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Abstract: Ultra wideband (UWB) technology remains a viable choice for very high speed data communication in future applications involving large bandwidth. For boosting the data communication efficiency and to mitigate the multipath fading issue faced by UWB system with existing narrowband systems, Multiple Input Multiple Output (MIMO) antenna system is used along with UWB. Mutual coupling which must be smaller in value plays a vital role in deciding the efficiency of MIMO antenna and hence it becomes as important aspect. The mutual coupling reduction techniques of various UWB MIMO antennas are surveyed in this bibliometric paper. The bibliometric survey aims to enlighten different types of mutual coupling reduction technique employed in various MIMO antenna like Neutralization lines, Electromagnetic Bandgap Structure, Defected Ground Structures, etc. that support UWB applications. The

Scopus database from January 2015 to 16thDecember 2020 is used to perform this bibliometric survey on UWB MIMO antennas.

Keywords: Scopus; Antenna; Bibliometric; UWB; MIMO; Applications; Survey

1. Introduction

Over the last few decades, wireless systems have made significant strides and the ultra-wideband (UWB) technique has become increasingly appealing. Because of its inherent benefits, UWB system has promising technologies, for getting high speed transmission, high protection, low cost, wide size high resolution, strong anti-interference and minimal power consumption [Youcheng et al.2019].Several works [Luo et al. 2015-Saxena et al. 2017] on compact UWB antennas have been studied which include widescreen, stable radiation patterns and strip-styling features. In order to minimize its conflict with other networks, the Federal Communications Commission (FCC) allocated unlicensed frequency band of 3.1-10.6 GHz for commercial implementations of UWB devices [Chandel et al. 2018].Reflection and diffraction is often correlated with a dense medium that causes multipath fading problems in traditional UWB technology [Iqbal et al. 2017].The issue of fading is therefore very severe, which ultimately decrease the efficiency of the UWB system [Luo et al. 2015], [Wei et al. 2016].

Multiple Input Multiple Output (MIMO) technique, which enhances the range of transmission with no increase in the power of signal, is one way to decrease the effects of decay. Combining UWB with MIMO is critical, which not only boost the efficiency of data transmission but can also suppress the effect of multipath. MIMO is the state-of-the-art technology to multiply radio link capabilities by using multiple signals and antennas in order to spread across multipath. MIMO techniques are mapped to realistic methods for simultaneously receiving and transmitting various independent channels from the identical radio station using various topologies with no additional loss of radiation in the rich distribution area. It is therefore forecasted as a new generation technology because of its ability to boost device stability and increase channel bandwidth using multiple antennas. Initially, MIMO was suggested in the beginning of 1990s as a viable alternative which could solve the data-rate constraint faced by the single input& output systems. The printed MIMO aerials in portable systems are commonly used: cell phones because of their software compliance, low prices, increased completeness and easy manufacturing. In addition, it increases the data rate by reducing channel errors in any communication systems. Moreover the decreased distance between antennas will enhances the mutually recognized coupling to deteriorate the angle of arrival to predict the offset frequency of the carrier and the signal interference to the noise ratio. The wide surface current generated from ports and surface waves strengthen the interconnected relation between tightly packed antennas. Furthermore, it is not possible to under valuate the opposing influence of reciprocal coupling on coefficients of reflection. Therefore, restricting coupling inside the compact printed antennas is the major hurdle in MIMO antenna design [Nadeem et al. 2018].

Mutual coupling is characterized as an energy that a second antenna absorbs when first antenna radiates. The mutual coupling appears to adjust the MIMO antennas pattern of radiation, coefficient of reflection and impedance. In practice, the reciprocal coupling relies on an array configuration& on the excitation of different components. It is normally measured in the dB value Scattering parameters among i, j elements and isolation of $-20*\log_{10}(|Sij|)$ between them. However, the precise process of the reciprocal coupling depends mainly on the modes of transmission & reception. It is important to ensure that the MIMO antenna device is compact in size. As long as the antenna dimensions are constant, various structures are utilized to separate antenna elements so as to minimize the mutual coupling of MIMO antennas [Nadeem et al. 2018].

Mutual coupling is essentially a link between transmitting and receiving antenna. High correlation between information channels neutralizes the advantages of the MIMO method by reducing overall system performance. While in case of a two-port antenna, process of mutual coupling appears to orthogonalize the radiation pattern, which affects the correlations. The correlation coefficient explains how many sources of communication are linked or isolated to each other. In order to obtain a third signal, the signal correlation uses two signals. There are mainly three types of correlations called correlation of power, signal and envelope. Square of the magnitude of correlation of signal is Power correlation& roughly the envelope correlation. The correlation coefficient square is often referred to as the Envelope Correlation Coefficient (ECC).Given these facts, the reduction of mutual coupling for MIMO antennas is very important [Shevada et al. 2021, Raut et al. 2021].

2. Mutual Coupling Reduction

The rigorous work had done to establish practical and efficient decoupling methods to eliminate antenna mutual coupling. In general, the current decoupling processes fall into three groups. The first group relies on the decomposition mode. By adding a hybrid coupling, it is possible to stimulate a couple of antenna with two orthogonal modes that decorate the signal. The method is technically applicable to a MIMO device consisting of a random number of antennas, but it still involves a dense network. In order to change the distribution of current on the ground, second type of decoupling uses artificial structures either defected ground structure or electromagnetic band gap. The artificial structure creates redistribution of a current, which alters the pattern of radiation & likely eliminates the coupling between antenna elements. The artificial structure technique provides a broader bandwidth as compared to mode-based approaches. This method is an ad hoc solution, and its value is typically fraction of the wavelength. As the design relies mainly on the geometry of the antenna, a minor variation in the design of an antenna can involve a complete structure redesign and thus restricted applications may be defined. The third decoupling method is used to mitigate the admittance between coupling antennas through the shunt-related passive network. The network has been deliberately configured to have a reverse admittance to mitigate the admittance of the antennas and thus improve isolation. The passive network can have various implementation choices, such as a reactive loading neutralization line or dumb components. The former decreases the matching bandwidth substantially, while the latter requests extra room for hosting dumb elements [Meng et al. 2017], [Zhang et al. 2015].

