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A Brief Bibliometric Survey on Flexible and Wearable Microstrip Patch Antennas

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A Brief Bibliometric Survey on Flexible and Wearable Microstrip Patch Antennas

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ABSTRACT

This study aims to analyze the work done on Flexible and Wearable Microstrip Patch antennas using different techniques from 2010 to 2021, using the bibliometric methods.

This paper presents a Scopus database review on "Flexible and Wearable Microstrip Patch antennas". As it is the emerging technique used by advanced wireless communication systems in recent years because of having benefits over other types of antennas.

The necessity of doing this bibliometric survey is that to know how the flexible and wearable antennas are advantageous for today's wireless communication systems and its practical usability. This paper shows the importance of flexible and wearable antennas from the year 2010 and continued up to 2021 January. The database analysis of the antennas is done through Scopus and tool like VOSviewer Version 1.6.15. Through this database survey it is revealed that maximum numbers of publications are from conferences and journals, affiliated to engineering, India lead publications followed by other countries.

Methods: The different articles on Flexible and wearable Microstrip Patch antenna were retrieved using one of the most popular database- Scopus. The research articles are considered between 2010 to 2021. Scopus analyzer is used for getting some analysis results such as documents by year, source, and country. VOSviewer Version 1.6.15 is used for the analysis of different types such as co-authorship, co-occurrences, citation analysis etc.

Results: In our study, a database search outputs a total of 405 articles on flexible and

wearable Microstrip antennas from 2011 to 2020. Statistical analysis and network analysis shows the maximum articles are published in the years 2019 and 2020 with India contributed the largest number of documents. Network analysis of different parameters shows a good potential of the topic in terms of research.

Conclusions: Scopus keyword search outcome has 405 articles with English language having the largest number. Authors, documents, country, affiliation etc are statically analyzed and indicates the potential of the topic. Network analysis of different parameters indicates that, there is a lot of scope to contribute in the further research in terms of advanced techniques and different material usage.

Keywords: flexible, Microstrip, wearable, patch antenna

I. INTRODUCTION

Flexible and wearable electronics plays important role in advanced wireless communication systems in recent years [10]. Wearable and flexible electronics technology is rapidly growing and is trending in today's era [1]. These wireless systems are becoming more and more popular due to their potential in many areas including military, commercial and industrial applications. The current trend in wireless communication has been to develop inexpensive, lightweight and small radio antennas that can maintain high-performance efficiency from the wearable electronics. An antenna is described in Webster's Dictionary as a "usually metallic device (as a rod or wire) for radiating or receiving radio waves"[6-7]. In comparison with traditional rigid type antennas, wearable and flexible antennas are characterized explicitly by their compactness, re-configurability, durability and flexibility along with suitable Specific Absorption Rate (SAR) [2][4].

Variety in design that is possible with a micro strip antenna (MSA) other than any other form of antenna element. [6-7]. These antennas consist of metallic patches on grounded substrates. So different configurations of patches [7] are shown in figure.1
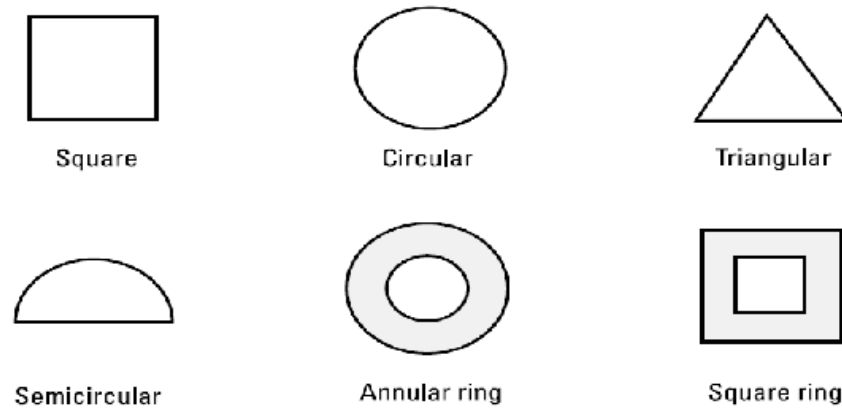
Figure 1: Different shapes of MSA Patches [7]

Microstrip antennas are also referred to as "patch" antennas[3] Deschamps first proposed the concept of the MSA in 1953 [1]. However, practical antennas were developed by Munson [2, 4,] and Howell in the 1970s.[7]

The microstrip antenna have various advantages such as small size, low-cost of manufacturing, low profile, light in weight, ease of installation process and integration with many feeds[21]. With increasing requirements for personal and mobile communications, the demand for smaller and low-profile antennas has brought the MSA to the forefront.

Flexible antennas are experiencing an exponential rise in demand for connected devices, the Internet of Things (IoT)framework, point-of-care devices, the customized medical platform, 5G technology, wireless sensor networks, and networking devices with a smaller form factor to name a few. The choice of non-rigid antennas is unique to the application and depends on the form of substrate [13].

So in engineering and research technology field rapid development is going on using different flexible materials for wearable designs. So different challenges RF engineers face while designing the flexible and wearable antennas like bending, crumping and effect of electromagnetic radiations on human body, which do not exists while designing conventional wireless systems. Various developments and techniques introduced after 2010 in this development which this paper indicates with the help of bibliometric analysis of Scopus database.

II.   MATERIALS AND METHODS

2.1 Primary Database Collection

There are many popular databases worldwide, such as scopus, web of science, google scholar, scimago etc. These databases are having a very wide range of publications. Out of

these scopus- the most popular and one of the largest database, is used for the analysis. The keywords are used for search have given a total of 405 number of publication results. The different keywords are used for the searching of the databases across the world. There is no any restriction on country, language etc. Each publication has the information such as author, country, citations, documents, sources etc. This information is used for the analysis.

Fundamental Keywords

Table 1: List of Primary and Secondary Keywords

Fundamental Keyword	**Flexible and Wearable Microstrip Patch antenna**
Primary Keywords using (AND)	**Flexible AND Microstrip AND antenna AND wearable**
Secondary Keywords using (OR)	**Patch antenna**

Thus the query for searching the documents in Scopus is:

(TITLE-ABS-KEY (flexible) OR TITLE-ABS-KEY (flexible AND substrate) AND TITLE-ABS-KEY (microstrip AND antenna) OR TITLE-ABS-KEY (patch AND antenna) AND TITLE-ABS-KEY (wearable)) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010))

2.2 Initial Search Outcomes

On the Scopus database, using the different keywords related to our work, the publications are obtained. These are analyzed according to the language. It is found that, English language has the highest number of publications of 404, followed by Chinese.

Table 2: Language Trends of Publications

Language of publishing	Publication count
English	404
Chinese	1
Total	405

2.3 Publication outcome based on Top 15 Keywords

During the search, many keywords are found in addition to the fundamental keywords. Top 10 keywords are listed here in the table. A "wearable antenna" is the keyword having the highest publications. Generally all these keywords are found to be related to engineering research and science.

Table 3: Publication Analysis based on Top 10 keyword Analysis

Sr. No.	Keyword	Publications
1.	Wearable Antennas	330
2.	Microstrip Antennas	273
3.	Slot Antennas	202
4.	Microwave Antennas	192
5.	Textiles	88
6.	Directional Pattern Antennas	81
7.	Wearable Antenna	73
8.	Antennas	72
9.	Substrate	71
10.	Wearable Technology	70

III. PERFORMANCE ANALYSIS

VOSviewer 1.6.15 [4][5] is the software that is used for the database analysis in addition to the analysis from Scopus. It provides a very effective way to analyze the co-citations, co-occurrences, bibliometric couplings etc.

Following types of analysis is performed [22].

