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IEEE Transactions on Antennas and Propagation: A Bibliometric Study

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ABSTRACT

This paper examines the bibliometric analysis of 3442 papers published in the journal *IEEE Transactions on Antennas and Propagation* during the period 2010-2014. The data was taken from the archives of the journal available in printed and online form. The study focuses on the articles published with respect to year-wise growth of the articles published, authorship pattern, collaborative measures like collaborative index, degree of collaboration, collaborative coefficient, modified collaborative coefficient, subject-wise distribution of articles, contribution of Indian authors, contribution of each country based on authors' nationality, number of references in each issue, year-wise references and citation analysis on the articles published in this journal during the above period. Finally, contribution of Indian authors during these five years is also highlighted.

Keywords: Citation analysis, authorship pattern, degree of collaboration (DC), collaborative index (CI), collaborative coefficient (CC), modified collaborative coefficient (MCC).

1. INTRODUCTION

Bibliometrics is statistical analysis of written publications, such as books and articles. The most commonly used bibliometric methods are citation analysis and content analysis[1]. Citation links or references give the details of earlier work on the topic being discussed. The topics which are cited more shall have greater impact on the area of research. The impact is measured based on the number of citations received by articles to the number of articles published by the journal in two years. The term bibliometrics was coined in 1969 by Pritchard . Before 1969 it was either called statistical bibliography or it had no title at all. The terms bibliometrics, informetrics, scientometrics, librametrics, webometrics are derived from the term 'metrics'. These are the measuring techniques of knowledge in library and information science[2]. Bibliometrics and scientometrics are two closely related approaches to measuring scientific publications and science in general, respectively. These two methods are widely used for studying growth pattern of publications, citation analysis, to calculate the impact factor of a journal title, development of scope and spectrum of any area of research, and ranking of scholarly output of researchers and institutions and identifying the centres of excellance in academia.

There are famous laws of bibliometric, i.e., (Lokta, 1926) of scientific productivity, Broadford's law (Broadford, 1934) of scattering and Zips law (Zips, 1949) on frequency of words. However, the bibliometric study is unique and common to all the subjects after sixties[3]. Research has become a collective effort in all fields. It is seen that there is consistent increase towards collaboration in research in various disciplines. Scientists realise the necessity of collaboration in research in present era of Information explosion[4].

2. IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION

IEEE Transactions on Antennas and Propagation is a peer-reviewed scientific journal published by the IEEE Antennas and Propagation Society. It covers research on and applications of all aspects of antenna technology and the propagation of electromagnetic waves. It was established in 1952 and is published monthly along with occasional special issues. Its former name was I*RE Transactions on Antennas and Propagation*. The major disciplines covered include antenna technology, arrays and periodical structures, electromagnetics, numerical techniques, wave propagation, scattering, wireless and communications.

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By impact factor, it ranks 11 (out of 15) and by Eigen Factor score, it ranks 2 (out of 10) in the Telecommunications discipline. By Eigen Factor score the journal stands in the 10th position out of 10 in the Electrical and Electronic Engineering discipline. According to the Journal Citation Reports, the journal has a 2013 impact factor of 2.459. The journal does not find a place in the Article Influence score[5] in both the disciplines of Telecommunication, and Electrical and Electronic Engineering.

Human knowledge has grown exponentially in the recent years demonstrating the technological breakthroughs in every area of science and engineering. This has led to the publication of literature in considerable volumes. Periodicals have emerged as main transmitting media for dissipation of primary information and knowledge. Due to cost constraints and budget limitations, it is difficult for many libraries to procure all the periodicals of their interest. Bibliometric studies help the librarians to plan and procure the periodicals of high demand and also to indicate the fields of research which need more attention to the researchers[6,7,8].

3. OBJECTIVES OF THE STUDY

The objectives of the study are to understand the following regarding IEEE Transactions:

- Year-wise published articles
- Geographical distribution of journal articles
- Subject-wise coverage of the journal articles
- Contribution of Indian authors
- Year-wise authorship pattern
- Collaborative measures
- Number of references versus number of articles and;
- Citation analysis.