The decoupling methods play a crucial role to achieve the optimal efficiency of MIMO antennas. These strategies are an unavoidable part of the MIMO antenna design which is explained below [Kumar et al. 2020] and shown in figure 1:

Neutralization Lines: Neutralization lines transfer electromagnetic waves between antenna elements with metallic slit or lumped element to reduce mutual coupling. It decreases the field of antenna and increases the bandwidth between ground planes. As a point on the neutralization lines changes, impedances adjust the effective bandwidth [Zhang et al. 2015].

Decoupling Network: Cross admittance transforms into purely imaginary value through addition of discrete components or transmission lines in the decoupling network. To reduce mutual coupling, this technique uses a plane decoupling network. The network of decoupling involves a number of patterns, dumb loads, and techniques of linking resonators. It is an economical option for improving isolation.

Electromagnetic Bandgap (EBG) Structure: It serves as a means for electromagnetic waves to be transmitted. EBG is a dielectric or metallic structure with a periodic configuration. It can generate more than one band gap due to this periodicity independent resonance. High efficiency and low mutual coupling can be obtained by using EBG [Ghosh et al. 2014] [Li Q. et al. 2015] [Zheng et al. 2019].

Dielectric Resonator: An antenna containing resonator that is dielectric is known as dielectric resonator antennas (DRA). Low loss, high radiation efficiency, and high gain are provided by DRA. Using dual band property, high isolation can be obtained using DRA.

Defected ground structure (DGS): It is the arrangement that consolidates slots or faults on the antenna floor. DGS can be used for obtaining optimum performance, wider bandwidth, and low mutual coupling.

Metamaterial: It is defined by an electromagnetic characteristic. Various types of metamaterials are frequency selective surface, electromagnetic bandgap, single negative, double negative, isotropic, anisotropic, terahertz, tuneable, photonic, chiral, photonic, and nonlinear metamaterial. Using two or more materials, metamaterials can be designed which is used to provide high gain, bandwidth, low mutual coupling and compact antenna size [Dixit et al.2020a, Dixit et al. 2020b, Dixit et al.2020c].

Slot Elements: It is utilized to increase the impedance bandwidth in the radiation patch or the ground plane using coupling method. The slot antenna offers high gain, high efficiency, and wider bandwidth.

Complementary Split Ring Resonators (CSRR): It consists of two concentric rings with slots facing each other. CSRR is used to perform filtering operations and to improve isolation along with high efficiency and compact size.

Frequency Reconfigurable: It is based on the principle of switching techniques. Micro Electro-Mechanical Systems (MEMS) switches, varactor diodes, and PIN diodes are used in reconfigurable antenna to expand frequency spectrum and increase the envelope correlation coefficient. It provides high efficiency, higher diversity gain with low mutual coupling.

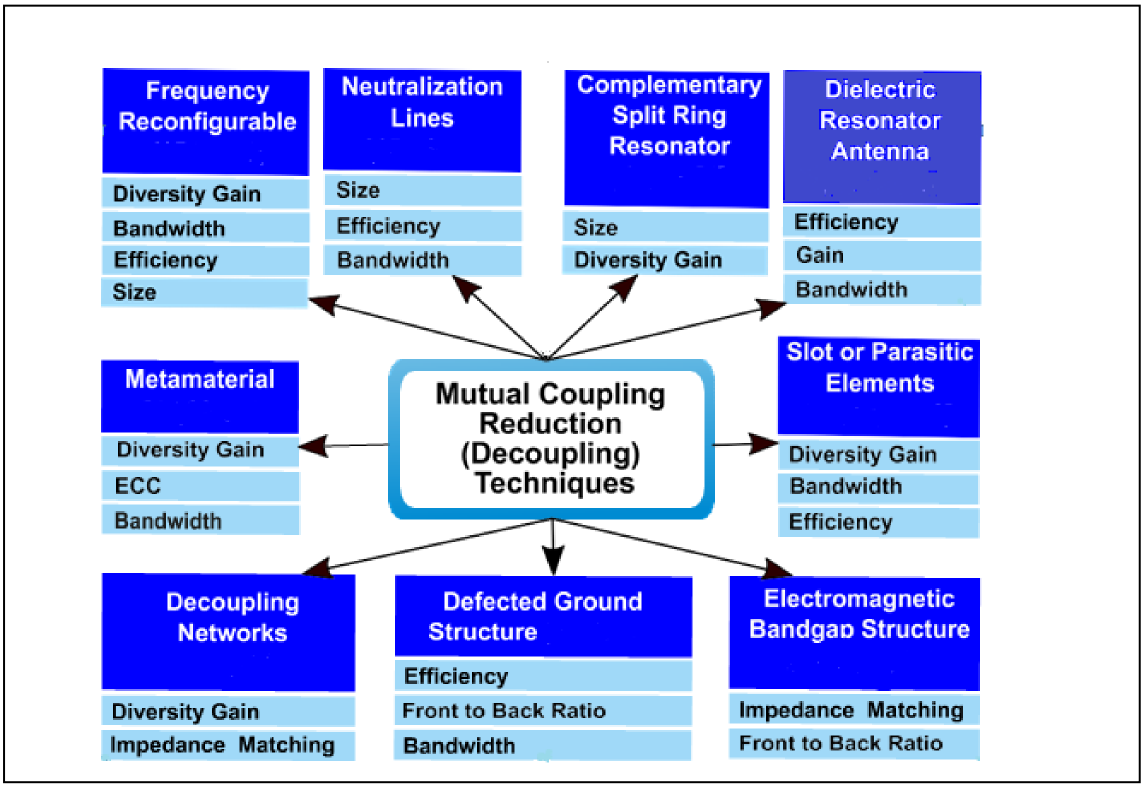

Figure 1: Mutual Coupling Reduction Techniques for UWB MIMO antenna (Kumar et al. 2020)

3. Bibliometric Analysis of UWB MIMO Antennas

This segment explains numerous bibliometric studies for UWB applications conducted on MIMO antennas. For the term 2015 to 16 December 2020, the appropriate database is drawn from the Scopus. The main purpose of this analysis is to explain the amount of work performed, the nature of work on UWB MIMO antennas, and to identify the best tools for the construction of this antenna.