Statistical Analysis of Databases

1. Documents by Source
2. Documents by year
3. Documents by subject area
4. Documents by Type
5. Documents by Country
6. Documents by author
7. Documents by affiliation
8. Documents by top funding agencies

Network Analysis of Databases

1. Co-authorship: Authors, organizations, country
2. Co-occurrence: All keywords, Author keywords, Index keywords
3. Citation Analysis: Sources, authors, organizations, country
4. Bibliographic coupling: Documents, Authors

IV. RESULTS AND DISCUSSION

Analysis is performed by two different ways, statistical analysis of database and network analysis.

4.1 Statistical Analysis

4.1.1 Document Analysis by Sources

Database indicates different sources such as conferences, journal, book chapter, conference review, reviews and so on. Year-wise publication statistics are shown in the table. Figure shows the graphical representation of the different sources with number of documents published year-wise.

Documents per year by source

Compare the document counts for up to 10 sources.

Compare sources and view CiteScore, SJR, and SNIP data

- IEEE Antennas And Wireless Propagation Letters
- Iet Microwaves Antennas And Propagation
- Lecture Notes In Electrical Engineering
- Microwave And Optical Technology Letters
- IEEE Transactions On Antennas And Propagation
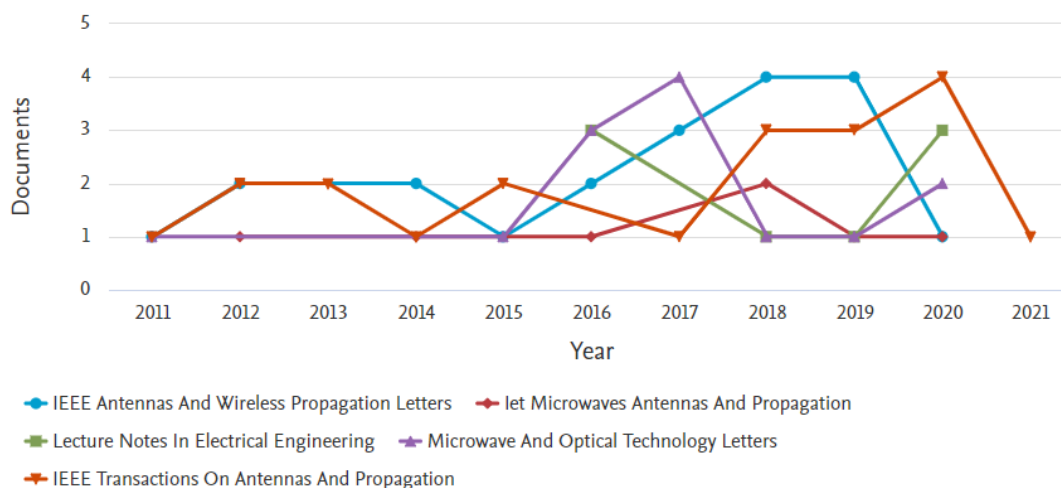
Figure 2: Analysis of Documents by Sources

Source: http://www.scopus .com (assessed on 17th Oct. 2020)

4.1.2   Documents Analysis by year

Documents are collected from scopus database in the year 2010 to 2021 including different sources such as conferences, journal, book chapter etc. The table shows the statistical information and graphical representation is as shown in figure. It is observed from the analysis that, highest number of publication is in the year of 2019 followed by 2020. This shows that, there is a good scope for working in this area in the preceding years.

Table 4: Number of Publication by Year

Year	Number of Publications
2021	8
2020	66
2019	88
2018	63
2017	48
2016	37
2015	30
2014	23
2013	13
2012	17

2011	06
2010	06
Total	**405**
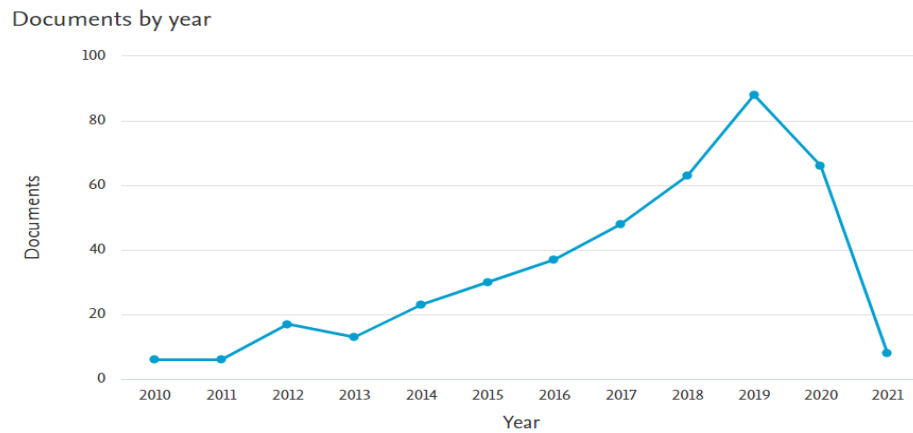
Figure 3: Analysis of Documents by years

4.1.3 Documents by Subject Area

Flexible and wearable technology maximum papers are found under engineering field (33.9%). Although computer science covers 21% of the papers and remaining documents are published in other subject area. The main reason for this is, the topic is related to research and engineering field.
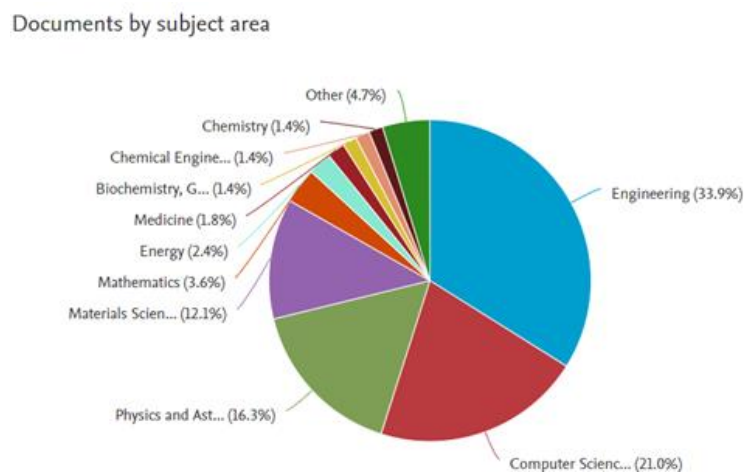
Figure 4: Analysis of Documents by Subject Area

4.1.4. Documents by Type

It is seen form the analysis that, most of the publications are journal articles followed by conference papers.

Table 5: Analysis by Document Types

Sr. No.	Document type	Publications
1.	Conference Paper	203
2.	Article	185
3.	Book Chapter	6
4.	Review	6
5.	Conference Review	4
6.	Undefined	1
Total		**405**

Documents by type
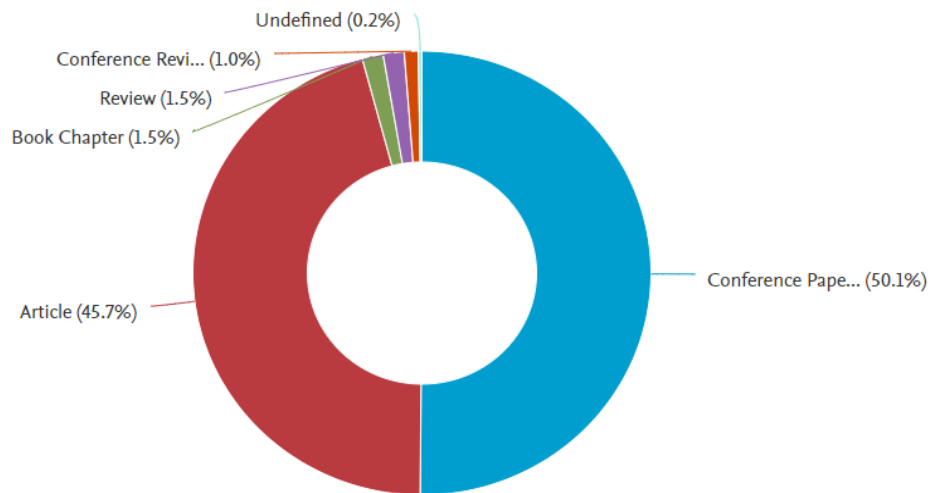
Source: http://www.scopus .com (assessed on 20th January. 2021)

Figure 5: Analysis of Publications by Document Type

4.1.5　Analysis of Publications by Country or Territory

Scopus database is analyzed for countries by considering the number of documents published. It shows that India has the highest number of documents published between the elected timeline. It is followed by United States and then China.

