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A Bibliometric Survey on Antipodal Vivaldi Antenna

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A Bibliometric Survey on Antipodal Vivaldi Antenna

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Abstract

In this paper bibliometric survey is presented on Antipodal Vivaldi Antenna. The Antipodal Vivaldi Antenna is a broad band and has symmetric E plane and H plane. It has been used extensively in radars, wireless communication and dual polarization applications. The antipodal Vivaldi antenna has significant researches in biomedical imaging, optical lens, Ground-Penetrating Radar (GPR) System, detecting cancer, 5G communications etc. The bibliometric analysis is done for the reason to understand the reach of antipodal Vivaldi antenna and performance enhancement analysis worldwide. The Scopus and web of science are used for accomplishing this survey. The study focuses on 449 documents of conferences, articles, book chapters, review etc in scopus, where in web of science the study was focused on 95 documents of articles. Web of science has research data base of AVA from 1980 and scopus has its database from 1993. The bibliometric analyses are done using i-mapbuilder, VOS builder, Word bar chart, Word It Out, etc in section 3. The bibliometric survey includes the research of document types, year of publications, the various sources involved in performing quality research, affiliations and funding agencies involved to make the research work completed and keywords. It was observed that documents published are mostly in English language. Apart from English language documentation is also done in Chinese and

Turkish. The study of this bibliometric analysis shows that the favorable field for antipodal Vivaldi antenna is done under Engineering and Computer Science fields.

Keywords: Scopus; Antipodal Vivaldi Antenna; Bibliometric; Applications; Survey

1. Introduction

The Vivaldi antenna is first introduced by Gibson in 1979 and later Antipodal Vivaldi Antenna (AVA) suggested by Gazit in 1988 [Gibson et al. 1979] [Gazit et al. 1988]. There have been rapid researches in domains of communication technology, Microwave imaging technology, ultra wideband (UWB) technology, etc. These technologies are used in industries, military, biomedical diagnostic systems, and other microwave imaging systems. Vivaldi antenna is used in these technologies due to its high directivity and broadband characteristics. The design of Vivaldi antenna using microstrip to slot line transition is very difficult in designing [Dixit et al. 2020] [Dixit et al. 2021]. Thus Antipodal Vivaldi Antenna is been designed to remove the feeding problem and making the design simpler. Antipodal Vivaldi antenna has 2 radiating arms which are 180◦ phase shifted. To improve the ultra wide band results, reducing antenna size, increasing gain, antipodal Vivaldi antennas are taken into consideration. The bibliometric survey presented here cover articles, author, country obtained from scopus and web of science. There are few advantages of antipodal Vivaldi antenna [Shevada et al. 2020]:

- High Gain
- Improved Return Loss
- High Efficiency
- Enhanced Beamwidth
- Low Sidelobe Level
- Compact Size
- Stable Radiation Pattern
- Higher Operating Frequencies
- More Front to Back Ratio

AVA has larger size as compared to microstrip patch antennas. Thus AVA cannot be rendered in application of 5G communication and smaller devices [Dixit et al. 2020]. In order to make the AVA design compact various methods can be applied: using meta-material, low tan δ substrate, low ε_r, shaping the flare of AVA, making slots of varied widths and positions, dielectric lens, array arrangement of AVA, and computational intelligence techniques. A high gain, small sized, wide bandwidth and less mutual coupling reduced back- and side-lobe levels is carried out by a corrugated and array combination [Dixit et al. 2020].

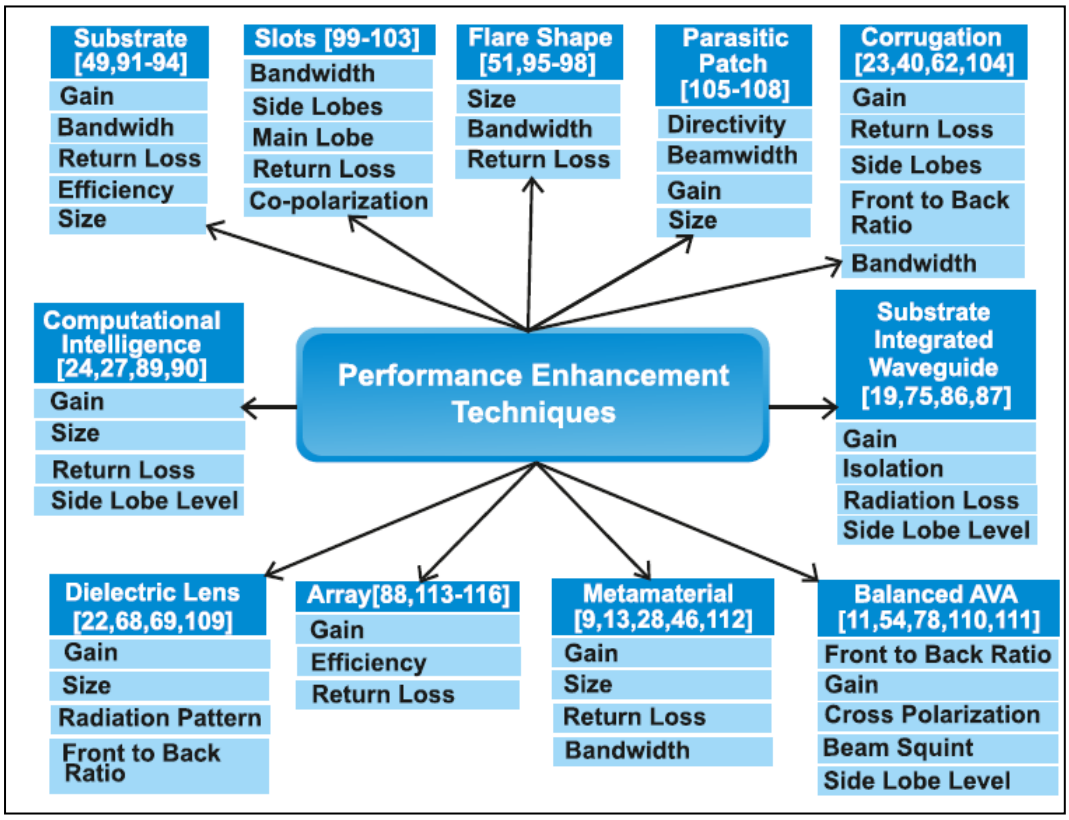

Figure 1: Performance enhancement techniques [Dixit et al. 2020]