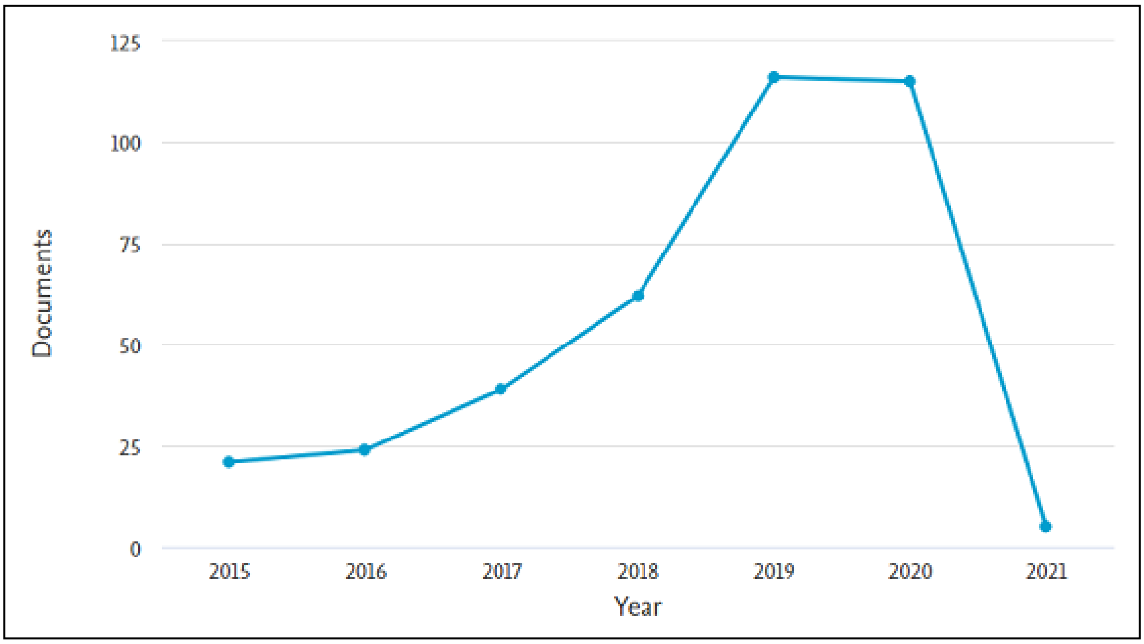

Figure 2: Number of documents published per year

Figure 2's rising curve indicates the gravitational pull of the MIMO antenna for UWB applications. This is a graph of the number of publications per year on UWB MIMO antenna. The research on the UWB MIMO antenna began with in 2015 with 21 publications and then expanded linearly. Therefore in the period from 2015 to 16 December 2020, a bibliometric study is carried out in the paper and it is found that 382 documents have been released in the Scopus. In 2019, the largest number of documents with a count of 116 is released and now, intensive research is going on in 2020 on UWB MIMO antennas.

The distribution of UWB MIMO antenna documents by its type is presented in Figure 3. According to this figure, 71.5% are research articles and 23.3% are conference papers. On the UWB MIMO antenna, only 2.9% of review articles are written. For the latest researchers on UWB MIMO antenna, this paper would be very useful to shed light on research holes in the field of UWB antenna designs.