4.1.6　Documents by Author

In this analysis, authors with the number of publications are considered. Publications with a very large number of authors (15) are excluded. Top 10 authors with this comparison are shown here. It is found that Rogier. H [15-17] has the highest number of publications of 13 in this area. Maximum authors have an approximate average publication count 4 to 6.

4.1.7 Documents by Affiliations

In this analysis, top 10 affiliations are considered. It is found that, University Saries Malaysis, Health Campus. More than half of the affiliations have at least 7 publications related to this field.

4.1.8　Analysis by Funding Sponsors

In this case, China is ahead amongst all, with highest funding to the National Nature Science Foundation, China. Analysis found most of the funding institutes are form Research and science field.
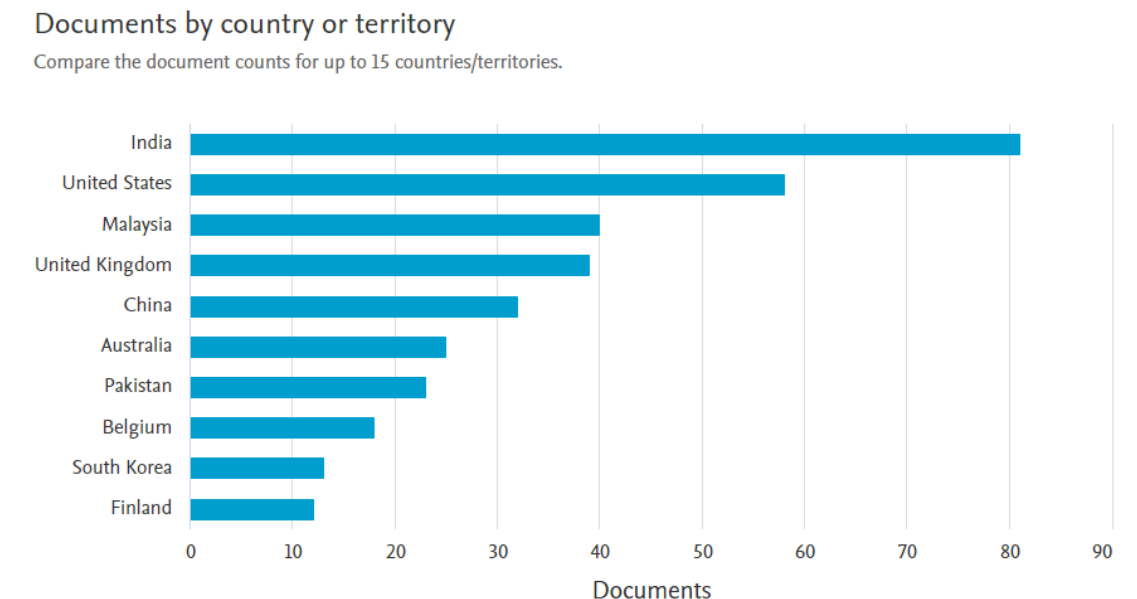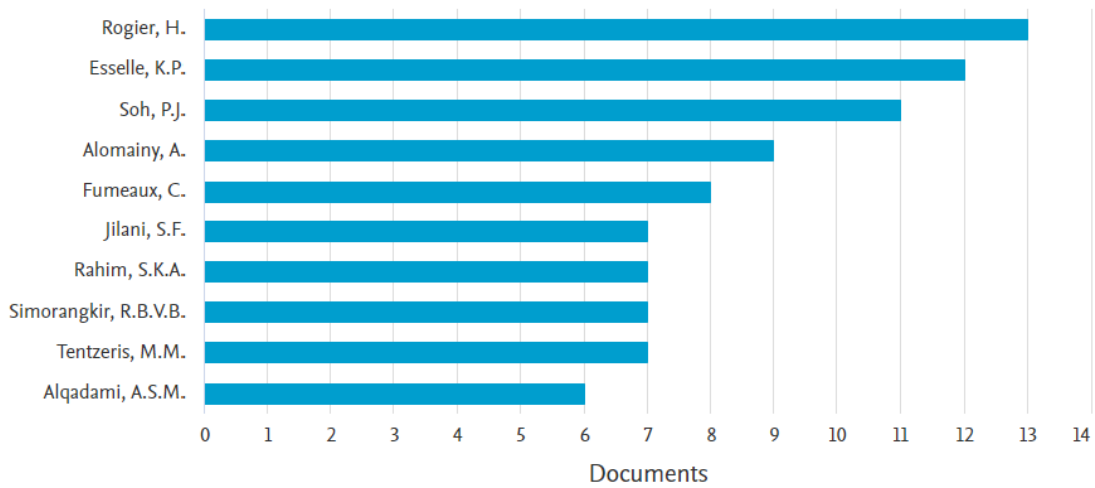

Figure 6: Analysis by Country

Source: http://www.scopus .com (assessed on 20th January. 2021)

Documents by author

Compare the document counts for up to 15 authors.

Author	Documents
Rogier, H.	13
Esselle, K.P.	12
Soh, P.J.	11
Alomainy, A.	9
Fumeaux, C.	8
Jilani, S.F.	7
Rahim, S.K.A.	7
Simorangkir, R.B.V.B.	7
Tentzeris, M.M.	7
Alqadami, A.S.M.	6

Figure 7: Analysis of Documents by Author
Source: http://scopus.com, (assessed on 20th January. 2021)

Documents by affiliation

Compare the document counts for up to 15 affiliations.

Affiliation	Documents
Universiti Malaysia Perlis	18
Universiti Teknologi Malaysia	15
Universiteit Gent	13
Macquarie University	12
National University of Sciences and Tec...	11
Tampere University of Technology	9
Queen Mary University of London	9
University of Glasgow	8
The University of Adelaide	8
Georgia Institute of Technology	8
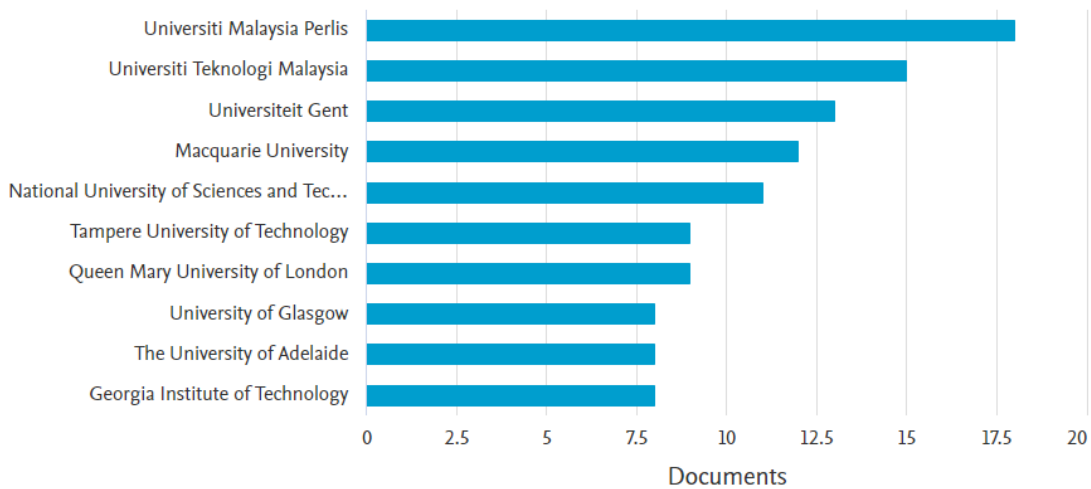
Figure 8: Analysis of Documents by Affiliation