The performance can be increased by following ways:

- Corrugation
- Metamaterial
- Array

- Dielectric Lens
- Parasitic Patch

To decide the dimension of antenna and to optimize the different antenna parameters, there are some techniques like Particle Swarm Optimization (PSO), Multi-objective PSO (MOPSO) and Multi-objective genetic algorithm. [Dixit et al. 2020]

Table 1: Techniques used to enhance performance of Vivaldi antenna [Dixit et al. 2020]

Techniques	**Reasons to use**
Particle Swarm Optimization	To reduce transient distortion, cross polarization and reflection coefficient
Multi-objective PSO	To enhance side lobe level and mutual coupling

If the size of AVA is reduced and performance is improved then AVA can be a good choice for mm-wave and UWB applications.

2. Need for bibliometric analysis

It is used to analyze books, articles, conference papers and other publications by statistical methods. The fields of library and information science mostly used bibliometric methods. Citation analysis is constructing the citation graph, these networks and graphs are the representation of document citation.

The mutual coupling can be reduced by various methods like Dielectric resonator antenna, electromagnetic Defected Ground Structures, Electromagnetic Bandgap Structure, Neutralization lines Metamaterial [Malekar et al. 2020] [Shevada at al. 2020]. Therefore a quantitative analysis will make the researchers of antipodal Vivaldi antenna to understand the background, varied fields, providing new opportunities [Dixit et al. 2020]. A detail study of different antenna designs where antenna designs are compact, efficient and isolated improves the performance of antenna [Kumar et al. 2020] [Dixit et al. 2020]. The various ways to represent the data of documents per year, Publishing authorities and the involvement of countries and institutes are referred [Patil et al. 2020]. The study on beam forming methods for 5G communication and high gain antenna for its applications in industrial, radar communication and commercial places made various systems and technology more easier

and efficient [Bhadoria et al. 2018] [Shevada et al. 2021] [Raut et al. 2021] [Gunjal et al. 2020]. The source publications which cover AVA are 52 sources from 1993 to 2021. The mostly used source by the researchers is “Microwave and Optical Technology Letters” and “IEEE Antennas and Propagation Society APS International Symposium Digest”. Paul Otlet was first one to use bibliometric in 1934 [Otlet 1934]. In 1969 a paper published by Alan Pritchard which was titled as "The application of mathematics and statistical methods to books and other media of communication" [Pitchard 1969].

The papers presented on the title of antipodal Vivaldi antenna are available in English, Chinese and Turkish. The first document was published in 1993 and till 2004, the number of researches on this title were very few. It was the year 2006, in which some quality amount of researches was published. After 2019 new researches have been dropped by significant numbers. Fayu Wan, Jun Chen and Binhong Li are the first one to documented antipodal Vivaldi antenna work with trapezoidal dielectric substrate [Wan et al. 2018]. The operational frequency was 3.3 to 40 GHz, using dielectric substrate of Rogers RO4003C.

2.1 Keywords

To obtain the bibliometric analysis keyword searched is “antipodal” AND “Vivaldi” AND “antenna”. From Table 2, we found that antipodal Vivaldi antenna is searched for 34 times and then microwave antenna is the hot topic among researchers.

It is also seen that “Vivaldi antennas” and “Vivaldi antenna” are also been popular in terms of antenna designing with the improved results and applications.

The keyword shows 449 document results were obtained, for 110 secondary documents and 136 patents have been registered. The keyword is searched for antipodal Vivaldi antenna and medical, polarizations, enhancement, wideband, directional are the related keyword to antipodal Vivaldi antenna.

Table 2: Selection of search keywords for antipodal Vivaldi antenna

Keywords searched in scopus	Search results in Scopus (No. of documents)
Antipodal Vivaldi Antenna	314

Microwave Antennas	195
Ultra-wideband (UWB)	172
Directional Patterns (antenna)	132
Vivaldi Antennas	125
Slot Antennas	119
Antennas	115
Antenna Arrays	92
Bandwidth	75
Vivaldi Antenna	67