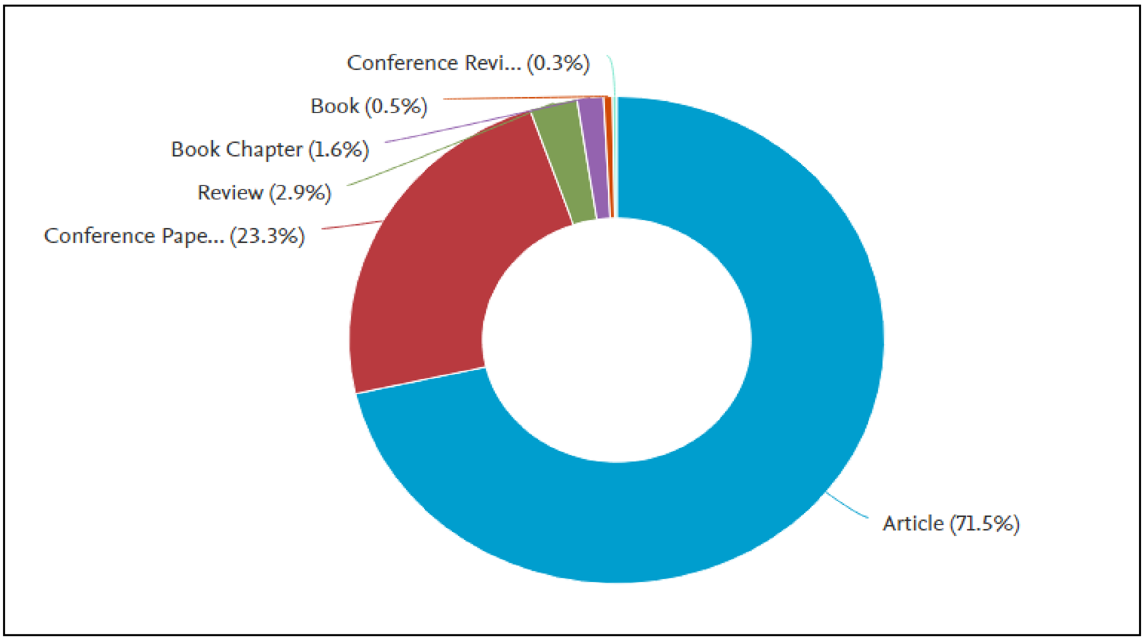

Figure 3: Distribution of UWB MIMO antenna documents by its type

Figure 4 displays the bar graph of UWB antenna documents released by the leading universities and its tabular form is mentioned in table 1. This illustrates that the University of Bradford, England (UK), is the leading UWB MIMO antenna design university. According to the Scopus database, 160 universities from all over the world have made a valuable contribution to the UWB antenna research field.

Figure 5 indicates the number of papers published in the top five journals per year. The IEEE access journal has been at the top since 2018 of these journals (greater than 10 research paper/year). The International Journal of RF and Microwave Computer Aided Engineering along with AEU International Journal of Electronics and Communications publish a small number of articles. In comparison, a few numbers of researchers have used IEEE transactions on antennas and propagation as well as a microwave and optical technology letters for their research article publication.

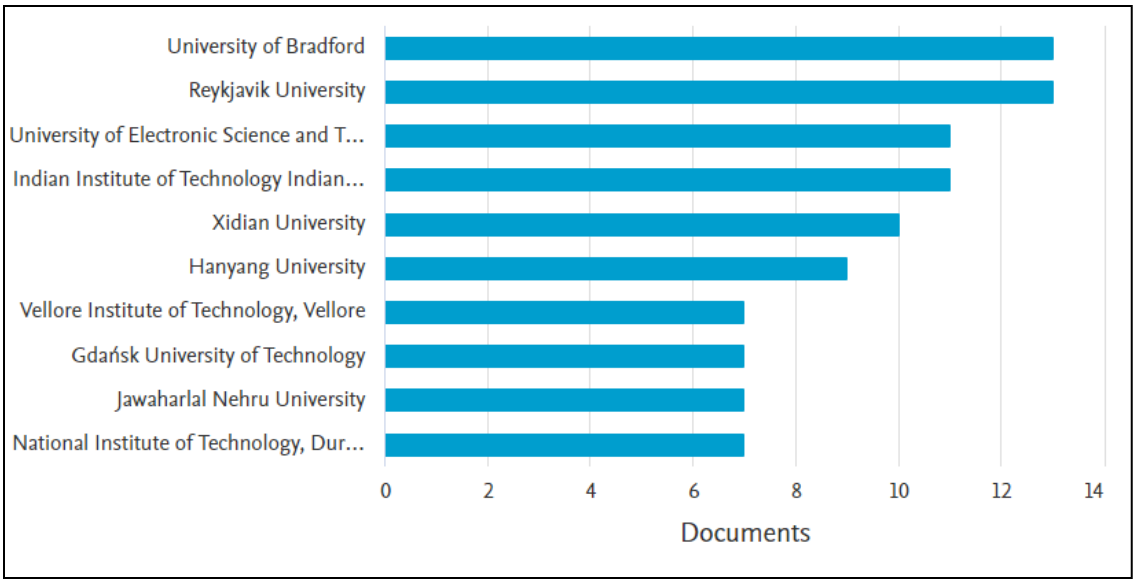

Figure 4: Bar chart of number of documents published by top ten universities

Figure 6 displays the map of the world with numbers of UWB MIMO antenna publications in different countries. Google sheet is used to create this map. The green colour indicates the maximum of journals published whereas a small number of publications suggest the red colour. The statistic indicates that the highest numbers of documents are published by India followed by China.

Table 1. Number of documents published by top ten universities

Sr. No.	University Name	No. of Papers Published
1	University of Bradford	13
2	Reykjavik University	13
3	University of Electronic Science and Technology of China	11
4	Indian Institute of Technology Indian School of Mines, Dhanbad	11
5	Xidian University	10
6	Hanyang University	9
7	Vellore Institute of Technology, Vellore	7
8	Gdańsk University of Technology	7
9	Jawaharlal Nehru University	7
10	National Institute of Technology, Durgapur	7

