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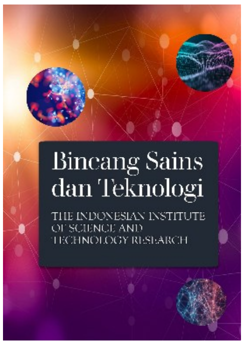

RIS for 5G and Beyond: A Bibliometric Survey

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Abstract

The rapid advancement of 5G technology has sparked significant interest and investment in research and development across various domains. As the world transitions towards the era of 5G and beyond, understanding the research landscape becomes imperative for guiding future innovations and investments. This article presents a comprehensive bibliometric survey of research on the topic of reconfigurable intelligent surfaces (RIS) for 5G and its evolutionary successors. This survey systematically analyzes scholarly publications and maps the trends, key contributors, influential works, and emerging themes within the field. By synthesizing data from diverse sources, including academic journals and conference proceedings, this survey offers insights into the evolution of RIS technologies, identifies prominent research clusters, and outlines potential directions for future investigation. Furthermore, it sheds light on the interdisciplinary nature of RIS research, spanning areas such as telecommunications, signal processing, antenna design, and network optimization. This bibliometric survey serves as a valuable resource for researchers and practitioners to navigate the complex landscape of 5G innovation and shape the trajectory of future wireless communication systems.

Keywords: *Reconfigurable intelligent surface* (RIS), *bibliometric study, fifth generation* (5G) *technology, wireless networks, wireless communications*

Introduction

The rapid advancement of wireless technology has led to an unprecedented increase in data rate demands, particularly with the emergence of fifth-generation (5G) networks and beyond. This surge in demand has raised significant concerns regarding reliability, energy consumption, and efficiency in wireless communication systems [1]–[5]. Reconfigurable Intelligent Surfaces (RIS) have emerged as a promising solution in response to these challenges. RIS is a planar surface composed of an array of passive reflector elements, each capable of independently adjusting the phase, magnitude, or frequency of incoming signals [6]–[10]. This innovative technology can potentially drive a significant paradigm shift in the design of traditional wireless networks [11]–[13].

Each RIS passive reflector element reflects incident signals according to specific reflection conditions. The reflection amplitude and phase shift of each unit cell element can be dynamically configured to match the wireless channel. The signals reflected by RIS can combine constructively or destructively with signals from other paths at the receiver, thereby enhancing signal power or collectively suppressing interference [14]–[16]. Compared to traditional relays, RIS are expected to operate in full-duplex mode without introducing self-interference or thermal noise. Furthermore, because almost all components are passive, RIS devices are cost-effective and significantly reduce energy consumption [17], [18]. Figure 1 illustrates two of the most common RIS-aided wireless communications scenarios.

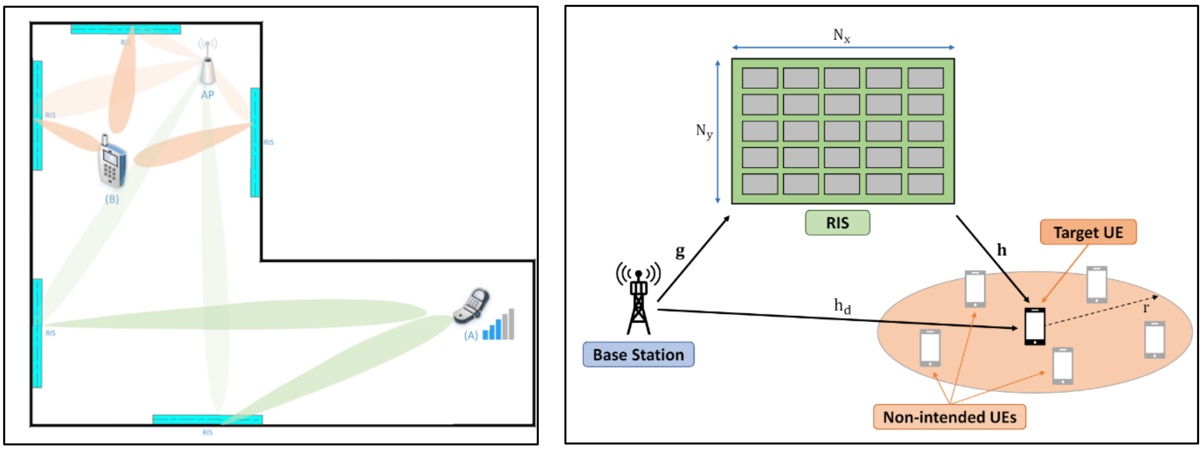

Fig. 1. Two most common RIS-aided wireless communications scenarios. RIS to provide alternative links to aid wireless communications in indoor scenario (left) [10] and outdoor scenario [19].