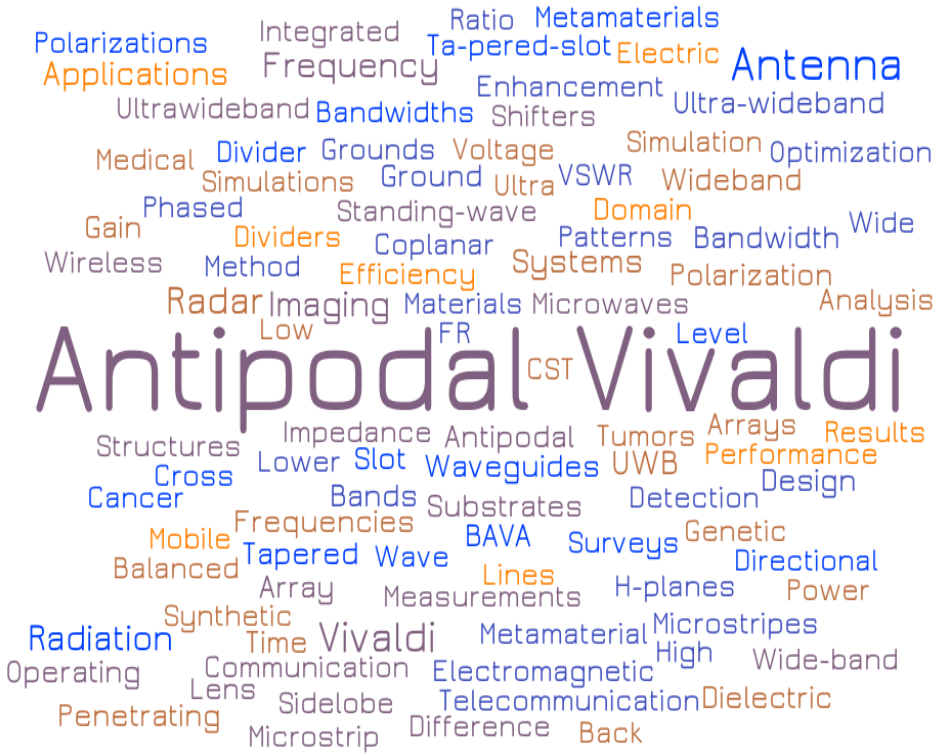

Figure 2: Word cloud of searched keywords

3. Bibliometric Analysis of AVA

To find the current research and issues faced in getting highly performed Antipodal Vivaldi Antenna, web of science and scopus is used. These platforms shows the information of paper published in various countries, contribution of institutes, application in fields, year wise work published in journals etc. In scopus there is facility that there are some plots are already available and in web of science all the plots are to be generated from other third party

softwares. All the fetched data and it pictorial and graphical representation is discussed in the following sections.

3.1 Source Title Statistics

The keyword searched for “Antipodal Vivaldi Antenna” Figure 3 and Figure 4 shows source statistics for AVA from scopus. There were 449 documents present in scopus list in the area of antipodal Vivaldi antenna.

Many documents type are present and these are submitted to an online and offline platform for the recognition and giving valuable assets to society. These platforms are sources. In this bibliometric analysis a brief analysis of source title has been shown through graphs.

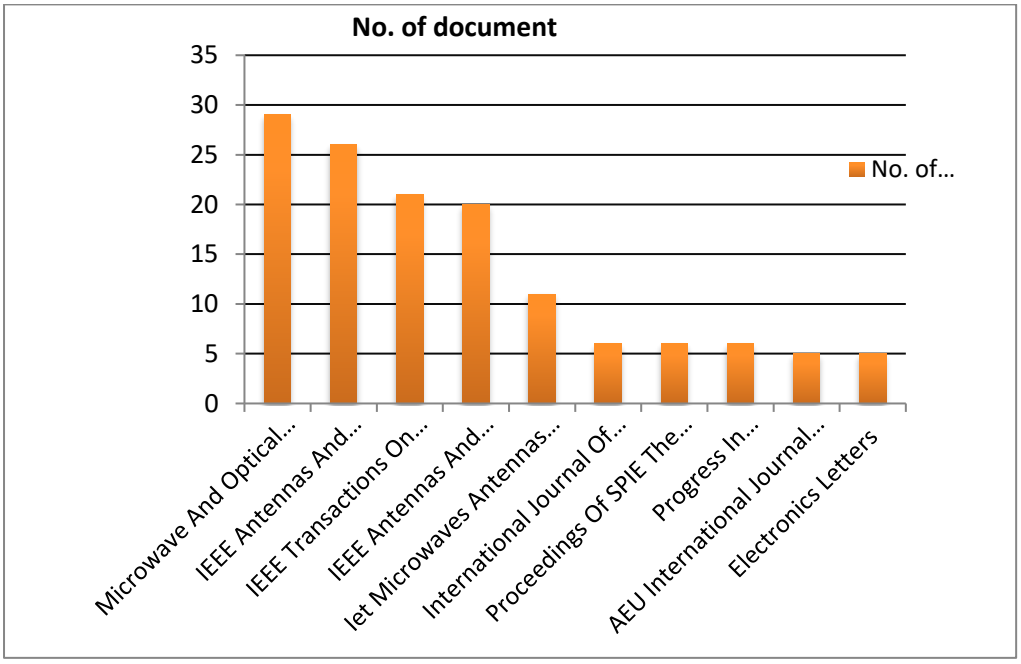

Figure 3: Statistics of source title and their corresponding number of documents from scopus

In Figure 3, the top ten mostly contributed sources have been shown. The graph shows that maximum numbers of publications are from Microwave and Optical Technology Letter, IEEE Antennas and Propagation Society APS International Symposium Digest.