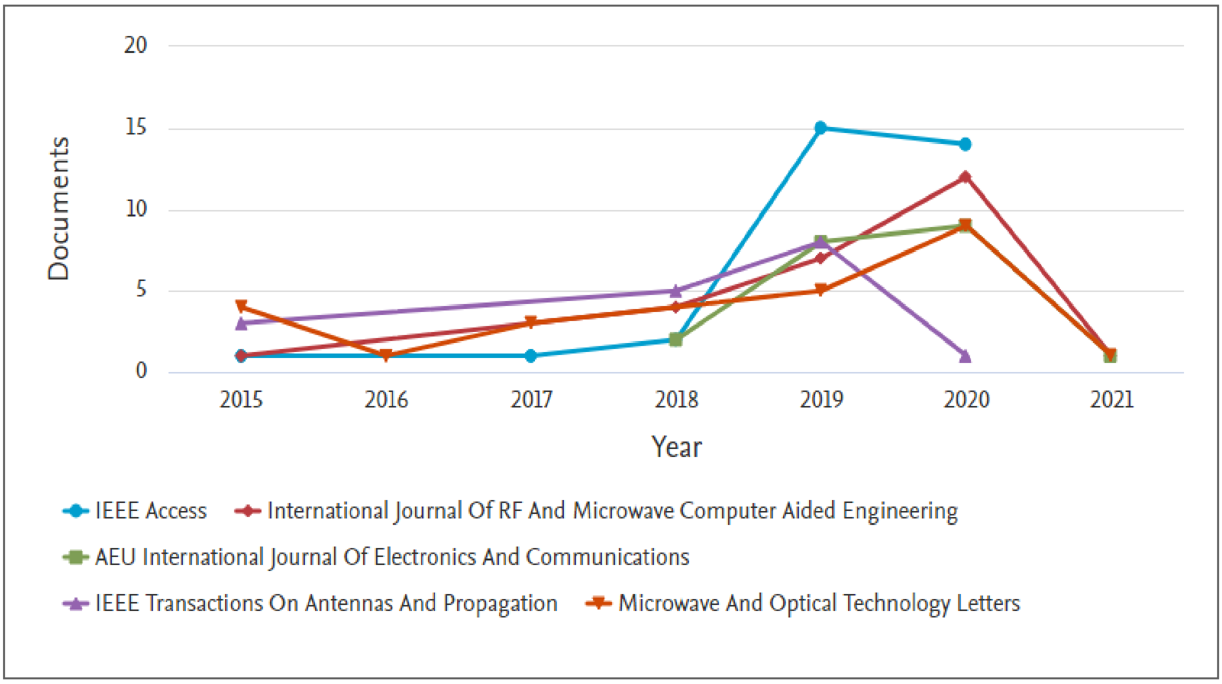

Figure 5: Number of documents published per year by various journals

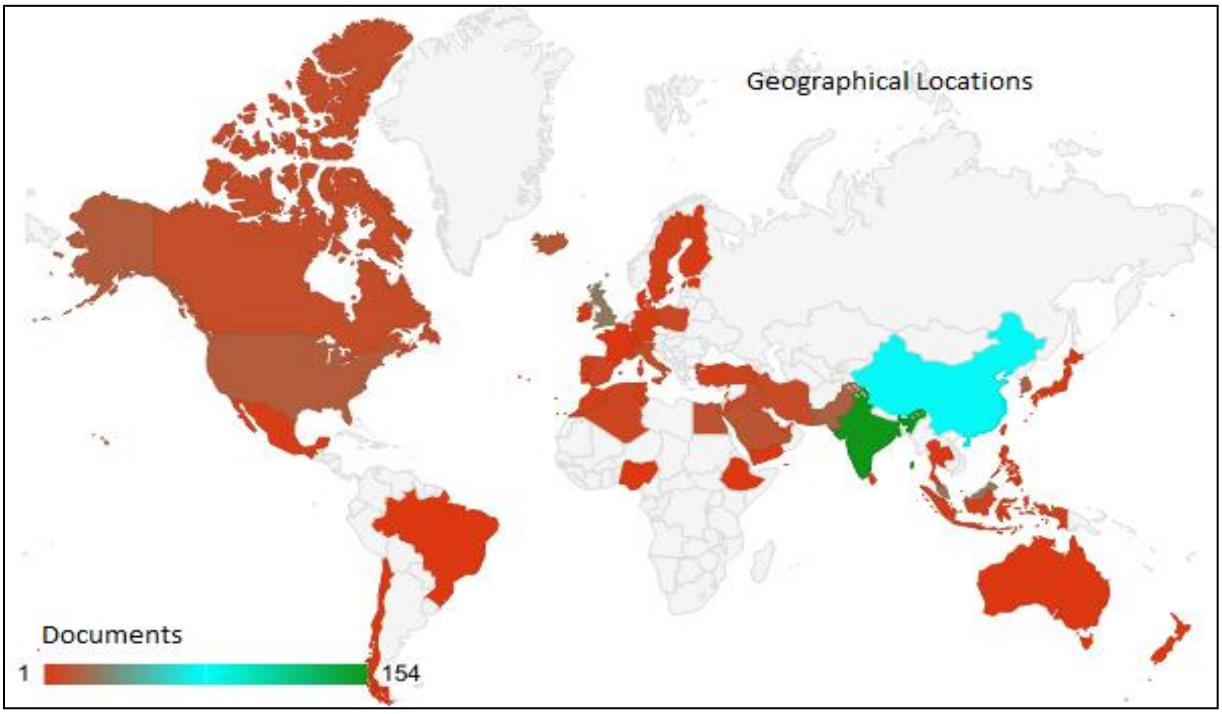

Figure 6: Country wise details of research done on UWB MIMO antenna

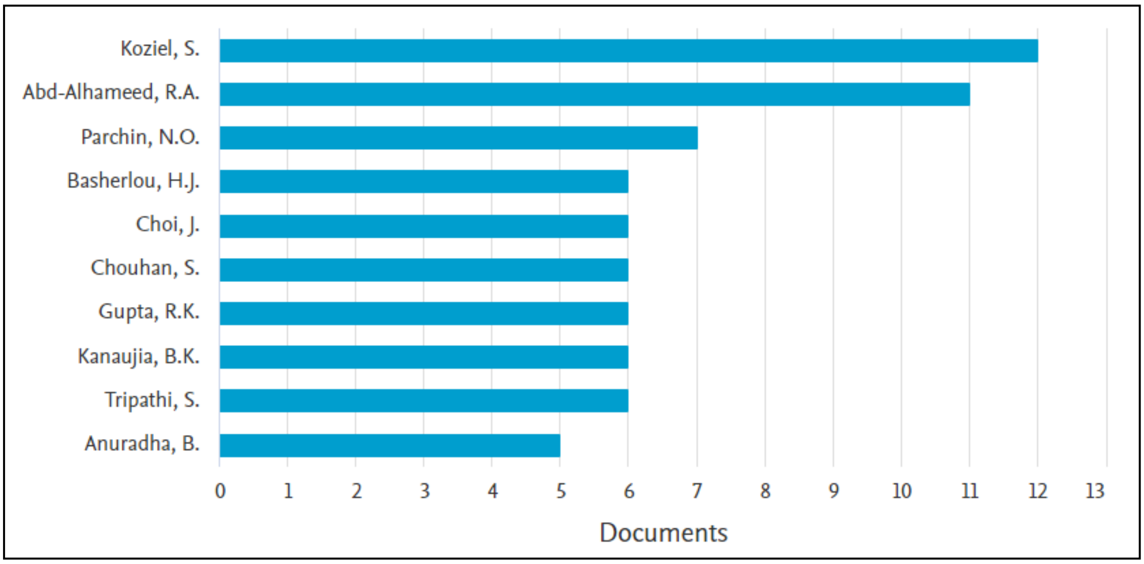

Figure 7: The bar chart of research contribution by top ten authors

Figure 7 and table 2 outline the contribution of the top ten authors in the area of UWB MIMO antenna. There were a total of 159 researchers working on antenna design for UWB applications. Out of them, Koziel S. has published a maximum number of documents (12) followed by Abd-Alhameed R.A. with a count of 11 documents.

Table 2. Details of number of documents published by top ten authors

Sr. No.	Author Name	No. of Documents Published
1	Koziel, S.	12
2	Abd-Alhameed, R.A	11
3	Parchin, N.O.	7
4	Basherlou, H.J.	6
5	Choi, J.	6
6	Chouhan, S.	6
7	Gupta, R.K.	6
8	Kanaujia, B.K.	6
9	Tripathi, S.	6
10	Anuradha, B.	5

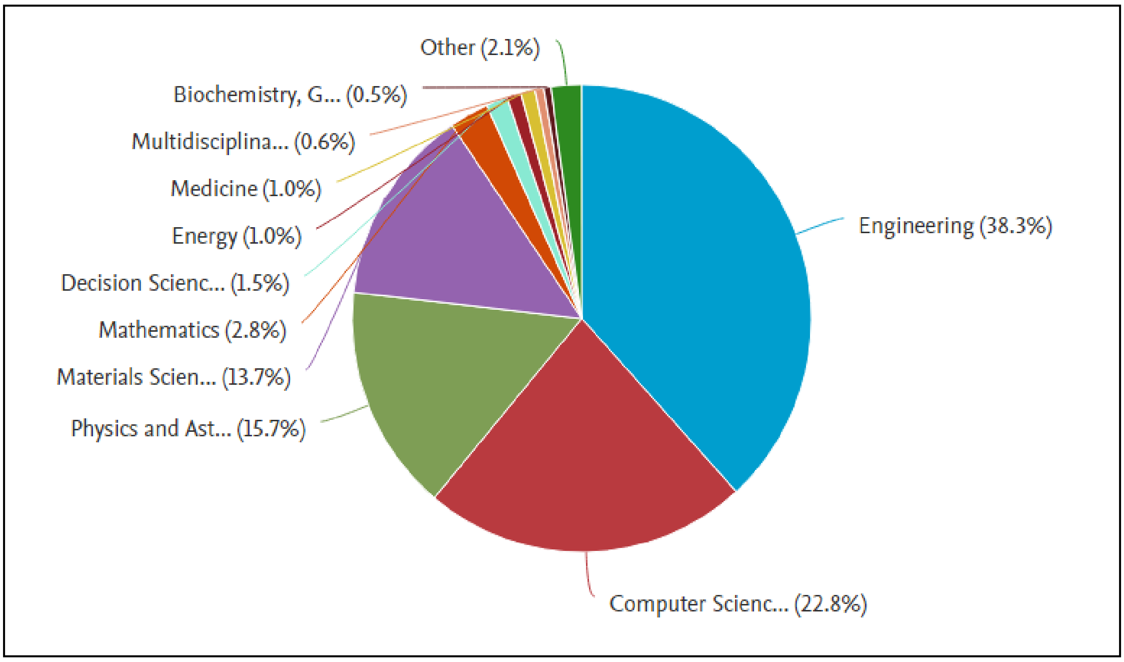

Figure 8: Distribution of documents by subject area

The percentage-wise distribution of UWB MIMO antenna documents in different subject areas is seen in figure 8, which portrays UWB MIMO antenna design primarily in the field of engineering and computer science, representing subject areas 38.3% and 22.8% of all subjects respectively. 15.7% from Physics and astronomy while material science includes 13.7% of research work on UWB MIMO antenna. Other subject areas like mathematics, decision science, medicine, etc. are merely involved in the UWB MIMO antenna designs.

In comparison, a cluster of paper titles and their accompanying year are seen in figure 9. This cluster figure is drawn with the help of the NodeXL tool in which nodes reflect the year of publication and publication titles. The density of the cluster shall be the number of publications in the following year. This statistics indicates that more research on UWB MIMO antenna is conducted in 2019 followed by the 2020 year.