This article presents a comprehensive bibliometric survey of RIS in 5G technology. This article was written on June 2nd, 2024. By analyzing the current literature, we aim to provide a detailed overview of RIS's development, applications, and future prospects. This survey highlights the significant contributions in this field and identifies gaps and opportunities for further research.

RIS Fundamental

RIS can revolutionize wireless communication by dynamically manipulating electromagnetic waves to enhance performance. At the core of RIS technology lies a surface composed of countless tiny, programmable elements. These elements are capable of adjusting the phase, amplitude, and polarization of incoming electromagnetic waves. Through precise control of these properties, RIS can effectively steer, reflect, or focus the waves to achieve desired communication outcomes.

When electromagnetic waves, such as signals from wireless transmitters, encounter an RIS, the elements on the surface interact with them based on instructions received from a control unit. This interaction allows the RIS to alter the properties of the incoming waves according to specific communication objectives. Key functions of RIS include beam steering, which redirects signals towards targeted areas to improve coverage and strength, and beamforming, which focuses signal energy towards specific receivers to enhance communication quality. Additionally, RIS can manage interference by controlling the reflection of signals, thus reducing cross-talk between communication channels.

RIS has the potential to drive the most significant paradigm shift in classic wireless network design. Key design considerations for RIS include the elements' geometry, arrangement of elements, the total number of elements, and the distance between elements. These factors directly influence the performance of a wireless network utilizing RIS. For example, research by F. Maresca [19] has shown that optimizing RIS may involve designing ad-hoc hardware based on modular patch antennas. Their

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proposed design is capable of supporting multiple frequencies with configurable settings. Such designs, as illustrated in Figure 1, highlight the potential for RIS to enhance wireless communication by improving signal strength and reducing interference.

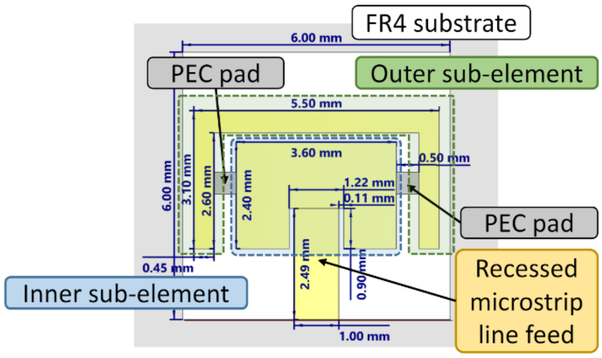

Fig. 2. An illustration of RIS design proposed in [19].

Figure 2 illustrates the geometry of a single RIS element proposed in [19], where the circuit's behavior from the connected pin diode is modeled through PEC bearings. Initially, the authors equip each RIS element with a transmission channel and evaluate its S11 parameter with the diode on either OFF or ON state. Figure 3 depicts their measured S11 and simulated RIS beam pattern. As shown in Figure 3, S11 significantly dips at $f_1 =$ 21.28 GHz (diode OFF: -34.85 dB) and at $f_2 =$ 27.96 GHz (diode ON: -36.5 dB), reaching its global minimum in the latter case. Additionally, the S11 obtained with the diode ON indicates a local minimum, though its value is higher (-15 dB) than the global minimum at f_2. This confirms the effectiveness of their design.

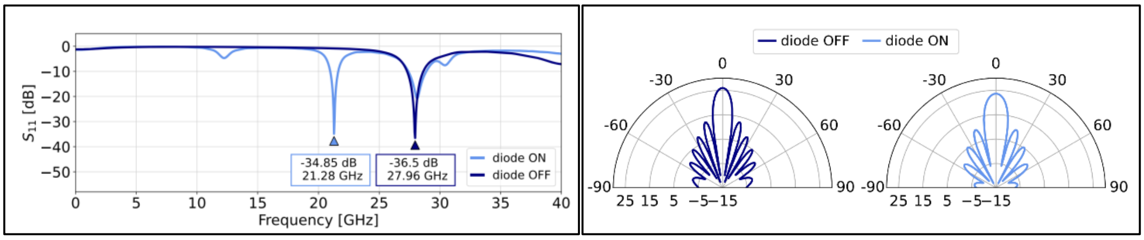

Fig. 3. Measured S11 of the proposed RIS design (left) and simulated RIS beam pattern (right) [19].