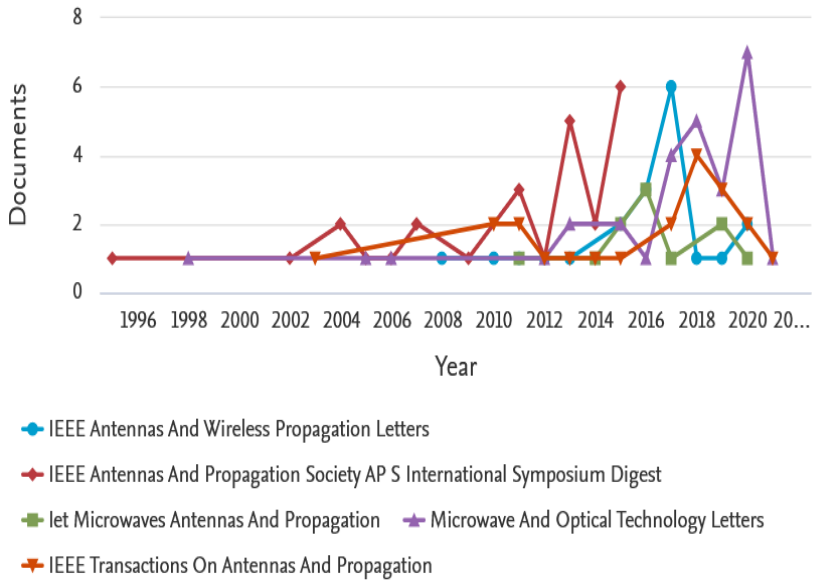

Figure 4: Documents per year by different sources from scopus

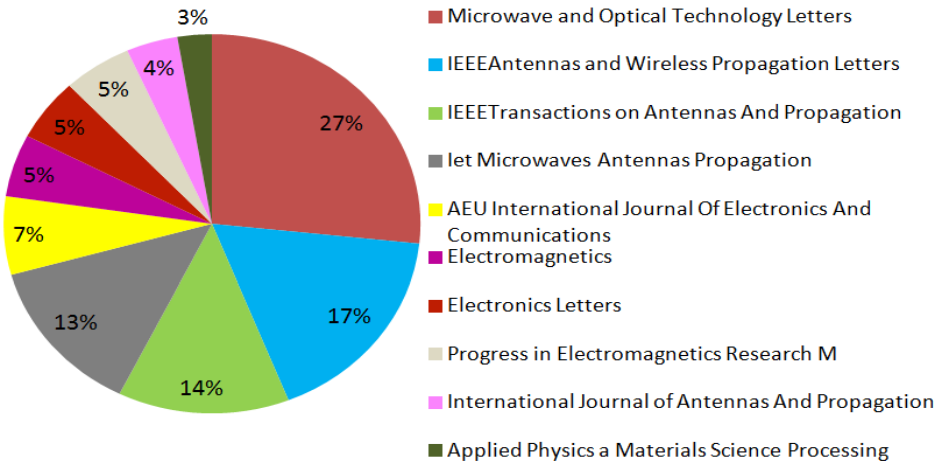

Figure 5: Statistics of source title and number of documents from web of science

Figure 4 source statistics of source title obtained from web of science. According to web of science, there are 95 records for keywords “antipodal” AND “Vivaldi” AND “antenna”. 29 numbers of documents were published in Microwave and Optical Technology Letters and IEEE Antennas and Wireless Propagation Letters. Figure 3 shows the document per year by source. IEEE Antennas and Propagation Society APS International Symposium Digest have started publishing document in 1995 and Microwave and Optical Technology Letters has longest span from 1998 to 2021. The source title contribution in antipodal Vivaldi antenna is

shown in Figure 5. The maximum numbers of papers are published under Microwave and Optical Technology Letters i.e. 33.

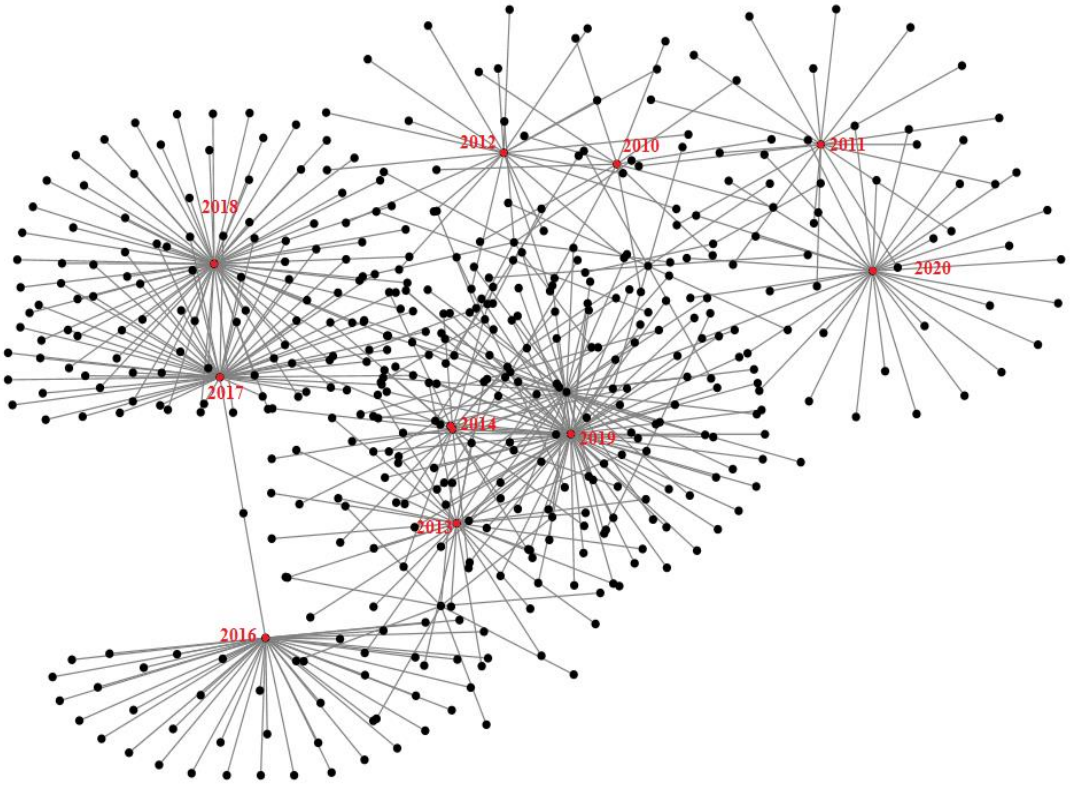

Figure 6: Node presentation of documents published for each year

3.2 Articles per year analysis

In comparison with the bar graphs and table format, representation nodes and branches shows better visualization. Using NodeXL tool year of publication and the publication titles are connected. The nodes represent the year and the connecting branches to other nodes show the amount of publications in that particular year. The denser node graph shows that the amount of publication in that year is very high and same goes with the lesser denser nodes.

3.3 Document Published in Affiliations and Country

Affiliation and country publication count from 1993 to 2021 is shown in Figure 7. The Figure 7 shows that top countries and number of documents published related to antipodal Vivaldi

antenna using scopus. China has highest number of documents and then United States has second highest publications. Figure 7 shows countries and publications of document in area of AVA from WoS. The maximum number of document published by Peoples R China and then by China. From Table 3 and Figure 7 it is concluded that China has large of publications in domain of antipodal antenna. They have started their contribution from 2012 with 7 articles.