4. LITERATURE REVIEW

The following are some of the relevant studies worthy of examination.

Kumar & Moorthy[9] carried out bibliometric analysis of *DESIDOC Journal of Library and Information Technology* during 2001-2010 and concluded that the number of papers published increased after 2006, and the maximum number of papers were published in 2008 and 2009. The maximum number of single-authored papers was 37.6 % followed by two-authored papers with 36.9 %. Alka Bansal[10] extended the bibliometric analysis to 2012 and concluded that the maximum number of articles was published in 2012 and the maximum number of contributions has the length of 6-10 pages, and majority of the authors preferred journals as the source of their citation.

Gupta,[11] *et al*., analysed on the articles published all over the world in the area of the social science research in India during the period 2001-2010. The annual Indian output average growth rate in social science was 17.66 %, the average citation impact per paper was 1.53.

Rao[12] *et al*., analysed bibliometric analysis of the *Journal of Propulsion and Power* during the period 1985-2013. A total of 4047 articles were published and it is observed that USA produced 61.24 %, Japan 6.92 %, Republic of China' 3.8 %, Germany 3.25 %, UK 3.03 % and India 2.66 % of the total articles.

Garg & Anjana[13] examined authorship pattern, average length of articles in terms of pages, geographical distribution of articles, most prolific institutions and authors, and citations earned by the articles of *Journal of Intellectual Property Rights*.

C.P Salini[14], *et al*., analysed organic chemistry research in India. They compared the Indian output with that of leading countries using Exergy, an indicator which combines quality and quantity of publications. They have noted that organic chemistry research in India during 2004-2013 is equal to the world average and its growth pattern is positive and similar to worldwide research growth.

Thanuskodi[15] studied the *Journal of Social Sciences.* It has published 273 articles during the period of study. The highest number of articles appeared in the area of economics. Also, he examined the authorship pattern, subject-wise distribution of articles, average number of references per articles, forms of documents cited, year wise distribution of cited journals, etc.

Vellaichamy & Jeyshankar[16] investigated that a total of 158 papers were published in the *Journal of Webology* from 2004-2013. The degree of collaboration ranges from 0.182 to 0.693 and its mean value is found to be 0.44. Web analysis (24.68 %) and social media (15.82 %) papers are the top most publications in subject-wise analysis. India has contributed more number of articles compared to any other countries, such as Iran, UK, USA and Australia.

Kumar & Naqvi[4] caluculated collaboration measures like collaborative index (2.38), degree of collaboration (0.73), collaborative coefficient, and modified collaborative coefficient in the fields of natural sciences during 1971-2007. It was found that 231 (18.38 %) papers were written by single author and rest 1026 (81.62 %) papers were contributed by two or more authors.

5. METHODOLOGY

In the present study, 60 issues and 4 additional issues of *IEEE Transactions on Antennas and*

Propagation published during the period 2010- 2014 are considered. This is mainly to highlight the latest developments in this area of research. The details of the journal, viz., number of articles, number of authors, number of references, year-wise growth of papers, etc., are recorded to study and analyse its bibliometrics. The analysis has been carried out as per the objectives of the study.

6. ANALYSIS OF DATA

The analysis was carried out in two parts, viz., analysis of articles and analysis of citations.

6.1 Analysis of Articles

6.1.1 Year-wise Distribution and Growth of Journal Articles

Totally 3442 research papers were published by the journal during the period of study with an average of 688 research papers per year. Figure 1 shows that the maximum number of (789 articles, 22.92 %) articles were published in the year 2014 and minimum number (527 articles, 15.30 %) in 2010. There is a steadily increase in the number of articles from the year 2010 to 2014.

