightning and Surge            Energy Conversion and Storage            Other Power System Apparatus</p>
Transactions C (Electronics, Information and Systems)	<p>(Electronics)            Electronic Materials and Devices            Optics, Quantum Electronics            Electrical and Electronic Circuit, LSI            Information and Communication Technology            Biomedical Engineering</p>	<p>(Information and Systems Engineering )            Systems, Instrument, Control Intelligence, Robotics            Media Information, User Interface            Speech and Image Processing, Recognition            Softcomputing, Learning            Information System, Electronic Commerce            Information Processing, Software            Energy, Environment and Sustainability</p>

Society Transaction	Scope	
Transactions D (Industry Applications)	<p>(Power Electronics)  Power Semiconductor Devices and their Application  Power Converter and Control Circuit Topology  Power Supply  Electric Machine Control  Reactive Power Compensation and Harmonic Reduction  Metal and General Industry</p> <p>(Industrial System)  Industrial Instrument and Control  Production Facility Control  Information Oriented Industrial System  Public Facilities  Automobile Technology  ITS Technology</p>	<p>(Electrical Machinery and Apparatus)  Rotating Machine  Rotating Machine Characteristic  Linear Drives  Magnetic Levitation and Magnetic Bearing  Static Apparatus  Superconductive Application  Electric Railway</p>
Transactions E (Sensors and Micromachines)	<p>(Fundamental Technology)  Design, Analysis, Simulation  Material  Material and device characterization  Fabrication  Packaging and assembling</p> <p>(Microsystem)  Actuator  Optical microsystem  RF MEMS  Power MEMS  NEMS  New terrain in microsystem</p> <p>(Sensor system)  Sensing system  Sensing algorithm  Sensor network  Sensor application</p>	<p>(Physical sensor)  Mechanical sensor  Temperature and humidity sensor  Light, radiation sensor  Electrical, Magnetic sensor  Resonant sensor  Sensor using new theory or method</p> <p>(Chemical sensor)  Gas sensor  Ion sensor  Bio sensor  Biomimetic sensor  Micro-chemical sensor  Chemical sensor system</p> <p>(Bopmicrosystem)  BioMEMS  Micro-TAS  Lab-on-chip  Micro healthcare system</p>
TEEE (IEEJ Transactions on Electrical and Electronic Engineering)	Covering all fields from Transaction A to E described above.	

**Table 2: Types of Submission and Forms to be Submitted (initial submission)**

		Paper	Technical Note	Letter	Discussion
Standard Number of Pages (Maximum Number of Pages)		6 pages or less (14 pages)	6 pages or less (14 pages)	2 pages or less (2 pages)	1 page or less (1 page)
Documents to be Submitted	Manuscript	○	○	○	○
	Extended Summary (Not applicable for “TEEE”)	○	○	-	-

**Table 3: Types of Submission and Forms to be Submitted (revised submission)**

		Paper	Technical Note	Letter	Discussion
Documents to be Submitted	Revised Manuscript	○	○	○	○
	Extended Summary (Not applicable for “TEEE”)	○	○	-	-
	Response paper to the inquiry	○	○	○	○

**Table 4-1: Publishing Fee including Reprints for Transactions A, B, C, D & E for members**

	(yen)					
Number of Copies Printed pages	50	100	200	300	400	500
1 page	25,300	27,300	32,600	38,700	45,000	51,600
2 pages	37,300	39,300	44,600	50,700	57,000	63,600
3 pages	49,300	51,300	56,600	62,700	69,000	75,600
4 pages	61,300	63,300	68,600	74,700	81,000	87,600
5 pages	79,400	81,400	86,700	92,800	99,100	105,700
6 pages	91,400	93,400	98,700	104,800	111,100	117,700
7 pages	124,400	126,400	131,700	137,800	144,100	150,700
8 pages	154,400	156,400	161,700	167,800	174,100	180,700
9 pages	189,500	191,500	196,800	202,900	209,200	215,800
10 pages	219,500	221,500	226,800	232,900	239,200	245,800
11 pages	264,500	266,500	271,800	277,900	284,200	290,800
12 pages	304,500	306,500	311,800	317,900	324,200	330,800
13 pages	349,500	351,500	356,800	362,900	369,200	375,800
14 pages	389,500	391,500	396,800	402,900	409,200	415,800

\* the consumption tax for residents of Japan.