Table 3: Contribution of countries in publication in area of antipodal Vivaldi antenna

COUNTRIES	NO. OF DOCUMENTS
China	107
United States	57
India	46
Canada	27
Australia	21
Iran	20
Malaysia	20
Saudi Arabia	15
Germany	14
United Kingdom	14
France	12
Algeria	10
Indonesia	9
Japan	9
South Korea	9
Turkey	9
Ireland	8
Brazil	7
Czech Republic	7
Egypt	7
Pakistan	7
Netherlands	6
Singapore	6
Tunisia	6
Italy	5
Peru	5

Russian Federation	5
Lebanon	4
Taiwan	4
Viet Nam	4
Bangladesh	3

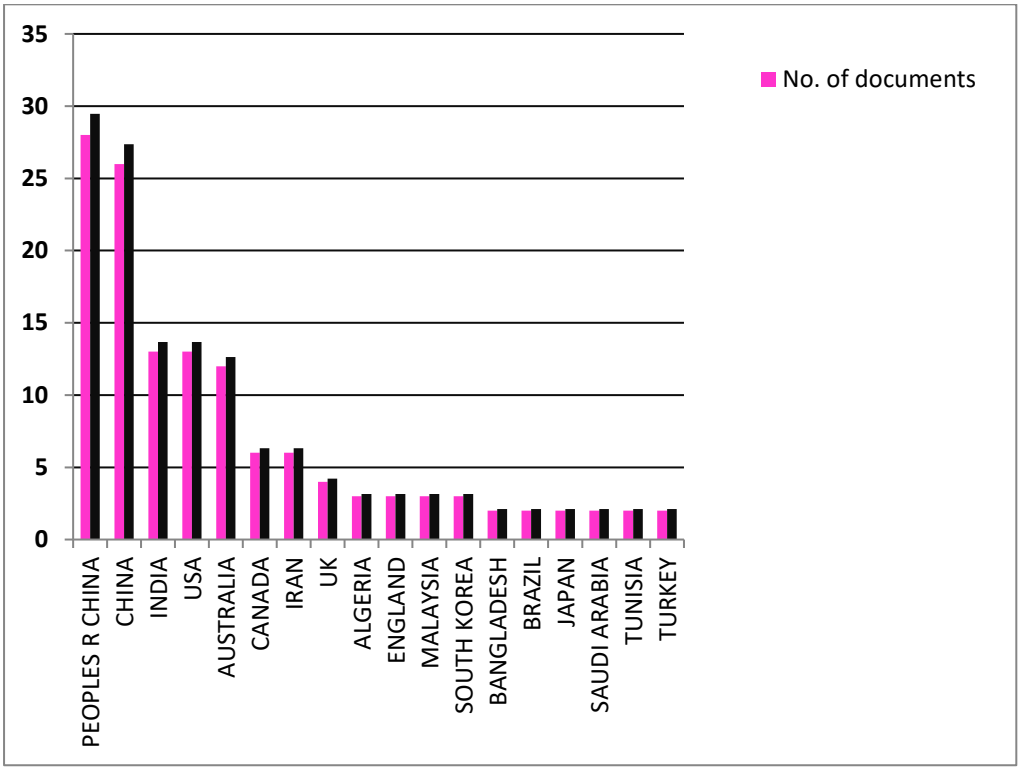

Figure 7: Country contribution in publication in area of AVA

China has researched about High gain of antipodal Vivaldi antenna, Ultra wideband, miniaturization, beam synthesis accuracy and scanning performance, 5G Mobile Communication, microwave imaging system, Printed Antipodal Vivaldi Antenna, balanced antipodal Vivaldi antennas, performance enhancement of antipodal Vivaldi antenna. Among these 101 papers are published in English language and 6 articles are published in Chinese language. Harbin Institute of Technology has contributed the maximum work with 16 publications and thereafter University of Electronic Science and Technology of China has contributed 14 publications. The publications are mostly sent to IEEE Antennas and Wireless Propagation Letters and Microwave and Optical Technology Letters for publications. After

China, USA has contributed in Antipodal Vivaldi Antenna according to scopus and India according to web of science. The coverage of AVA in different countries of world can also be shown in map.

By looking map we can conclude that research in AVA has been carried out globally. The following Figure 8 shows the data obtained from scopus.

Figure 8: Geographical locations of researchers in Antipodal Vivaldi Antenna from scopus database

We have total 95 documents researched in web of Science and 24 countries have researched on AVA from 1996 to 2021 as shown in Figure 9.

Figure 9: Geographical location from web of science

3.4 Top 10 Authors

Figure 10 shows the top ten authors published the documents and their affiliations to AVA from scopus. Moosazadeh, Mahdi has highest number of documents and overall he has 32 documents which are 550 citations by 374 documents.