Figure 1. Year-wise distribution and growth of journal articles

6.1.2 Geographical Contribution of Journal Articles

In all, 86 countries have contributed articles during the period 2010-2014. Out of these, 21 countries contributed 50 or more articles with USA as leading followed by China, Canada, Italy, Spain and UK. India stood at the position 21 with 52 (1.51 %) papers. Fourteen countries contributed between 48 to 11 articles while the remaining countries contributed 1 or 2 articles in a year (Table 1).

6.1.3 Subject-wise Coverage of Articles

It is also necessary to examine the subject-wise publications in the major subjects of the journal which include antennas, arrays and periodical structures, electromagnetics, numerical techniques, wave propagation and scattering, wireless and communication. From Table 2 it is evident that the majority of publications are in the areas of communication, and antennas with 926 and 733 articles, respectively followed by 497 on numerical techniques and 476 on arrays and periodical structures. It shows that communication area received highest importance followed by Antennas and Numerical Techniques.

Table 1. Geographical contribution of journal articles during 2010-2014

S. No.	Country	Total (%)
1.	U.S.A	921 (26.75)
2.	China	572 (16.62)
3.	Canada	263 (7.64)
4.	Italy	247 (7.17)
5.	Spain	213 (6.19)
6.	U.K	213 (6.19)
7.	France	169 (4.91)
8.	Singapore	160 (4.65)
9.	Taiwan	153 (4.45)
10.	Japan	111 (3.22)
11.	Korea	105 (3.05)
12.	Sweden	99 (2.88)
13.	Germany	97 (2.82)
14.	Netherlands	87 (2.53)
15.	Belgium	82 (2.38)
16.	Australia	80 (2.32)
17.	Iran	80 (2.32)
18.	Finland	73 (2.12)
19.	Hong Kong	62 (1.80)
20.	Greece	54 (1.57)
21.	India	52 (1.51)

6.1.4 Contribution of Indian Authors

During the period of study, overall contribution of Indian authors is 1.51 %. The maximum contribution by India authors is in the area of communication followed by antennas. In all other fields, the contribution by Indian authors is less than 1 % (Table 3).

Table 2. Subject-wise coverage of articles during 2010-2014

Year	Antennas	Arrays & periodical structures	Electromagnetics	Numerical techniques	Wave propagation & scattering	Wireless	Commu-nication	Other areas	Total
Total	733	476	217	497	156	342	926	95	3442

Table 3. Contribution of Indian authors

S. No.	Year	Antennas	Arrays & periodical structures	Electromagnetics	Numerical techniques	Wireless	Communications	Total
1.	2010	2/104	0/71	0/38	0/58	0/32	5/156	7
2.	2011	1/128	1/79	0/33	0/100	0/46	5/166	7
3.	2012	5/156	1/107		0/144	1/92	6/188	13
4.	2013	5/169	1/127		2/172	1/92	4/199	13
5.	2014	4/176	1/92	1/146	1/23	1/80	4/217	12
6.	**Total**	**17/733 (2.32 %)**	**4/476 0.84 %**	**1/217 (0.46 %)**	**3/497 (0.60 %)**	**3/342 (0.88 %)**	**24/926 (2.6 %)**	**52 (1.51 %)**

6.1.5 Year-wise Authorship Pattern

Collaborative research is very much a feature of S&T especially during the 21st century. Table 4 reveals the authorship pattern of the articles published during the period of study. Maximum number, i.e., 991 (28.79 %) of articles were contributed by 3 authors. This is followed by 2 authors with 949 (27.57 %) articles, 4-author articles were 669 (19.44 %), 5-author articles were 351 (10.20 %), while single author contribution is 207 articles (6.01 %) only.