**Table 4-2: Publishing Fee including Reprints for TEEE for members**

	(yen)					
Number of Copies Printed pages	50	100	200	300	400	500
1 page	9,524	9,524	9,524	9,524	9,524	9,524
2 pages	19,048	19,048	19,048	19,048	19,048	19,048
3 pages	24,650	25,650	28,300	31,350	34,500	37,800
4 pages	30,650	31,650	34,300	37,350	40,500	43,800
5 pages	39,700	40,700	43,350	46,400	49,550	52,850
6 pages	45,700	46,700	49,350	52,400	55,550	58,850
7 pages	62,200	63,200	65,850	68,900	72,050	75,350
8 pages	77,200	78,200	80,850	83,900	87,050	90,350
9 pages	94,750	95,750	98,400	101,450	104,600	107,900
10 pages	109,750	110,750	113,400	116,450	119,600	122,900
11 pages	132,250	133,250	135,900	138,950	142,100	145,400
12 pages	152,250	153,250	155,900	158,950	162,100	165,400
13 pages	174,750	175,750	178,400	181,450	184,600	187,900
14 pages	194,750	195,750	198,400	201,450	204,600	207,900

\* the consumption tax for residents of Japan.

**Table 4-3: Publishing Fee including Reprints for Transactions A, B, C, D & E for non-members**

		(yen)					
Number of Copies Printed pages	50	100	200	300	400	500	
1 page	27,300	29,300	34,600	40,700	47,000	53,600	
2 pages	41,300	43,300	48,600	54,700	61,000	67,600	
3 pages	55,300	57,300	62,600	68,700	75,000	81,600	
4 pages	69,300	71,300	76,600	82,700	89,000	95,600	
5 pages	89,400	91,400	96,700	102,800	109,100	115,700	
6 pages	103,400	105,400	110,700	116,800	123,100	129,700	
7 pages	138,400	140,400	145,700	151,800	158,100	164,700	
8 pages	170,400	172,400	177,700	183,800	190,100	196,700	
9 pages	207,500	209,500	214,800	220,900	227,200	233,800	
10 pages	239,500	241,500	246,800	252,900	259,200	265,800	
11 pages	286,500	288,500	293,800	299,900	306,200	312,800	
12 pages	328,500	330,500	335,800	341,900	348,200	354,800	
13 pages	375,500	377,500	382,800	388,900	395,200	401,800	
14 pages	417,500	419,500	424,800	430,900	437,200	443,800	

\* the consumption tax for residents of Japan.

**Table 4-4: Publishing Fee including Reprints for TEEE for non-members**

		(yen)					
Number of Copies Printed pages	50	100	200	300	400	500	
1 page	10,524	10,524	10,524	10,524	10,524	10,524	
2 pages	21,048	21,048	21,048	21,048	21,048	21,048	
3 pages	27,650	28,650	31,300	34,350	37,500	40,800	
4 pages	34,650	35,650	38,300	41,350	44,500	47,800	
5 pages	44,700	45,700	48,350	51,400	54,550	57,850	
6 pages	51,700	52,700	55,350	58,400	61,550	64,850	
7 pages	69,200	70,200	72,850	75,900	79,050	82,350	
8 pages	85,200	86,200	88,850	91,900	95,050	98,350	
9 pages	103,750	104,750	107,400	110,450	113,600	116,900	
10 pages	119,750	120,750	123,400	126,450	129,600	132,900	
11 pages	143,250	144,250	146,900	149,950	153,100	156,400	
12 pages	164,250	165,250	167,900	170,950	174,100	177,400	
13 pages	187,750	188,750	191,400	194,450	197,600	200,900	
14 pages	208,750	209,750	212,400	215,450	218,600	221,900	

\* the consumption tax for residents of Japan.

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Paper

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# Analysis of SO<sub>2</sub> Measurement Accuracy by Multiwavelength DIAL

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Taro Denshi\* Member  
Hanako Denki\*\* Non-member

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This paper presents two multiwavelength methods to improve the accuracy of a DIAL system for measuring SO<sub>2</sub> in the lower atmosphere : a dual-DIAL method using three or four wavelengths, and a curvefitting method using five wavelengths. By the selection of appropriate wavelengths, these methods can eliminate the effects of ozone and aerosols. Since there is no significant difference in accuracy between the four wavelength dual-DIAL and curvefit methods, the former is advantageous for SO<sub>2</sub> detection in view of the measurement and data processing speeds.