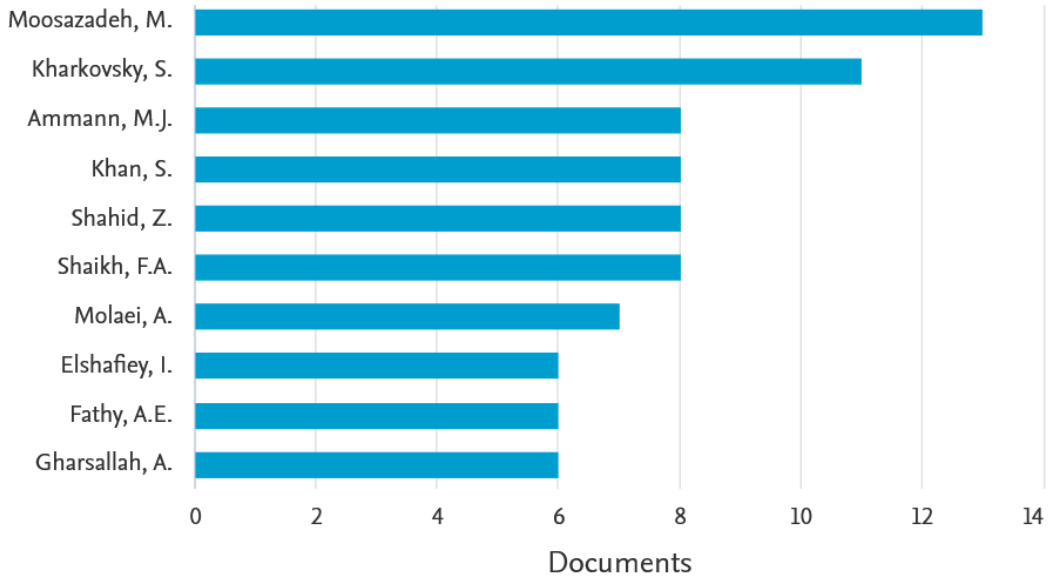

Figure 10: Top 10 authors and their corresponding documents published from scopus

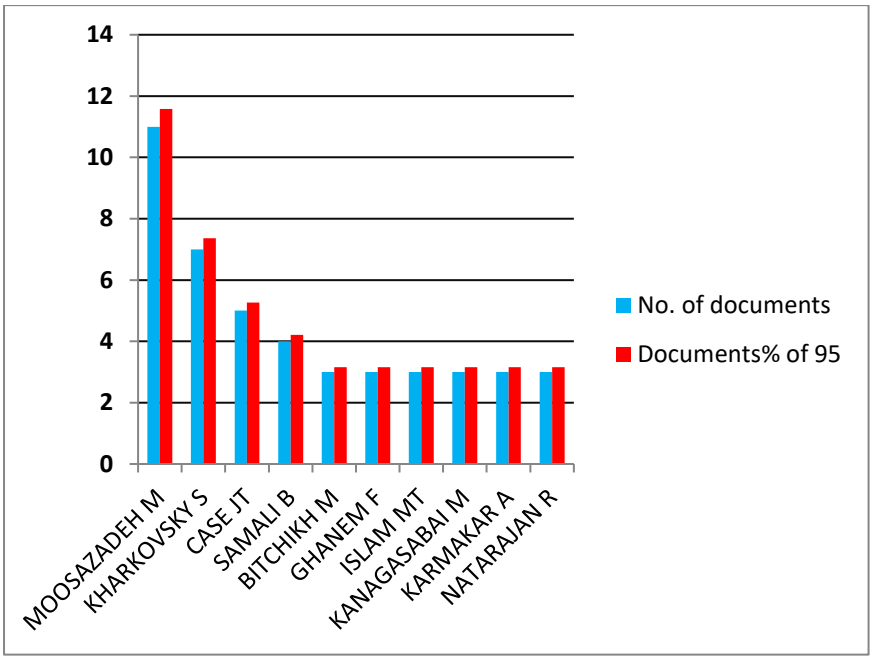

Figure 11: Top ten author and their corresponding documents published from web of science

The Figure 11 shows the top ten authors among 95 research documents in web of science. The highest number of publications is by Moosazadeh, Mahdi and he has 11 other related documents present in web of science. Then Kharkovsky S has second highest number of publications.

Many institute has contributed to antipodal Vivaldi antenna in areas of 5G Mobile Communication, Ultra-wideband Operation, microwave imaging, Airborne GPR Application, radar application etc. Among all institutes Harbin Institute of Technology has 16 researches in varied areas. After this University of Electronics Science from 2012 to 2019 and Technology of China and Western Sydney University has published 14 publications from 2010 to 2021.

The documents published by the author in web of science are shown in percentage format. The percentage is taken out by using total number of documents i.e. 95.

3.5 Statistical analysis based on Affiliations

The topmost ten institutes and organizational affiliations contributing towards the field of are represented in Table 4. Harbin Institute of Technology has maximum contribution in research field of antipodal Vivaldi antenna. So it can clearly observe that China has most actively working in this area.

Table 4: Affiliation statistics for Antipodal Vivaldi Antenna from scopus

Affiliation	Documents
Harbin Institute of Technology	16
University of Electronic Science and Technology of China	14
Western Sydney University	14
King Saud University	11
Technological University Dublin	8
K. N. Toosi University of Technology	8
International Islamic University Malaysia	8
Beijing Institute of Technology	8
Rockwell Collins	7
Southeast University, Nanjing	7

3.6 Funding Sponsors Statistics

Bibliometric analysis of funding sponsored for the documentation is shown in Figure 12. The top ten funding organization are representated and it was observed that National Natural Science Foundation of China has highest funding foundation. After this National Foundation has provided the second highest funding in researches.