Table 4. Year-wise authorship pattern

S. No.	No of authors	2010	2011	2012	2013	2014	Total papers
1.	One	37	44	46	47	33	207
2.	Two	158	188	213	184	206	949
3.	Three	164	194	193	215	225	991
4.	Four	87	89	154	172	167	669
5.	Five	48	54	71	96	82	351
6.	Six	20	29	35	40	45	169
7.	Seven	7	6	19	15	20	67
8.	Eight	4	3	6	2	5	20
9.	Nine	2	1	1	3	5	12
10.	Ten	-	-	-	1	1	2
11.	Eleven	-	-	-	2	-	2
12.	Twelve	-	-	-	1	-	1
13.	Thirteen	-	-	-	1	-	1
14.	Forty eight	-	1	-	-	-	1
	Total	**527**	**609**	**738**	**779**	**789**	**3442**

6.1.6 Collaboration Measures

Different measures for collaboration are in vogue like collaborative index, degree of collaboration, collaborative coefficient and modified collaborative coefficient. The following notations are used in the equations to calculate collaborative index, degree of collaboration, collaboration coefficient and modified collaborative coefficient.

fj is number of papers having j authors during a certain period of time; N is the total number of papers published during a certain period of time, and k is the greatest number of authors per paper in a discipline.

(a) Collaborative Index (CI)

This is a measure of mean number of authors per paper. It is not easily interpretable as a degree. It has no upper limit and cannot be expressed as a percentage. It gives a non-zero weight to single authored papers, which involve no collaboration. To determine collaborative index, the formula given by Lawani[17] was used. The formula is:

$$CI = \frac{\sum_{j=1}^{k} j\left(f_j\right)}{N}$$

(b) Degree of Collaboration (DC)

The DC gives the proportion of multiple authored papers, as measures of strength of collaboration in a discipline. The DC can be interpreted as a degree, i.e., lies between 0 and 1. It gives a zero weight to single-authored papers, and does not differentiate among levels of multiple authorships.The DC equals 1 for maximal collaboration. To determine degree of author collaboration in quantitative terms, the formula given by K. Subramanyam[18] was used. The formula is:

$$C = \frac{Nm}{Nm + Ns}$$

where C is the degree of collaboration, Nm is number of multi authored papers, and Ns is the number of single authored papers. In the present study the average value of C is 0.94. As a result, the degree of author collaboration in the journal under study clearly indicates its dominance on multiple author contributions.

(c) Collaborative Coefficient (CC)

The CC was defined by Ajiferuke, *et al*.,[19]. It was designed to remove the short comings pertaining to CI and DC. The CC always lies between 0 and 1. As the number of single authors dominate, CC 0. CC distinguishes between single-authored, two authored, three-authored, etc. The problem with CC is that it does not give the value 1 for maximal collaboration except in the case where the number of authors is infinite.

The collaborative coefficient is defined as (CC), recreate as:

$$CI = 1 - \frac{\sum_{j=1}^{k} (1/j)(f_j)}{N}$$

(d) Modified Collaborative Coefficient (MCC)

CC gives 0 for single-auhored papers, but it does not give the value 1 for maximal collaboration. This is taken care of MCC which is defined by Savanur & Srikanth[20]

$$\kappa = \frac{A}{A-1}\left\{1 - \frac{\sum_{j=1}^{A} (1/j)(f_j)}{N}\right\}$$

Table 5. Collaboration measures during 2010-2014

Year	CI	DC	CC	MCC
2010	3.1347	0.92	0.60707	0.6082241
2011	3.1609	0.93	0.60277	0.6037613
2012	3.2818	0.94	0.62203	0.6228740
2013	3.4313	0.94	0.6371	0.6379188
2014	3.4258	0.96	0.64412	0.6449374
Average	**3.2869**	**0.94**	**0.622618**	**0.6235432**

Table 5 shows the various collaboration measures in the articles published in the journal. In this study, it is observed that collaborative index, degree of collaboration, collaborative coefficient and modified collaborative coefficient increased from 2010 to 2014 except in 2011(CC & MCC).