Source: http://scopus.com, (assessed on 20th January. 2021)

Documents by funding sponsor
Compare the document counts for up to 15 funding sponsors.
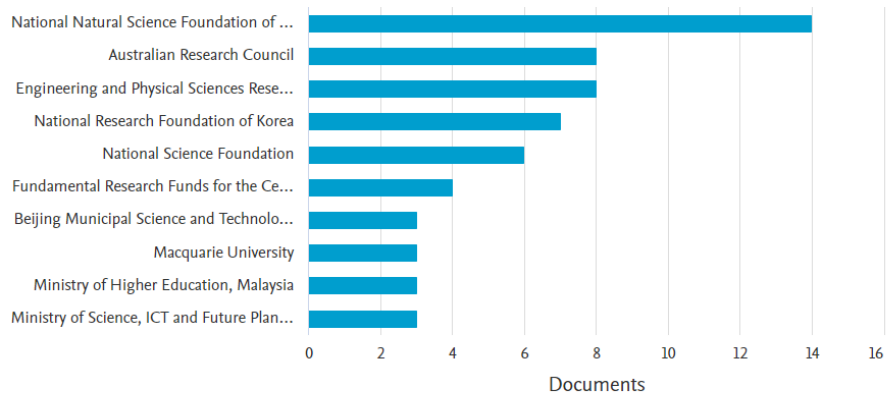
Figure 9: Analysis of Documents by Funding Sponsor

Source: http://scopus.com, (assessed on 20th January. 2021)

4.2 Network Analysis

4.2.1 Co-authorship Analysis

A) Co-authorship in terms of Authors

This parameter of analysis is considered with 03 different parameters related to it. The authors, organizations, and countries are considered for analyzing this parameter.

Documents with a very large number of authors are ignored in this analysis. This number is considered to be 25. Threshold is considered as 2 for minimum number of documents of an author.

It is seen that out of 1162 authors, 232 authors met the criteria. The total strength of the co-authorship is calculated with other authors. By this method, the link strengths are obtained. Soh. P.J [18-20] found the highest link strength of 30 with the total number of citations to be 215 for 13 different documents of rogier h. Here total of 51 authors found to have the relation in terms of co-authorship. So these are only shown in the figure .10.
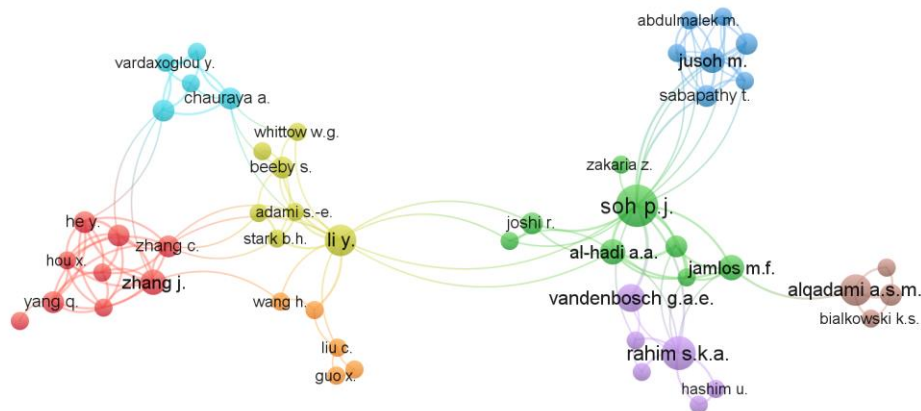
Selected	Author	Documents	Citations	Total link strength
✓	soh p.j.	11	186	30
✓	esselle k.p.	12	190	25
✓	rogier h.	13	215	24
✓	li y.	6	195	19
✓	ukkonen l.	6	122	18
✓	zhang c.	3	48	18
✓	zhang j.	4	6	18
✓	he y.	3	5	17
✓	zhang k.	3	5	17
✓	simorangkir r.b.v.b.	7	190	16
✓	jusoh m.	4	1	16
✓	van torre p.	5	72	15
✓	bergheul s.	3	47	15
✓	hamouda z.	3	47	15
✓	kone l.	3	47	15
✓	lasri t.	3	47	15
✓	pud a.a.	3	47	15
✓	wojkiewicz j.-l.	3	47	15
✓	rahim s.k.a.	7	36	15
✓	hashmi r.m.	6	23	15

Figure 10: Co-authorship Network Analysis in Terms of Authors

Source www.scopus.com, (assessed on 20th January. 2021)

B) CO-authorship in terms of Organizations

Co-authorship in the unit of organizations is calculated considering minimum 02 documents in organizations with neglecting the citation of the same,

43 organizations meet the criteria out of 709 number of total organizations, that are shown in the figure 11. A total of 43 organizations have highest link strength of 6 with the highest citations of 173 by School of electronic Engineering and computer science , queen mary University (with 5 documents).
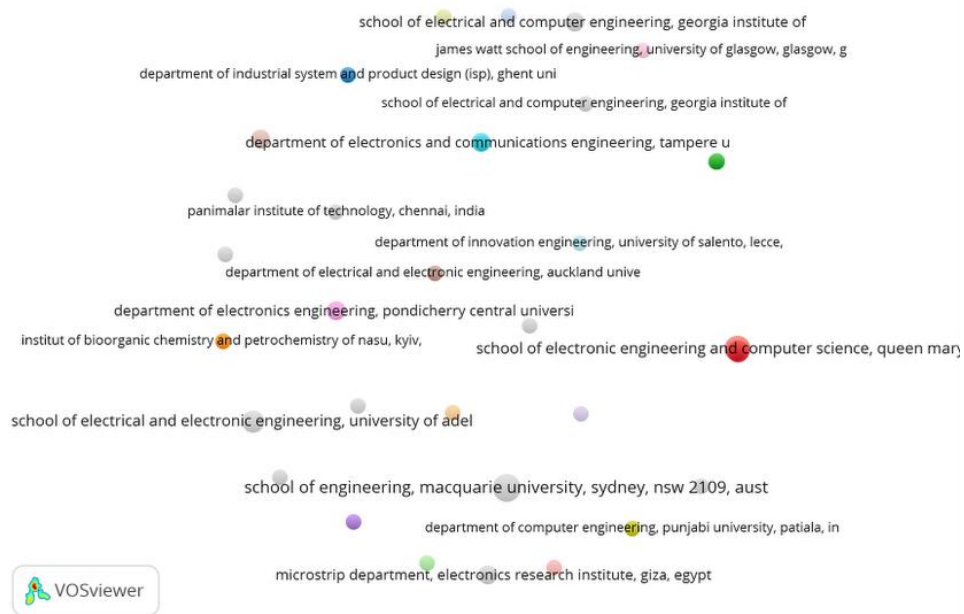
Figure 11: Co-authorship analysis in terms of Organizations

Source www.scopus.com, (assessed on 20th January. 2021)

C) Co-authorship in terms of Country

Co-authorship can also be obtained in relation to the country. A total of 59 countries are there, in which this databases are present. After considering the threshold of minimum 5 documents in a country, 23 countries met the threshold.