The multifrequency RIS consists of $N_x = N_y = 10$ elements and is designed with a distance between elements of $d = 0.56\lambda_i$, where λ_i corresponds to the maximum supported working frequency $f_1 = 27.96$ GHz. Additionally, the RIS is designed to support a working frequency $f_2 = 21.28$ GHz, with the element spacing appropriately set to a wavelength ratio of 0.42.

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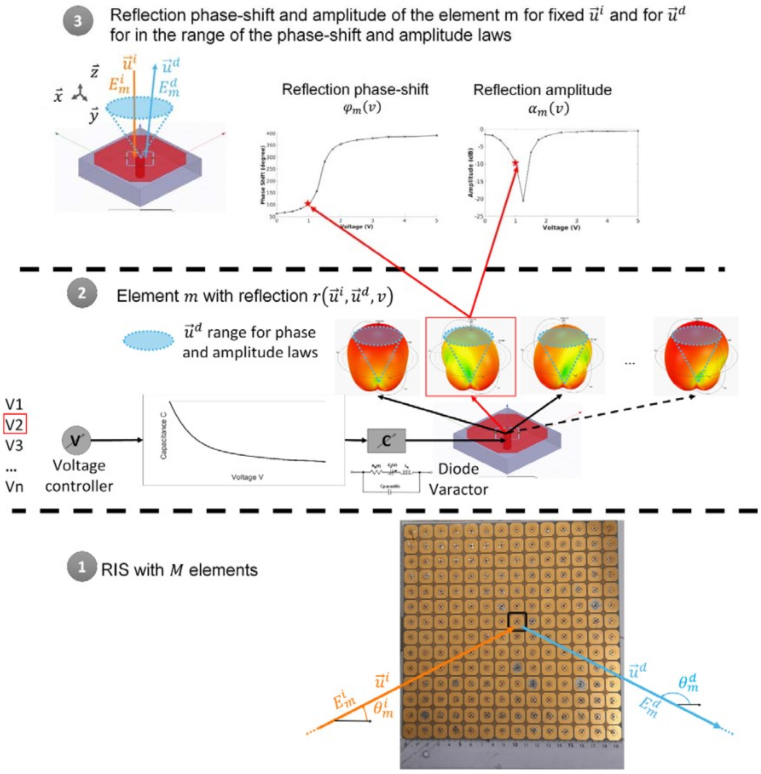

Fig. 4. RIS design proposed in [9].

The authors in [9] proposed an RIS prototype with continuous control of the reflection phase. The proposed design is depicted in Figure 4. The authors characterized its properties using full-wave simulations and experimental measurements. Specifically, they introduced a phase shift model to predict the signals reflected by the RIS prototype. They then apply this model to optimize an RIS-assisted Ambient Backscatter Communication (AmBC) system (see Figure 5), demonstrating that incorporating an RIS can substantially enhance system performance.

Fig. 5. Illustration of the considered testbed for RIS-assisted AmBC in [9].

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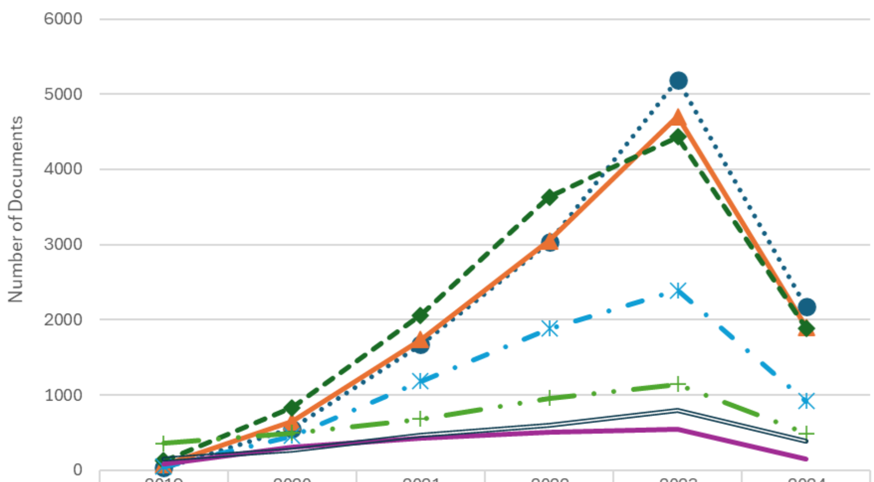
Bibliometric Analysis of RIS Research