6.2 Citation Analysis

6.2.1 Number of References vs Number of Articles

Table 6 shows that there is a gradual increase in the number of references listed in articles from 2010 to 2014; maximum number of 19863 (24.22 %) references is in 2014. This may be because of the growth of interdisciplinary research and also the gradual increase in number of researchers (and so authors) as reflected in the increased number of papers published in that period. Accordingly,

Table 6. Number of references vs number of articles

Year	No. of references	Total no. of articles	Average ref per article
2010	11499	527	21.81
2011	13944	609	22.90
2012	17872	738	24.22
2013	18847	779	24.19
2014	19863	789	25.11
Total	**82025**	**3442**	**118.23/5= 23.646**

the average references per article also increased during the period covered from 21.81 in 2010 to a maximum of 25.11 in the year 2014 with an overall average 23.65 references per paper for the 5-year period.

6.2.2 Highest Cited Articles during 2010-2014

It is well established that articles receive citations over a period after publication; the citations increase gradually over a period of time from the year of their appearance in journals, reaching a peak and slowly fall down, the plot of which resembles a bell shape. Thus 10 papers published in 2010, two published in 2011 and one published in 2012 received more than 100 citations as shown in Table 7. It is also found that another 50 articles are cited in the range of 63-98 times. For the present study, articles with more than 100 citations are considered. The paper titled Analysis and Design of Ultra Thin Electromagnetic Absorbers Comprising Resistively Loaded High Impedance Surfaces received highest number of 194 citations, followed by Handling Sideband Radiations in Time-Modulated Arrays Through Particle Swarm Optimisation with 187 citations which may be on their way to become citation classics[21].

6. SUMMARY AND CONCLUSIONS

IEEE Transactions on Antennas and Propagation is a peer-reviewed scientific journal. It published 3442 papers during 2010-2014 with maximum number of 789 articles in 2014 and an average of 688 papers per year. It has been found that largest number of articles was published in the months of April, February, and June, mainly due to the publication of special issues in these months. These 3442 articles were contributed by 86 countries with a maximum number of 57 countries in the year 2013. Expectedly, most of the contributions (921) are from USA followed by China (572); India stands in the 21st position with 52 articles. The journal published 2374 articles in core areas, viz. communication (926), antennas (733), wireless (342), electromagnetics (217), wave propagation and scattering (156). These are the fields which received highest attention in research justifying the journal title *Antennas and Propagation.*