Here, United States found to have the highest citations of 941, and the link strength of 14 in united kingdom that is highest amongst all. As far as the number of document is concerned, India has the highest of all that is 81.
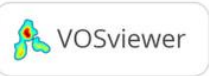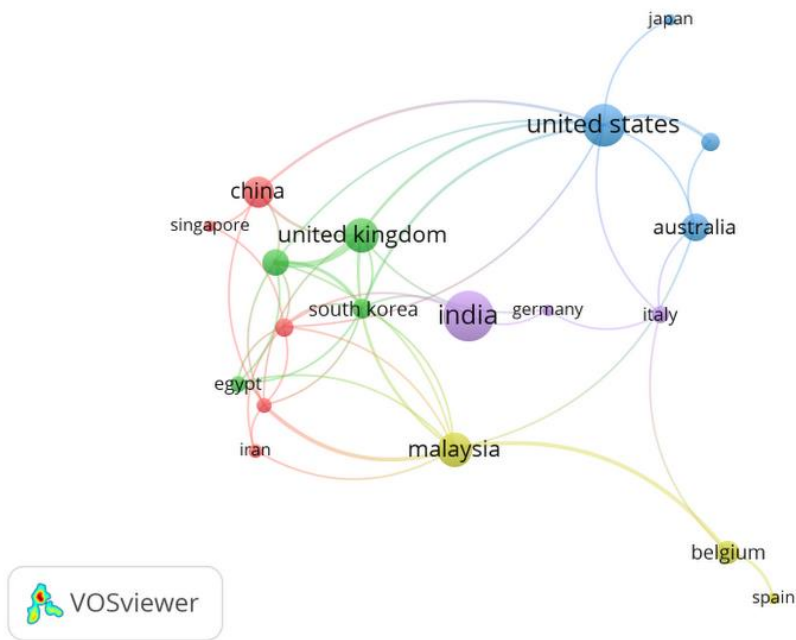
Selected	Country	Documents	Citations ∨	Total link strength
✓	united states	58	941	14
✓	united kingdom	39	446	17
✓	belgium	18	398	7
✓	finland	12	342	4
✓	australia	25	340	4
✓	malaysia	40	299	16
✓	china	32	269	7
✓	italy	10	248	4
✓	india	81	224	3
✓	pakistan	23	219	17
✓	japan	5	137	1
✓	taiwan	5	105	0
✓	south korea	13	87	11
✓	singapore	5	86	2
✓	france	9	75	0
✓	canada	11	65	9
✓	saudi arabia	8	61	11
✓	iran	7	45	3
✓	egypt	9	40	5
✓	spain	5	33	2

**Figure 12: Co-authorship analysis in terms of Countries (Scale is with number of documents)**

Source www.scopus.com, (assessed on 20th January. 2021)

4.2.2. Network Analysis of Co-occurrences

A) Co-occurrence analysis in terms of all keywords

For the analysis of co-occurrences, different keywords are considered. Minimum number of occurrences in the keywords is considered to be 5. Out of 2727 keywords, 252 keywords met the threshold. The keyword "Wearable antennas" having 3699 link strength with 330 times occurrence in various documents as shown in figure 13.
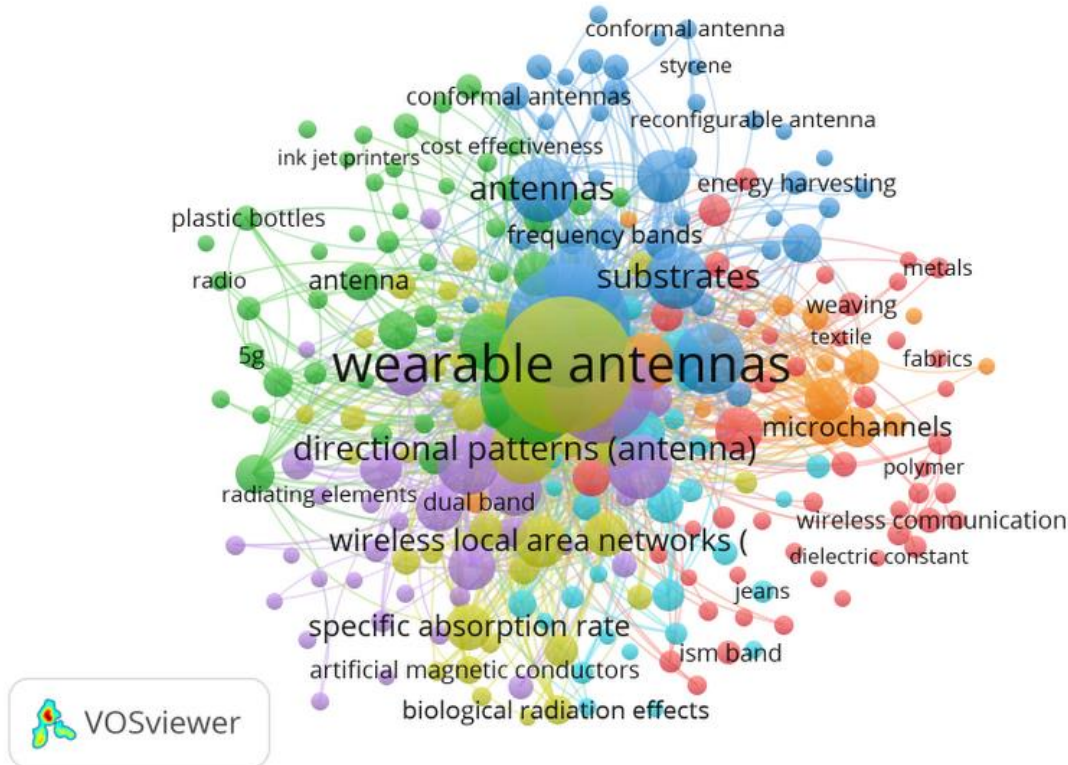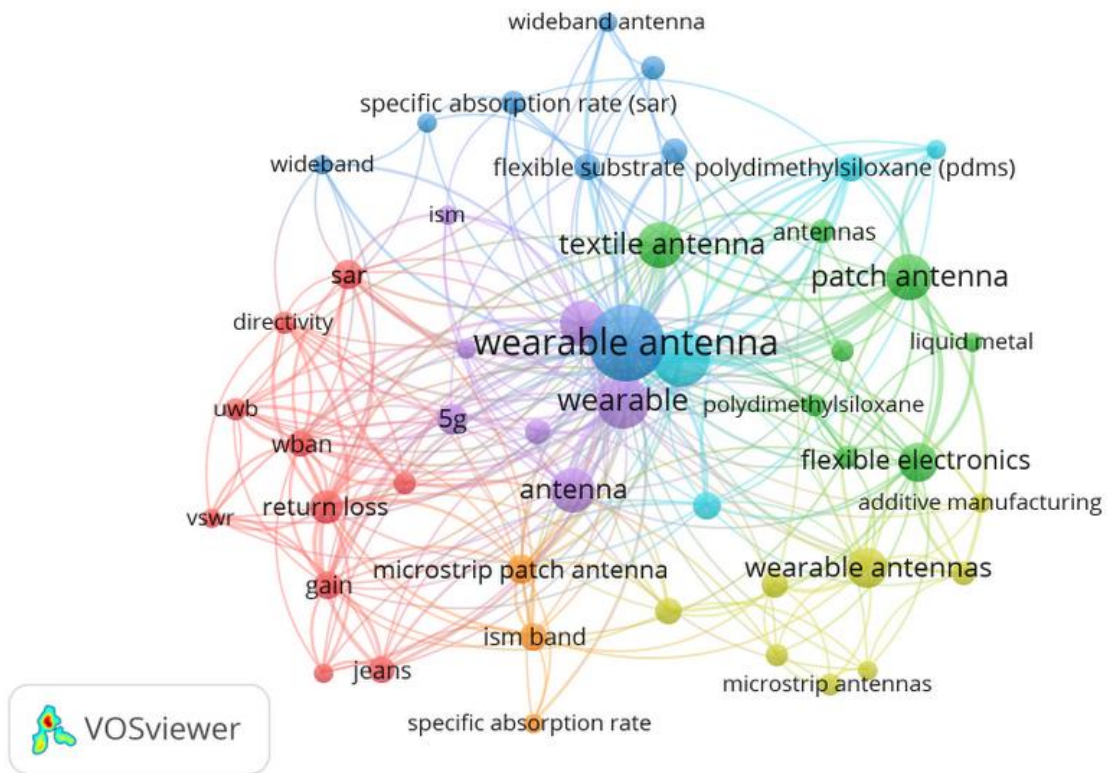