The RIS has recently emerged as a promising technology for future generations of wireless communications. Consequently, the amount of research on RIS has surged in the last few years. To evaluate the breadth and depth of research in the field of RIS, we conducted a comprehensive bibliometric analysis using data from the Google Scholar and Web of Science databases for the last few years. This analysis aims to quantify the volume of research output, identify key trends, and highlight influential works and authors within the field. By leveraging tools such as line charts, bar charts, tables, and VOSviewer, we visualize and summarize the collected data effectively. The main objective of this quantitative analysis is to explore the volume of work conducted and to enable researchers to identify the limitations of their research.



	2019	2020	2021	2022	2023	2024
"reconfigurable intelligent surface"	36	554	1670	3030	5190	2170
"reconfigurable intelligent surfaces"	74	646	1740	3050	4700	1900
"intelligent reflecting surface"	127	834	2060	3630	4430	1890
"intelligent reflecting surfaces"	48	456	1180	1880	2390	921
"large intelligent surface"	78	301	430	506	544	154
"coding metasurface"	354	498	682	956	1140	487
"programmable metasurface"	153	267	462	598	795	387

Fig. 6. Annual document publications within the RIS field.

Figure 6 illustrates the statistical trend in annual document publication within the RIS field. RIS is also known as intelligent reflecting surface (IRS), large intelligent surface (LIS), coding metasurface, or programmable metasurface. Therefore, we use "*reconfigurable intelligent surface*" OR "*reconfigurable intelligent surfaces*" OR "*intelligent reflecting surface*" OR "*intelligent reflecting surfaces*" OR "*large intelligent surface*" OR "*coding metasurface*" OR "*programmable metasurface*" as the searching keywords. Over the last five years, as per data sourced from Google Scholar (January 2019 to May 2024), there has been a consistent increase in the number of studies on RIS. In 2019, 870 studies were published, which escalated to 3556 in 2020, further to 8224 in 2021, surged to 13650 in 2022, peaked at 19189 in 2023, and 7909 in 2024 (as of May 2024). These figures underscore the growing interest among researchers in the RIS topic.

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The distribution of published works on RIS includes articles, conference papers, conference reviews, reviews, book chapters, and short surveys, as shown in Figure 7. According to the quantitative data, out % of all published documents on the RIS topic, 45.4% are journal articles, followed by 37.8% conference papers, 8.4% conference review documents, 7% review articles, 0.7% book chapters, and 0.7% short surveys. Journal articles constitute the majority of research work in this field. It is worth noting that the diversity in document types indicates that RIS is a hot topic. However, since RIS is a relatively new and still maturing technology, there are currently limited book chapters, surveys, reviews, and tutorials available.

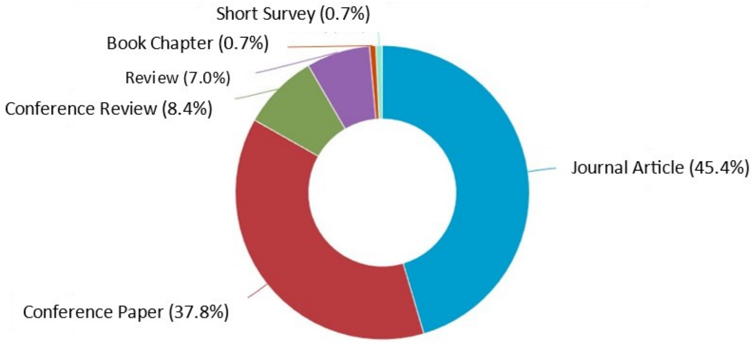

Fig. 7. The distribution of the type of published works within the RIS topic.