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**Key words** : laser radar, SO<sub>2</sub>, DIAL, multiwavelength differential absorption

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Use 2 lines for the heading

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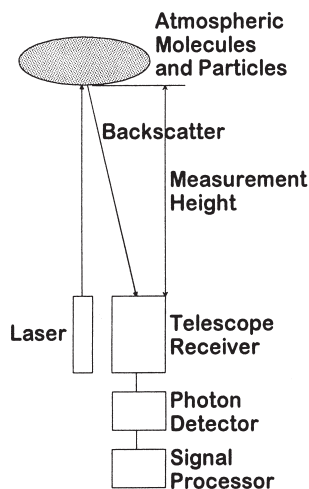
## 1. Introduction

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LIDAR (LIght Detection And Ranging) has been used for measurement of atmospheric pollutants by Raman scattering, resonant fluorescence, and differential absorption<sup>(1)</sup>. Fig. 1 is a schematic diagram of a LIDAR system. This apparatus transmits laser radiation into the atmosphere, collects light backscattered by atmospheric molecules and particulates using a receiving telescope, and converts it to an electric signal using a photodetector such as a photomultiplier tube. The measurement height is obtained from the time delay between illumination and detection. Therefore, to measure the height profile one measures the received photon counts as a function of time delay relative to illumination using a multichannel scaler. The measurement range resolution  $\Delta R$  is determined by the time width of the channel  $\Delta t = 2\Delta R/c$ , where  $c$  is the speed of light. The smaller the time  $\Delta t$ , the better the range resolution, but the photon count per channel becomes less and the relative error larger.

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Do not fill the blank space around the figures with text

Center the caption

Fig. 1. Schematic diagram of a LIDAR system.

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We performed a theoretical analysis of the measurement accuracy of conventional two-wavelength DIAL, and indicated the necessity of eliminating effects due to ozone and other substances which cause measurement error<sup>(5)</sup>. In this paper, we examined the measurement accuracy of dual-DIAL methods using three or four wavelengths (consisting of a combination of two two-wavelength DIAL pairs) and a curvefit method using five wavelengths.

## 2. Multiwavelength Differential Absorption

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**2.1 Fundamentals of DIAL** The received energy for a LIDAR is given by the following LIDAR equation :

(An equation starts at two-stroke indent)

$$E_r(R, \lambda_i) = [E_0 \eta A] \frac{\Delta R}{R^2} \beta_\pi(R) \times$$

$$\exp \left[ -2 \int_0^R (a_0 + a_x) dR' \right]$$

..... (1)

\*Technical Research Labs., Shin-nichi Electric Co., Ltd.  
7-2, Gobancho, Chiyoda-ku, Tokyo 102-0076  
\*\*Technical Labs., Kagoshima Electron Corp.  
2-100, Daikan-cho, Kagoshima 890-0099

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Table 2. Nominal parameters and rated values of tested DC servo motor. Center the caption

rated output	0.8 kW	$K_t$	0.48 N·m/A
rated current	11 A	$L$	1.8 mH
rated speed	1,750 rpm	$R$	0.66 $\Omega$
$K_e$	0.48 V·s/rad	$J$	$9.8 \times 10^{-3} \text{kg} \cdot \text{m}^2$

Double Space

Here  $E_r(R, \lambda_i)$  is the backscattered photon energy received from range between  $R$  and  $R + \Delta R$  from the illumination laser,  $\lambda_i$  the illumination wavelength,  $E_0$  the illumination energy,  $\eta$  the optical efficiency of the

#### 4. Conclusion

In this paper, we calculated the error due to ozone and aerosols in measurement of  $\text{SO}_2$  concentrations of ppb order using DIAL. The statistical error of the return signal and background noise can be overcome by improving the system constant (laser output, receiver area, optical efficiency of the receiver). On the other hand, systematic errors due to ozone and aerosols are inherent in the measurement method, and cannot be eliminated solely by improving the system constant. In conventional two-wavelength DIAL, the systematic error is over 1.5 ppb and the measurement accuracy is insufficient. In order to improve the measurement accuracy, a multiwavelength differential absorption method using three or more wavelengths is effective. In this paper we have considered dual-DIAL methods using three or four wavelengths and a curvefit method using five wavelengths, and indicated that the measurement errors due to ozone and aerosols can be reduced relative to conventional DIAL or eliminated. When these methods are compared, four-wavelength dual-DIAL is superior in view of measurement accuracy and measurement/processing speeds.

(Manuscript received September 25, 2009,  
revised March 10, 2010)

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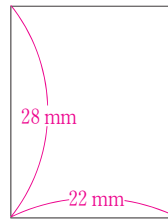
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Use boldface

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# Analysis of SO<sub>2</sub> Measurement Accuracy by Multiwavelength DIAL

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**Keywords** : laser radar, SO<sub>2</sub>, DIAL, multiwavelength differential absorption

LIDAR (Light Detection And Ranging) has been used for measurement of atmospheric pollutants by Raman scattering, resonant fluorescence, and differential absorption<sup>(1)</sup>. Fig.1 is a schematic diagram of a LIDAR system. This apparatus transmits laser radiation into the atmosphere, collects light backscattered by atmospheric molecules and particulates using a receiving telescope, and converts it to an electric signal using a photodetector such as a photomultiplier tube. The measurement height is obtained from the time delay between illumination and detection. Therefore, to measure the height profile one measures the received photon counts as a function of time delay relative to illumination using a multichannel scaler. The measurement range resolution  $\Delta R$  is determined by the time width of the channel  $\Delta t=2\Delta R/c$ , where  $c$  is the speed of light. The smaller the time  $\Delta t$ , the better the range resolution, but the photon count per channel becomes less and the relative error larger.