Figure 13: Co-occurrence Analysis in Terms of All Keywords

Source www.scopus.com, (assessed on 20th January. 2021)

B) Co-occurrence analysis in terms of Author keywords

Co-occurrence of author keywords is analyzed with the minimum threshold of 5 per author. Out of 955 keywords by the authors, 48 keywords met the threshold. Wearable antennas keyword occurrence is 73 times with 101 link strength.
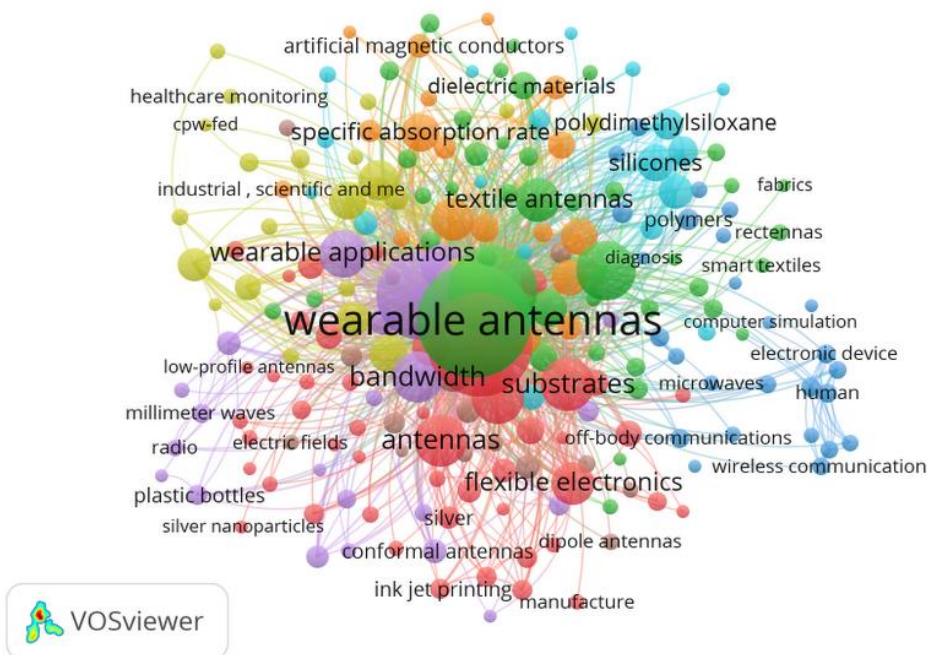
Figure 14: Co-occurrence Network Analysis (Author Keywords)

Source www.scopus.com, (assessed on 20th January. 2021)

C) Co-occurrence in terms of Index Keywords

Co-concurrence is also considered by index keywords of 2120, only 215 met the threshold.

**Figure 15: Co-occurrence of Index Keywords**

4.2.3. Network Analysis of Citations

This analysis is done with the units of analysis including documents, sources, authors, country and organization.

A) Citation Analysis of Documents

Out of total of 405 documents, minimum 5 citations are considered as a threshold per document. So 161 documents met the threshold. rose d.p (2015) has the highest number of citations 207 while the link strength is 12 which is the highest for lin c. –p.(2011) .
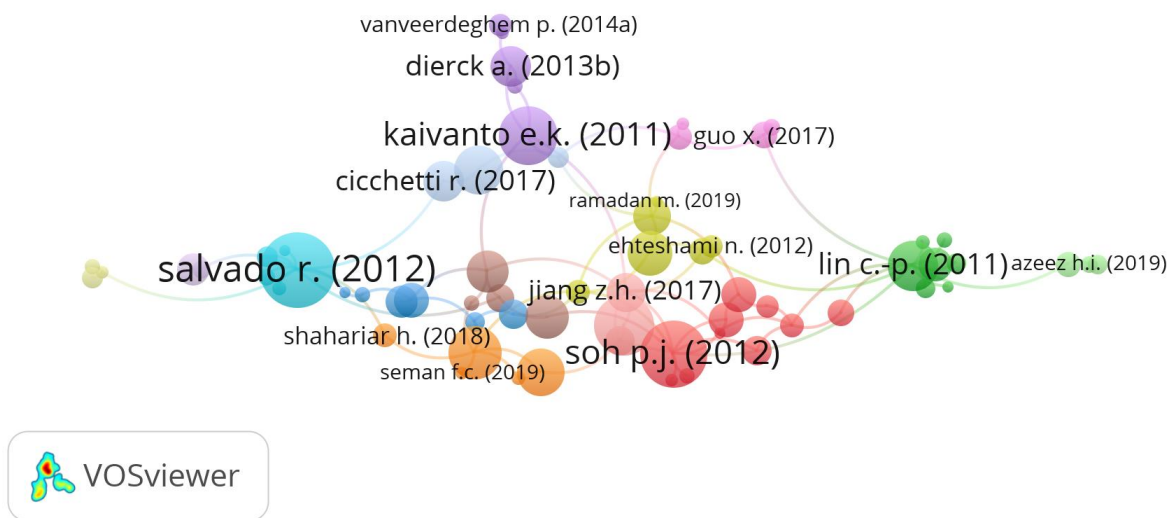
Figure 16: Network Analysis of Citations (In terms of Documents)
Source www.scopus.com, (assessed on 20ᵗʰ January. 2021)

B) Citation Analysis of Sources

Citation analysis of sources is obtained by considering the threshold of 5 citations per source. Out of the 240 sources only 11 met the threshold. ieee antennas and wireless propagation letters has got maximum citations of 705.
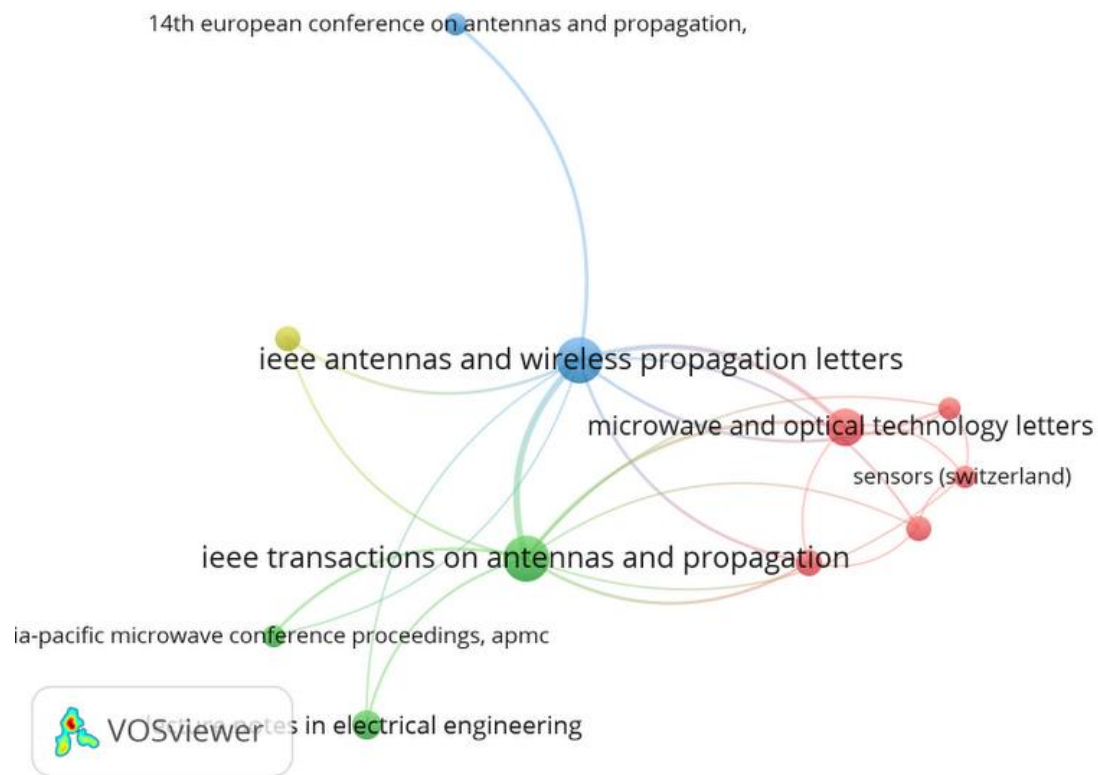
Figure 17: Network Analysis of citation by sources, Source www.scopus.com, (assessed on 20th January. 2021)