Table 7. Highly cited articles during 2010-2014

S. No.	Highest cited articles during 2010-2014	No. of times cited
1.	Analysis and Design of Ultra Thin Electromagnetic Absorbers Comprising Resistively Loaded High Impedance Surfaces. F Costa, A Monorchio, G Manara; Dept. of Inf. Eng., Univ. of Pisa, Pisa, Italy. *Antennas and Propagation, IEEE Transactions* on **58** (5), 2010, 1551-1558	194
2.	Handling Sideband Radiations in Time-Modulated Arrays Through Particle Swarm Optimisation. L Poli, P Rocca, L Manica, A Massa; Dept. of Inf. Eng. & Comput. Sci., Univ. of Trento, Trento, Italy. *Antennas and Propagation, IEEE Transactions* on **58**(4), 2010, 1408-1411	187
3.	Bayesian Compressive Sampling for Pattern Synthesis With Maximally Sparse Non-Uniform Linear Arrays G Oliveri, A Massa; Dept. of Inf. Eng. & Comput. Sci., Univ. of Trento, Trento, Italy *Antennas and Propagation, IEEE Transactions* on **59**(2), 2011, 467-481	134
4.	Harmonic Beamforming in Time-Modulated Linear Arrays. L Poli, P Rocca, G Oliveri, A Massa; Dept. of Inf. Eng. & Comput. Sci., Univ. of Trento, Trento, Italy.*Antennas and Propagation, IEEE Transactions on* **59**(7), 2011, 2538-2545	131
5.	Scalar and Tensor Holographic Artificial Impedance Surfaces; BH Fong, JS Colburn, JJ Ottusch, JL Visher, DF Sievenpiper; HRL Labs., LLC, Malibu, CA, USA. A*ntennas and Propagation, IEEE Transactions on* **58**(10), 2010, 3212-3221	122
6.	Optimal Frequency for Wireless Power Transmission Into Dispersive Tissue ASY Poon, S O'Driscoll, TH Meng; Edward S. Rogers Sr. Dept. of Electr. Eng., Stanford Univ., Stanford, CA, USA. *Antennas and Propagation, IEEE Transactions on* **58**(5), 2010, 1739-1750	121
7.	A Compact Tri-Band Monopole Antenna With Single-Cell Metamaterial Loading J Zhu, M Antoniades, GV Eleftheriades; Dept. of Electr. & Comput. Eng., Univ. of Toronto, Toronto, ON, Canada. *Antennas and Propagation, IEEE Transactions on* **58**(4), 2010, 1031-1038	109
8.	Asymmetric-Circular Shaped Slotted Microstrip Antennas for Circular Polarisation and RFID Applications. ZN Chen, X Qing; Inst. for Infocomm Res., Singapore, Singapore *Antennas and Propagation, IEEE Transactions on* **58**(12), 2010, 3821-3828	108
9.	Complex-Weight Sparse Linear Array Synthesis by Bayesian Compressive Sampling G Oliveri, M Carlin, A Massa; ELEDIA Res. Center DISI, Univ. of Trento, Trento, Italy *Antennas and Propagation, IEEE Transactions on* **60**(5), 2012, 2309-2326	108
10.	A Simple Ultrawideband Planar Rectangular Printed Antenna With Band Dispensation KG Thomas, M Sreenivasan; SAMEER-Centre for Electromagn., Chennai, India *Antennas and Propagation, IEEE Transactions* on **58**(1), 2010, 27-34	107
11.	Invasive Weed Optimisation and its Features in Electromagnetics S Karimkashi, A Kishk; Dept. of Electr. Eng., Univ. of Mississippi, MI, USA *Antennas and Propagation, IEEE Transactions on* **58**(4), 2010, 1269-1278	107
12.	Planar Monopole With a Coupling Feed and an Inductive Shorting Strip for LTE/GSM/UMTS Operation in the Mobile Phone; CT Lee, KL Wong; Dept. of Electr. Eng., Nat. Sun Yat-sen Univ., Kaohsiung, Taiwan; *Antennas and Propagation, IEEE Transactions on* **58**(7), 2010, 2479-2483	103
13.	Balanced Antipodal Vivaldi Antenna With Dielectric Director for Near-Field Microwave Imaging. J Bourqui, M Okoniewski, EC Fear; Dept. of Electr. & Comput. Eng., Univ. of Calgary, Calgary, AB, Canada. *Antennas and Propagation, IEEE Transactions on* **58**(7), 2010, 2318-2326	100

Expectedly majority of 991 (28.79 %) articles were contributed by 3 authors, clearly establishing the collaborative research in the frontier research fields of cutting edge technologies. This is supported by the maximum number of references (19863) listed by papers published in 2014 with an overall 23.65 references per paper with a peak of 25.11 references per paper in the year 2014. This fact also explains the vigorous research efforts made by a number of researchers worldwide in the core areas of the journal. The analysis clearly establishes the importance of one research paper published in the year 2010 which received 194 citations. The paper also establishes that apart from journals, conferences, symposia and letters also are used as primary mediums to publish research.

The present study has observed that the number of publications in the journal from Indian authors is very less when compared to European and Western countries. Although, India has third largest scientific community, its overall contribution is a mere 1.51 % with 2.6 % in the field of communication and 2.32 % in antennas. It indicates lack of infrastructure or lack of expertise to guide research in the area of antennas and wave propagation areas in the country and that more serious efforts are required to be done to increase scientific output in this crucial subject in the country. The major contribution of the Indian authors in this journal is in the area of communications.

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