This paper examines DIAL (Differential Absorption Lidar), a method to obtain the concentration profile of the measurement target molecule from the backscatter intensity at two or more illumination wavelengths. The measurement target is atmospheric SO<sub>2</sub>, which is a substance causing acid rain. Until now, measurements of atmospheric SO<sub>2</sub> have been limited mainly to cases of localized SO<sub>2</sub> concentrations, e.g. smokestack exhaust and volcanic eruptions<sup>(2)-(4)</sup>. In these cases, the SO<sub>2</sub> concentration is over 100 ppb, therefore the measurement was relatively easy and the measurement accuracy was not a problem. However, when measuring SO<sub>2</sub> in the ambient atmosphere, its concentration is of ppb order, and the measurement accuracy becomes an issue. We performed a theoretical analysis of the measurement accuracy of conventional two-wavelength DIAL, and indicated the necessity of eliminating effects due to ozone and other substances which cause measurement error<sup>(5)</sup>. In this

paper, we examined the measurement accuracy of dual-DIAL methods using three or four wavelengths (consisting of a combination of two two-wavelength DIAL pairs) and a curvefit method using five wavelengths.

The received energy for a LIDAR is given by the following LIDAR equation:

$$E_r(R, \lambda_i) = [E_0 \eta A] = \frac{\Delta R}{R^2} \beta \pi(R) \times \exp\left[-2 \int_0^R (\alpha_0 + \alpha_x) dR'\right] \dots (1)$$

Here  $E_r(R, \lambda_i)$  is the backscattered photon energy received from range between  $R$  and  $R+\Delta R$  from the illumination laser,  $\lambda_i$  the illumination wavelength,  $E_0$  the illumination energy,  $\eta$  the optical efficiency of the

In this paper, we calculated the error due to ozone and aerosols in measurement of SO<sub>2</sub> concentrations of ppb order using DIAL. The statistical error of the return signal and background noise can be overcome by improving the system constant (laser output, receiver area, optical efficiency of the receiver). On the other hand, systematic errors due to ozone and aerosols are inherent in the measurement method, and cannot be eliminated solely by improving the system constant.

In conventional two-wavelength DIAL, the systematic error is over 1.5 ppb and the measurement accuracy is insufficient. In order to improve the measurement accuracy, a multiwavelength differential absorption method using three or more wavelengths is effective. In this paper we have considered dual-DIAL methods using three or four wavelengths and a curvefit method using five wavelengths, and indicated that the measurement errors due to ozone and aerosols can be reduced relative to conventional DIAL or eliminated. When these methods are compared, four-wavelength dual-DIAL is superior in view of measurement accuracy and measurement/processing speeds.

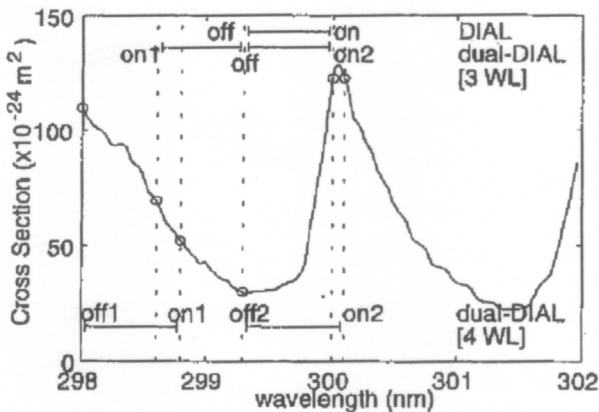


Fig. 1. Absorption cross section of SO<sub>2</sub> indicating wavelengths used in DLAL and dual-DIAL.

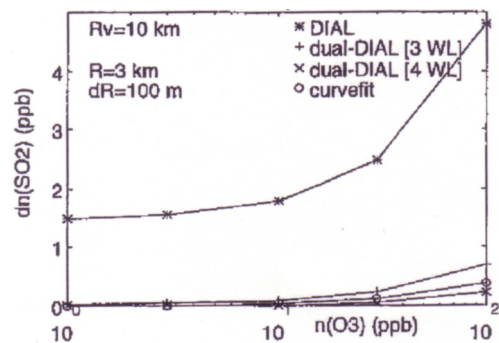


Fig. 2. SO<sub>2</sub> measurement error due to ozone.