C) Citation analysis by Authors

Threshold considered here is 3 citations per author. A total of 100 authors met the threshold amongst the total of 1162 authors. Rogier.h has maximum citations of 215.
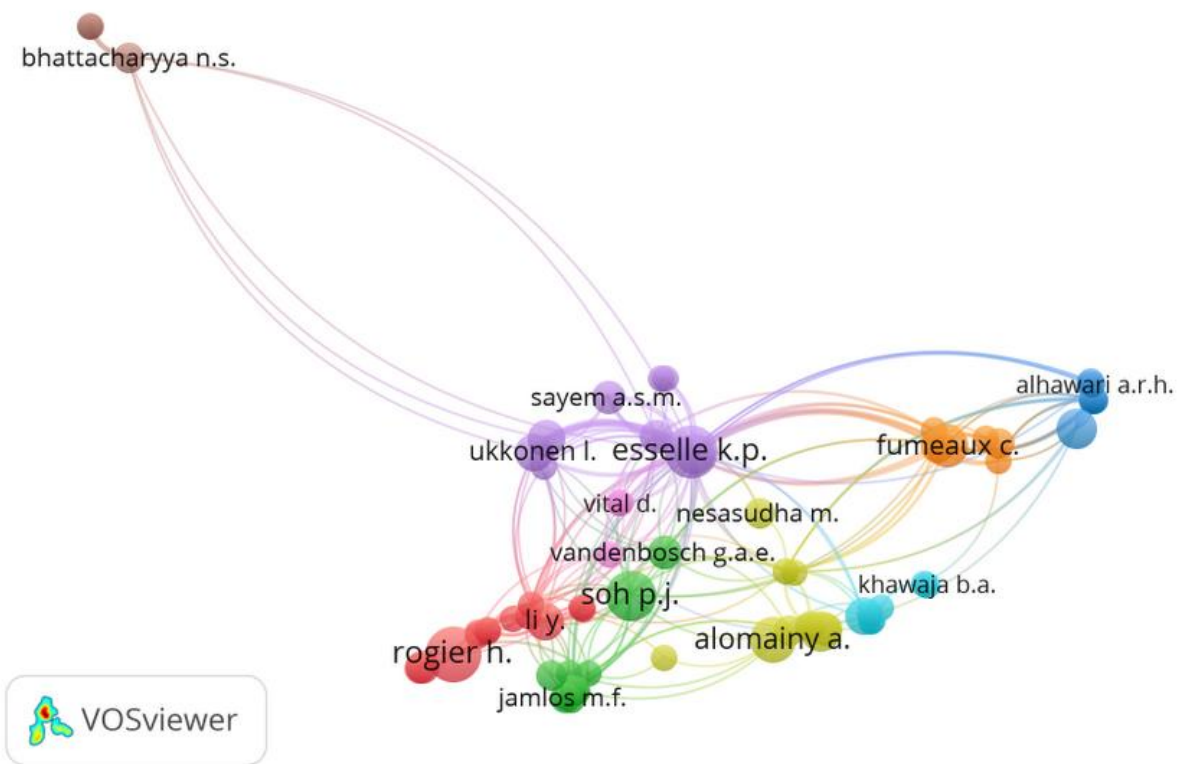
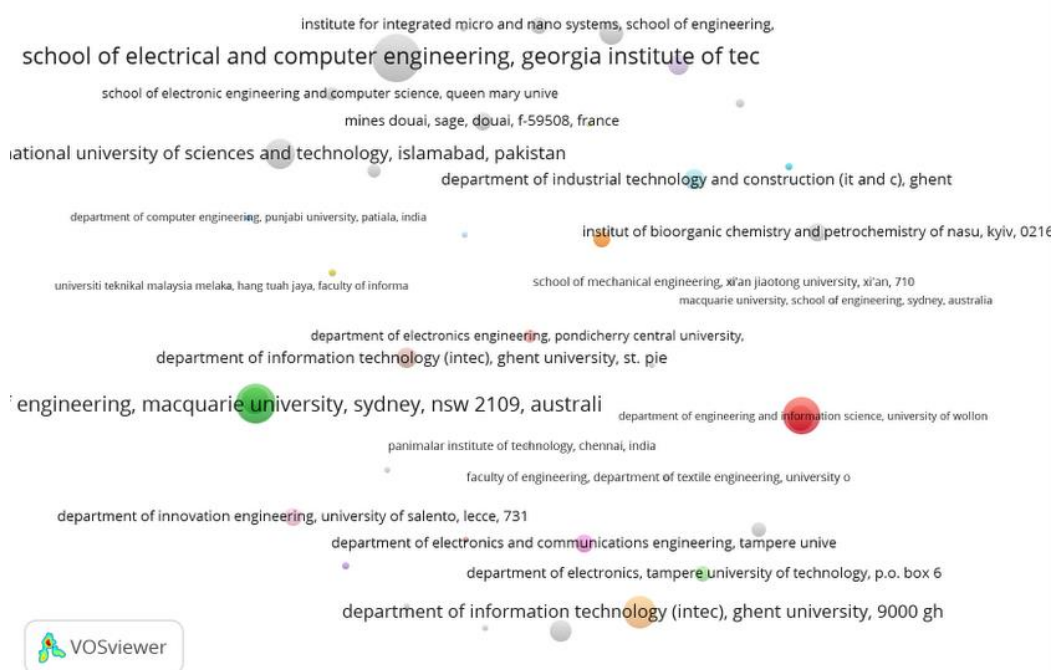**Figure 18: citation analysis by Authors, Source www.scopus.com, (assessed on 20th January. 2021)**

D) Citation analysis by organization

Considering minimum documents of 3 per organization as threshold, 9 organizations met the threshold out of 709 organizations. School of electrical and computer engineering, georgia institute of technology has Maximum citations of 173.