A bar chart representing the number of published RIS documents by the top 10 institutions worldwide is shown in Figure 8. The data were gathered from the Web of Science platform. Southeast University China occupies the top ranking with 182 published documents, followed by the Chinese Academy of Sciences with 150 documents. University of Electronic Science Technology of China, the University of London, and the Beijing University of Posts Telecommunications occupy third, fourth, and fifth place, respectively, with 113, 109, and 76 published documents. According to the Web of Science database, from 1992 to the present, at least 160 institutions worldwide have contributed to RIS research, underscoring its global significance. It is worth noting, however, that the number of RIS-related works remained low until it surged several years ago.

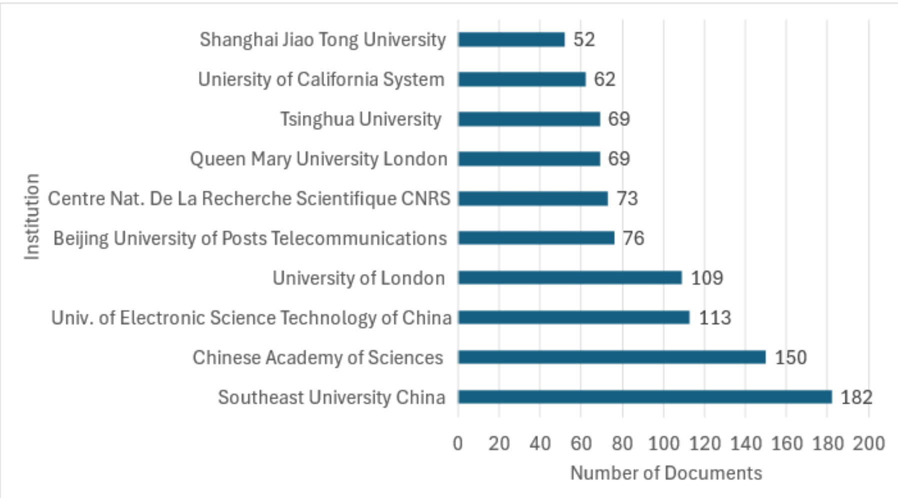

Fig. 8. Top institutions in terms of the number of published RIS works.

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Table 1 and Figure 9 highlight the leading journals in terms of the number of published RIS research. The data was gathered from Google Scholar. Among the top-ranking venues, IEEE Transactions on Communications holds the highest share at 8.58% of published RIS documents, followed by IEEE Transactions on Wireless Communications and IEEE Internet of Things, each contributing 5.51% to the RIS literature. IEEE Transactions on Antennas and Propagation and IEEE Access complete the top five ranking, respectively, with 5.25% and 4.74% share. Figure 10 presents the top conferences in terms of the number of published RIS research. Two IEEE ComSoc flagship conferences (i.e., IEEE GLOBECOM and IEEE ICC) topped the list, each with 161 and 151 articles. Regarding publishers, IEEE dominates the list of journals and conferences. This indicates that IEEE offers numerous publishing venues that are well-suited for the RIS topic.

Table 1. Top journal venues in terms of the number of published RIS works.

Name of the Journal	Published RIS Works (%)
IEEE Journal of Sel. Topics in Signal Processing	1.02%
IEEE Open Journal of Antennas and Propagation	1.02%
IEEE Signal Processing Magazine	1.02%
IEEE Transactions on Vehicular Technology	1.15%
MDPI Electronics	1.28%
IEEE Open Journal of the Communications Society	1.41%
IET Communications	1.54%
IEEE Wireless Communications Letters	2.05%
IEEE Journal on Sel. Areas in Communications	2.30%
IEEE Communications Magazine	2.94%
IEEE Wireless Communications	2.94%
IEEE Communications Letters	3.46%
IEEE Access	4.74%
IEEE Transactions on Antennas and Propagation	5.25%
IEEE Internet of Things	5.51%
IEEE Transactions on Wireless Communications	5.51%
IEEE Transactions on Communications	8.58%
Other Journal and Conferences	48.27%