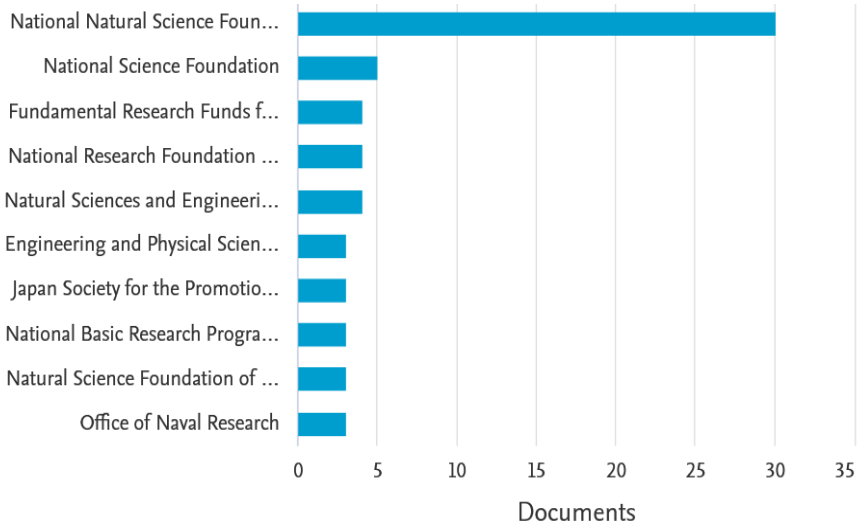

Figure 12: Funding sponsors analysis in area of AVA

3.7 Publication trends

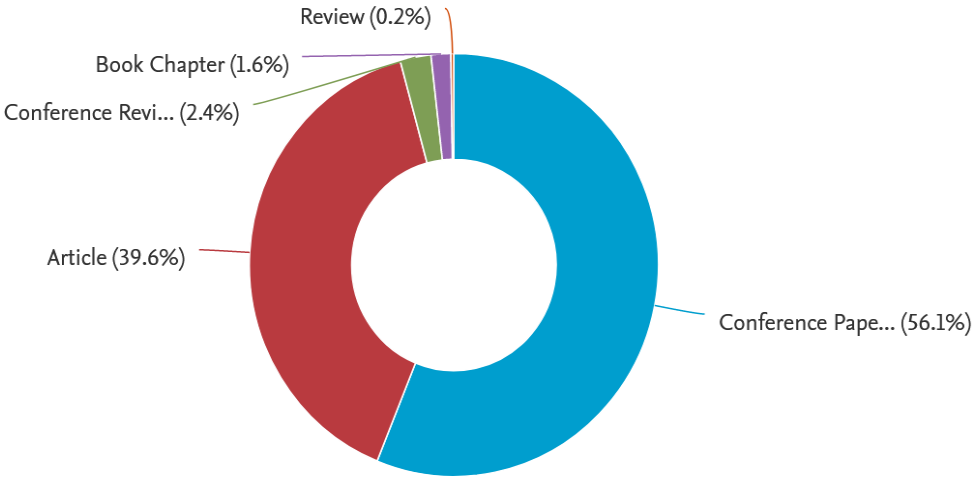

Figure 13: Document types in scopus

The document written on antipodal Vivaldi antenna is mostly conference papers and articles as shown in Figure 13. Among all publication type conference paper and article are mostly chosen by the researchers to publish their work.

Apart from scopus data, Web of science is also used. In Table 5, we can see that most of documents are in article and then 3 documents are in review.

Table 5: Document types in web of science

Document type	No. of documents
Article	200
Review	3
Correction	1
Meeting	1
Other	3
Early Access	2

3.8 Documents by subject area

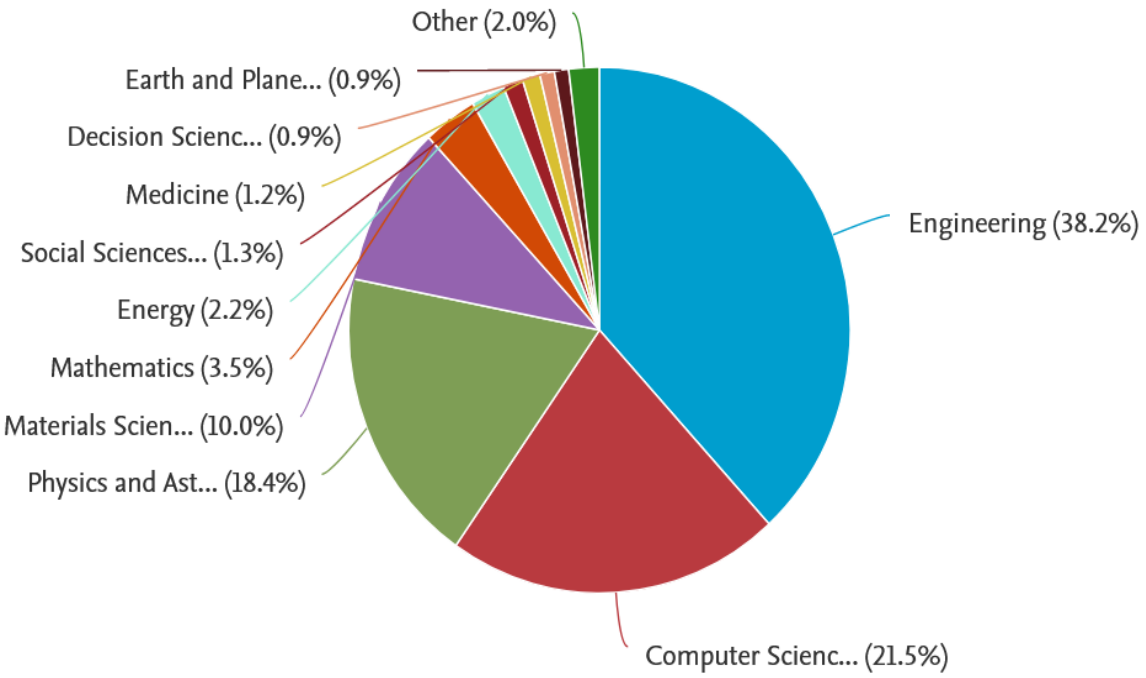

Figure 14: Antipodal Vivaldi Antenna in different subject area

There have been many fields where researches are focused. It is believed a good antenna is one which has applications in industrial, medical, military, commercial products etc. In

Figure 14, it was observed that Engineering, computer science and Physics and astronomy has many publications under them.

Another representation subject area has been shown by Table 6 where exact number of documents under each field is shown. In this exact number of documents in a particular field is shown. It is clearly mention that “Engineering” has 330 documents, “Computer Science” has 186 documents and “Physics and Astronomy” has 159 documents.