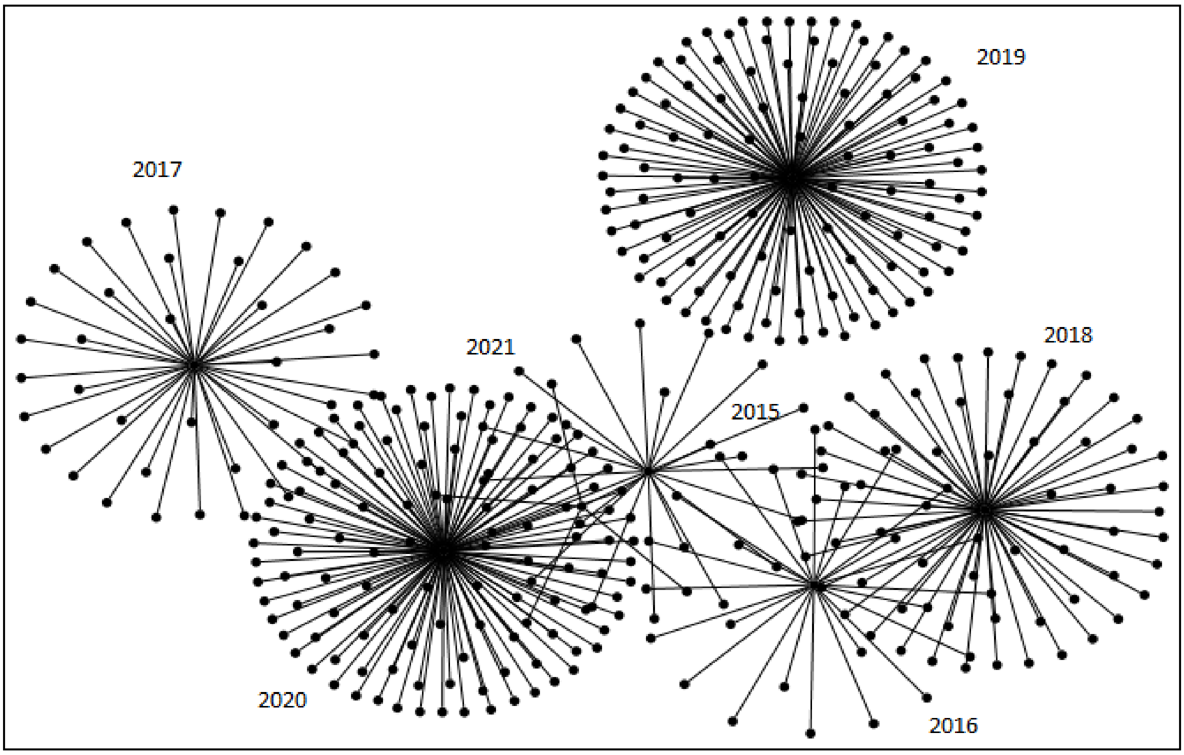

Figure 9: Cluster of publication year and article titles

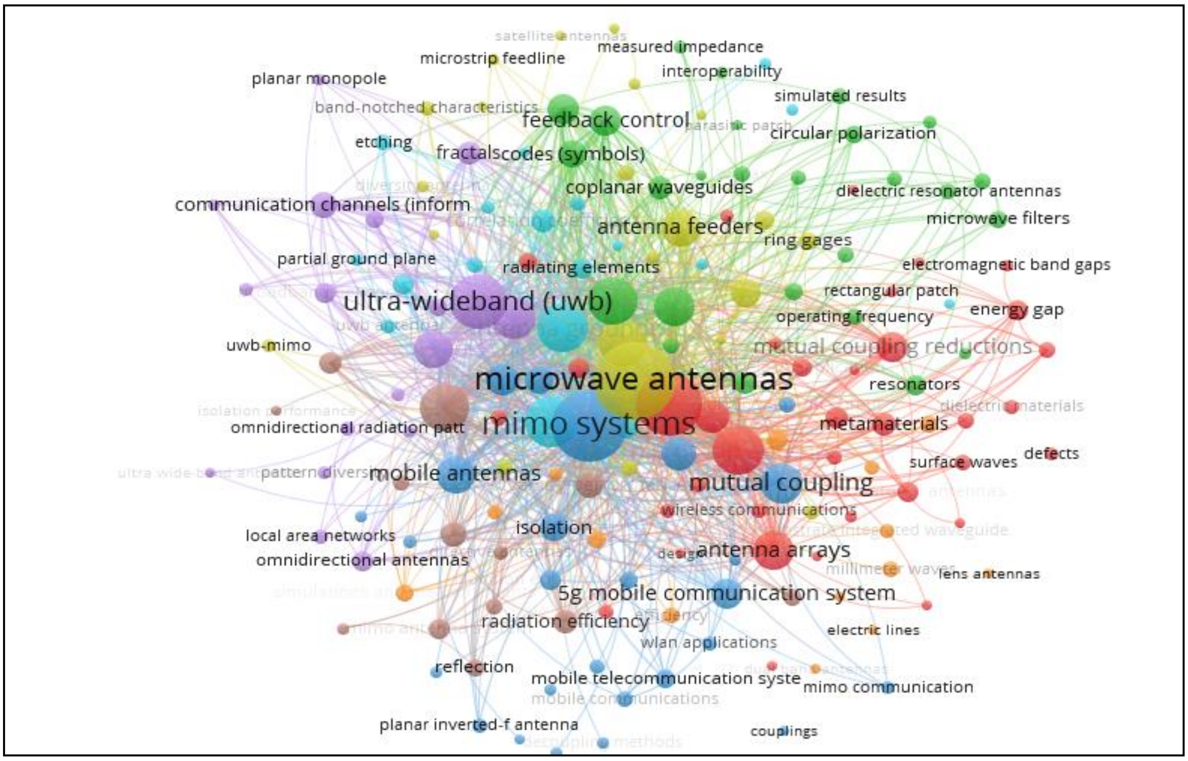

Figure 10: Network visualization depicting the inter linkage of indexed keywords

The VOS viewer tool is used to acquire figure 10which depicts a network map comprising ties between keywords and source titles. The circles in the network reflect the different keywords of the source titles. For example, the size of the circle reflects the number of occurrences of that keyword in the source title; the circle indicating the MIMO systems is of the greatest size since it has the maximum number of repetitions. Next, the distance between two keywords is directly proportional to the association between those keywords. As seen in figure 11, microwave antennas and ultra wide band are more closely related to the MIMO systems. These statistics are also very useful to understand the keywords of the UWB MIMO antenna and their interactions.