E) Citation analysis by country

Total of 59 countries have the databases of the leukemia work. Out of which 23 met the citation criteria considering a threshold of minimum 5 citations per country. United states having maximum citations 941 and India having maximum documents 81.
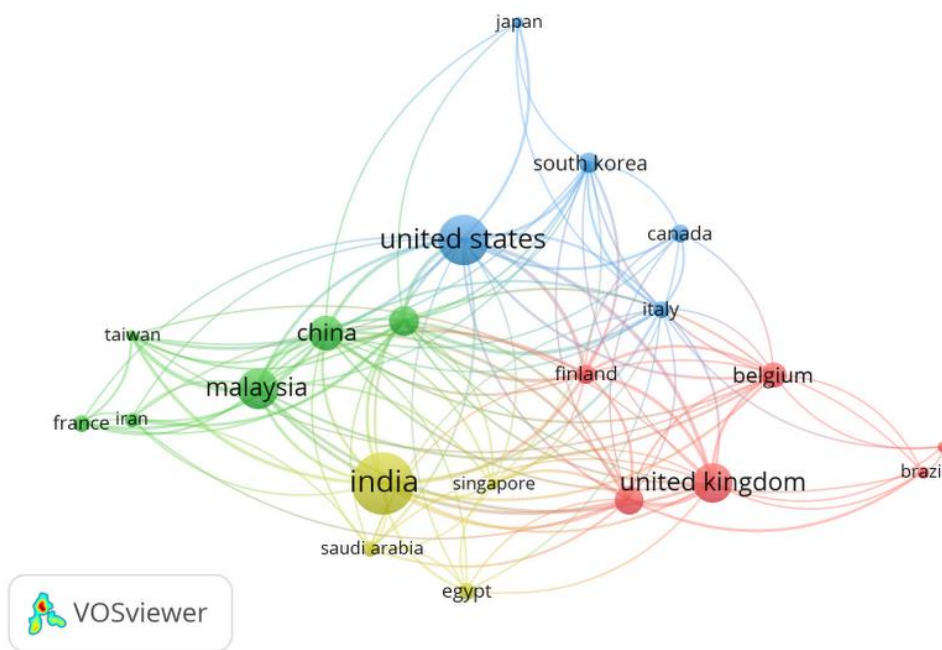
Figure 20: Citation analysis of country, Source www.scopus.com, (assessed on 20th January. 2021)

4.2.4. Network Analysis of Bibliographic Coupling

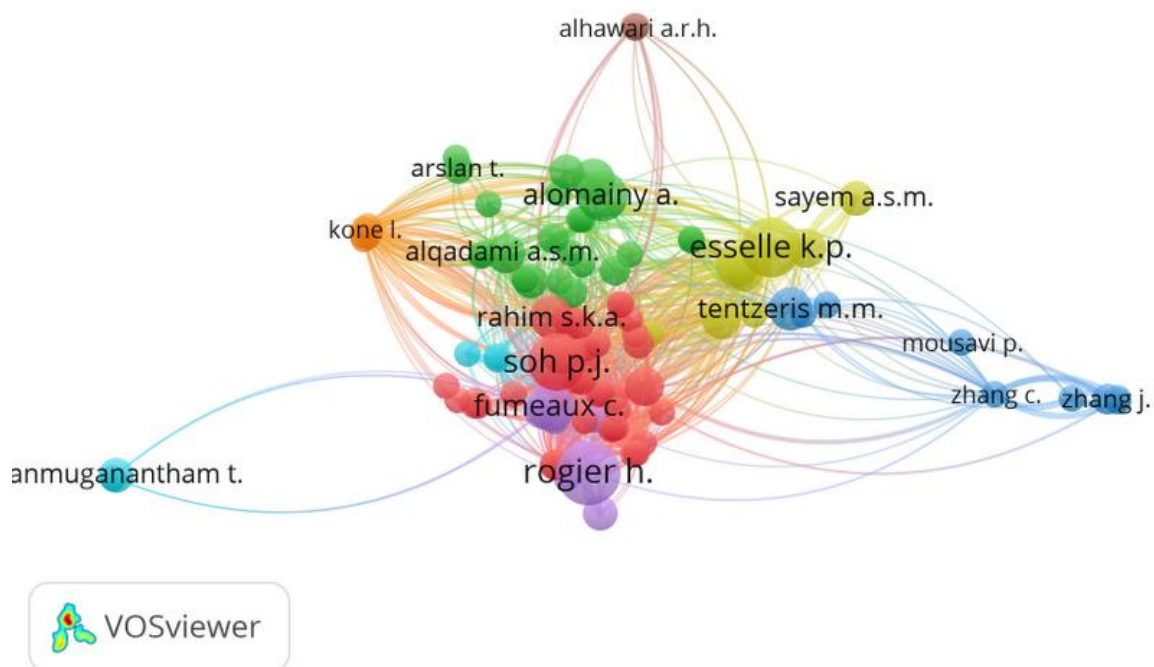### A) Bibliographic Coupling of Documents
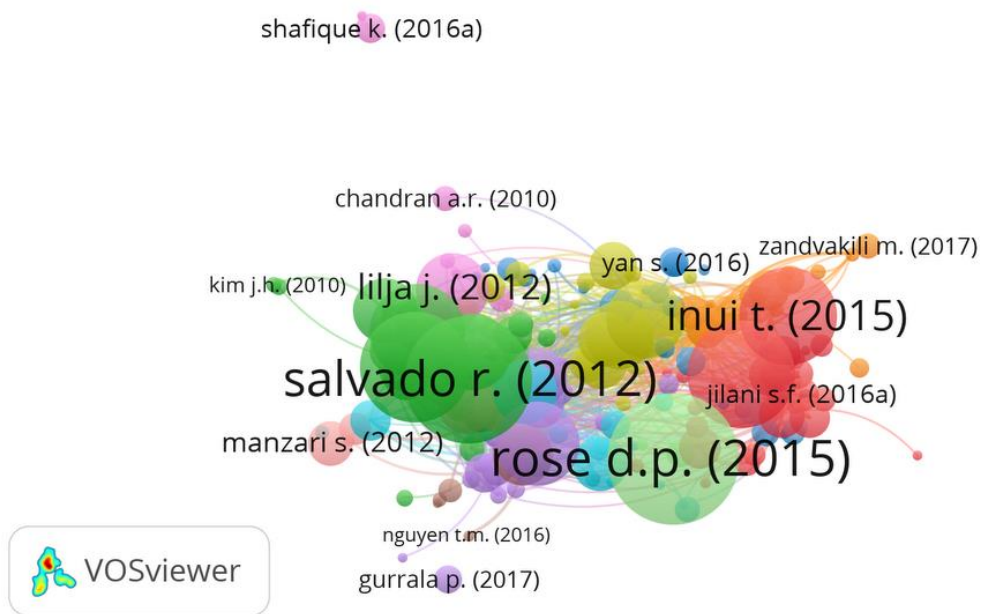
Figure 21: Bibliographic coupling of documents, Source www.scopus.com, (assessed on 20th January. 2021)

B) Bibliographic coupling of Authors

Considering, 3 documents per author as a minimum threshold value. Out of total 1162 authors, 100 authors met the threshold criteria. rogier h having maximum citations 215 along with maximum 13 documents.

Figure 22: Bibliographic coupling of Authors, Source www.scopus.com, (assessed on 20th January. 2021)

V.   CONCLUSION

Bibliometric survey on flexible and wearable microstrip patch antennas is carried out by considering the most popular and the largest database used worldwide- Scopus. The database is considered from the year 2010 to 2021. By using the keyword search with AND operator and OR operator the database searching is done. A total of 405 documents are obtained as the outcome of the specific keywords search.

The different parameters are considered for analysis of this database. It is seen that English language has most of the documents 404 followed by Chinese. The outcome of Keyword search indicates that maximum publications are with the keyword *"wearable antennas."* Maximum documents are published in the year 2019 followed by the year 2020. The subject area Engineering covered almost 33.9% of the documents. As far as, the type of document is considered, article of journal are the major occupants followed by the conference papers. The analysis of countries proved, India as the highest number of documents within the period.

Documents by different authors also analyzed and maximum authors average Publications account 4 to 6. The highest number of documents is from University e sarees Malaysia health campus and China is the highest funding sponsor in this area.

The network analysis is also done by VOSVierer 1.65 version software. The different analysis types such as co-authorship analysis co-occurrence analysis citation analysis and bibliographic coupling are done with the same database. All these different network analysis indicates a quite significant information about different mentioned above. It could also be seen that the major work in flexible and wearable antenna is done in 2019 and 2020 so in coming years vast and major work is expected in this area.

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