Table 6: Subject area statistics and their corresponding documents

Subject Area	No. of documents
Engineering	330
Computer Science	186
Physics and Astronomy	159
Materials Science	86
Mathematics	30
Energy	19
Social Sciences	11
Medicine	10
Decision Sciences	8
Earth and Planetary Sciences	8
Chemistry	4
Biochemistry, Genetics and Molecular Biology	3
Chemical Engineering	3
Business, Management and Accounting	2
Agricultural and Biological Sciences	1

3.9 Document statistics in source title per year

The table 16 shows the documents published per year in different journals/articles. The documents are arranged in the order of maximum number of published documents. Most of the documents are published in “IEEE Transactions on Antenna and Propagation” which are 252 and then “IEE Proceedings: Microwave, Antennas and Propagation” has 198 documents. There are lot many publishers for the documents publishing which are listed in following Table. In the table 13 documents are listed with the name of source publisher and the year in which document is published. Documents are listed from 1996 to 2018.

Table 7: Documentation per year with source title and the document count per year

Sr. No.	Title of document	Year	Source Title	No. of document
1	Balanced antipodal vivaldi antenna with dielectric director for near-field microwave imaging	2010	IEEE Transactions on Antennas and Propagation	252
2	Balanced antipodal Vivaldi antenna for wide bandwidth phased arrays	1996	IEE Proceedings: Microwaves, Antennas and Propagation	198
3	Design of compact Vivaldi antenna arrays for UWB see through wall applications	2008	Progress in Electro-magnetics Research	172
4	Novel ultra wide-bandwidth Vivaldi antenna with low cross polarisation	1993	Electronics Letters	142
5	Modified compact antipodal Vivaldi antenna for 4-50-GHz UWB application	2011	IEEE Transactions on Microwave Theory and Techniques	141
6	A miniaturized antipodal vivaldi antenna with improved radiation characteristics	2011	IEEE Antennas and Wireless Propagation Letters	138
7	A small antipodal vivaldi antenna for ultra wide-band applications	2008	IEEE Antennas and Wireless Propagation Letters	136
8	A Novel Method for Improving Antipodal Vivaldi Antenna Performance	2015	IEEE Transactions on Antennas and Propagation	103
9	Research on a novel miniaturized antipodal vivaldi antenna with improved radiation	2013	IEEE Antennas and Wireless Propagation Letters	95
10	A new design tapered slot antenna for ultra-wideband applications	1998	Microwave and Optical Technology Letters	91
11	A palm tree Antipodal Vivaldi Antenna with exponential slot edge for improved radiation pattern	2015	IEEE Antennas and Wireless Propagation Letters	76
12	A compact gain-enhanced vivaldi antenna array with suppressed mutual coupling for 5G mmwave application	2018	IEEE Antennas and Wireless Propagation Letters	67
13	A Compact High-Gain and Front-to-Back Ratio Elliptically Tapered Antipodal Vivaldi Antenna With Trapezoid-Shaped Dielectric Lens	2016	IEEE Antennas and Wireless Propagation Letters	65

3.10 Journal Statistics

Table 8: Citation of documents per year

Documentation Title	Yearly citations received by the publication						
	<2017	2017	2018	2019	2020	2021	Total
Balanced antipodal vivaldi antenna with dielectric director for near-field microwave imaging	125	38	44	24	19	2	252
Balanced antipodal Vivaldi antenna for wide bandwidth phased arrays	155	12	13	8	9	1	198
Design of compact Vivaldi antenna arrays for UWB see through wall applications	113	16	21	15	6	1	172
Novel ultrawide-bandwidth Vivaldi antenna with low crosspolarisation	93	18	15	10	6	0	142
Modified compact antipodal Vivaldi antenna for 4-50-GHz UWB application	59	25	19	23	14	1	141
A miniaturized antipodal vivaldi antenna with improved radiation characteristics	56	27	16	24	12	3	138
A small antipodal vivaldi antenna for ultrawide-band applications	85	9	13	14	14	1	136
A Novel Method for Improving Antipodal Vivaldi Antenna Performance	8	24	26	24	18	3	103
Research on a novel miniaturized antipodal vivaldi antenna with improved radiation	31	25	15	14	8	2	95

A new design tapered slot antenna for ultra-wideband applications	81	2	3	3	2	0	91
A palm tree Antipodal Vivaldi Antenna with exponential slot edge for improved radiation pattern	9	25	17	12	12	1	76
A compact gain-enhanced vivaldi antenna array with suppressed mutual coupling for 5G mmwave application	0	0	4	31	28	4	67
A Compact High-Gain and Front-to-Back Ratio Elliptically Tapered Antipodal Vivaldi Antenna With Trapezoid-Shaped Dielectric Lens	2	21	15	10	15	2	65
Dielectric rod antenna array with substrate integrated waveguide planar feed network for wideband applications	26	9	10	9	9	2	65
Time-domain design of UWB vivaldi antenna array using multi objective particle swarm optimization	28	10	18	3	3	0	62
A Compact Antipodal Vivaldi Antenna for UWB Applications	7	13	9	16	11	1	57
Dielectric lens balanced antipodal Vivaldi antenna with low cross-polarization for ultra-wideband applications	10	19	14	5	5	1	54

Gain and radiation pattern enhancement of balanced antipodal Vivaldi antenna	18	11	9	8	6	0	52
A Fern Fractal Leaf Inspired Wideband Antipodal Vivaldi Antenna for Microwave Imaging System	0	0	5	17	22	6	50

There are numerous papers have been published under many different topics, the list of cited documents shows the area of interest of researchers. Table 8 shows cited paper on yearly bases.

4. Conclusion

Paper provides the reason to use Antipodal Vivaldi Antenna for the current and challenging future. It also discusses about the performance enhancement methods for Antipodal Vivaldi Antenna. The bibliometric survey gives a detailed analysis of the sources for publications, the areas in which progress is fast, the document published per year, countries which has contributed to the society and industry, the publications of various journal, and which organization have funded for this cause. From this analysis we found that there are only 449 documents published in the field of Antipodal Vivaldi Antenna. Thus there is lot of scope of doing work in this field. By going the geographical locations of world map which has worked in AVA, China has done maximum work in AVA and other countries are still doing. So, more research can be done in AVA area for the betterment of society, industry, hospital, organizations etc.

Acknowledgement

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