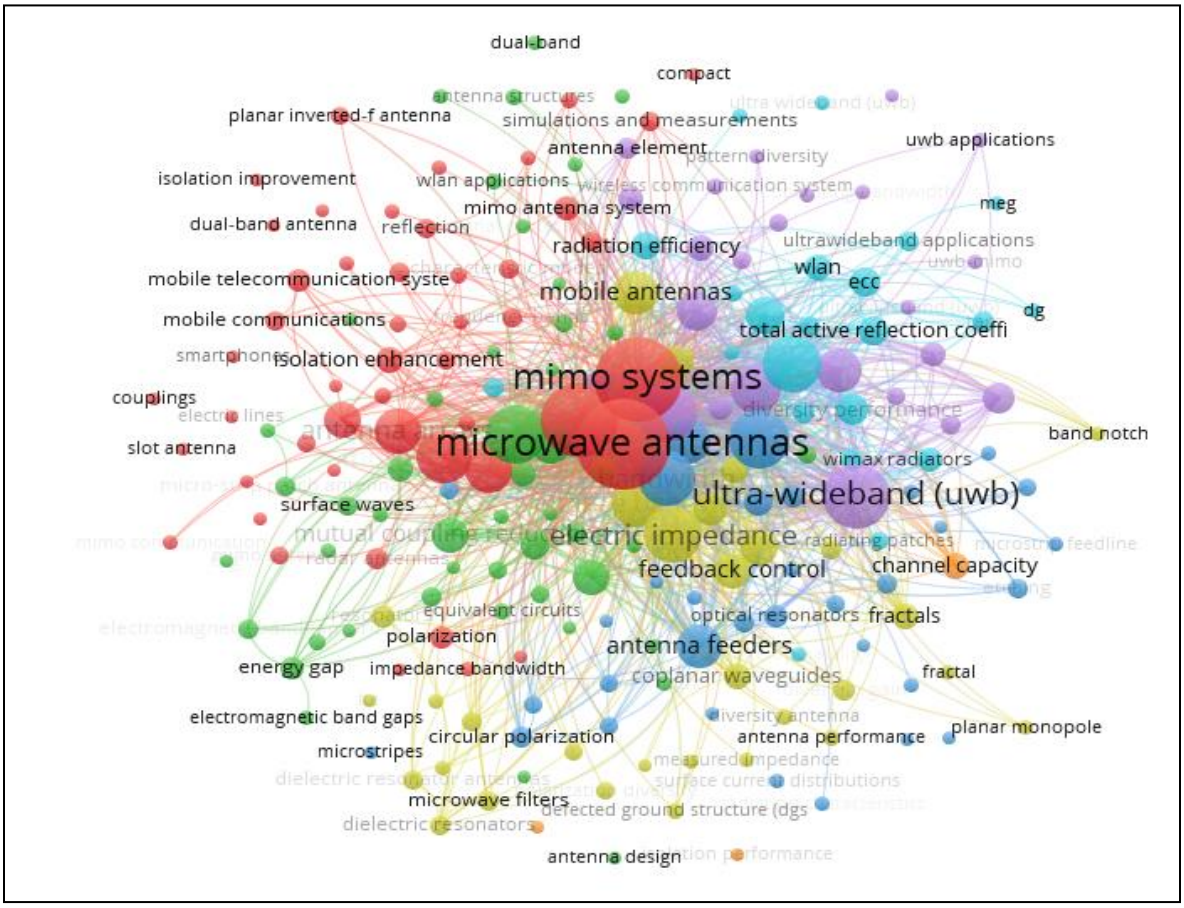

Figure 11: Network visualization indicating the inter linkage of UWB MIMO system keyword with other keywords

Table 3 describes the details of the top five publications that are highly cited in the field of UWB MIMO antenna. All documents are from IEEE and IEEE Transactions on Antennas and Propagation journal is the leading source for UWB MIMO antenna design. All five documents are research articles and research article of Liu L. et al. is at the top and cited by 141 times followed by a research article of Li Q. et al. which is cited by 133 times. The research article of Liu L. et al. elaborates deep band notch to suppress interference in the WLAN band of MIMO antenna for a UWB application.

Table 3. Top five highly cited documents in the field of UWB MIMO antenna

Sr. No.	Document Title	Authors	Year	Journal Title	Citation Count
1	Compact MIMO Antenna for Portable UWB Applications With Band-Notched Characteristic	Liu L., Cheung S.W., Yuk T.I.	2015	IEEE Transactions on Antennas and Propagation	141
2	Miniaturized double-layer EBG structures for broadband mutual coupling reduction between UWB monopoles	Li Q., Feresidis A.P., Mavridou M., Hall P.S.	2015	IEEE Transactions on Antennas and Propagation	133
3	Mutual Coupling Reduction Using F-Shaped Stubs in UWB-MIMO Antenna	Iqbal A., Saraereh O.A., Ahmad A.W., Bashir S.	2017	IEEE Access	101
4	A Compact Koch Fractal UWB MIMO Antenna with WLAN Band-Rejection	Tripathi S., Mohan A., Yadav S.	2015	IEEE Antennas and Wireless Propagation Letters	97
5	Dual-Band Textile MIMO Antenna Based on Substrate-Integrated Waveguide (SIW) Technology	Yan S., Soh P.J., Vandenbosch G.A.E.	2015	IEEE Transactions on Antennas and Propagation	79

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4. Conclusion

This bibliometric analysis is undertaken to demonstrate the magnitude and potential reach of UWB MIMO antenna. It offers statistics about publishing rates each year in different journals, countries, subjects, and magazines. Most notably, the study of publishing numbers each year reveals that in the field of UWB MIMO antenna there is still plenty of space for research. To understand the relation between various keywords, network analysis has been performed. It would provide potential research with recommendations for study by different authors depending on the number of publications or the number of citations they produce. In addition, this bibliometric survey makes it possible to identify and target the journals for publications with sufficient information on the UWB MIMO antenna. The statistical analysis in this bibliometric study has shown that India leads in the UWB MIMO antenna design followed by China. For finding the research gap in the field of UWB MIMO antenna design, this bibliometric study is very useful for new researchers.

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