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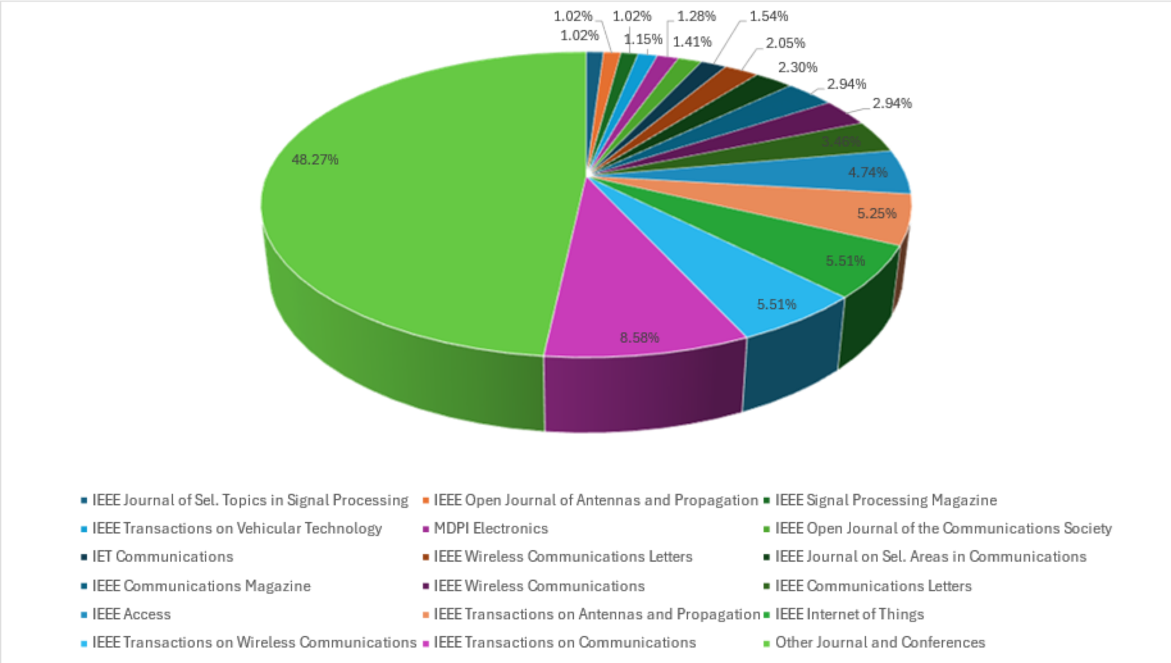

Fig. 9. Top journal venues in terms of the number of published RIS works.Top conference venues in terms of the number of published RIS works.

Fig. 10. Top conference venues in terms of the number of published RIS works.

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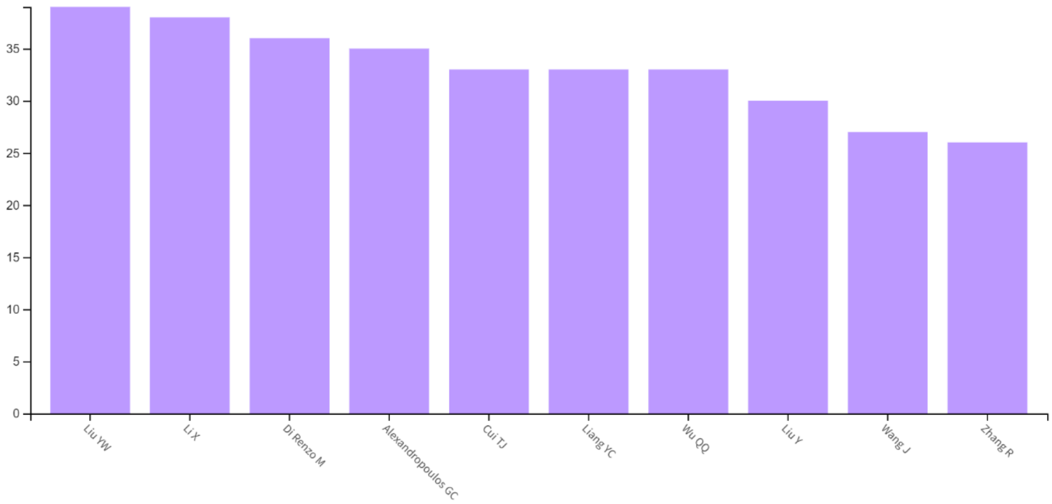

Fig. 11. Authors with the highest number of published RIS works according to Web of Science.

Numerous researchers have made significant contributions to RIS design since 1992. The quantitative analysis in Figure 11 depicts the top 10 authors' contributions to the field in terms of the number of works on the RIS topic. According to the Web of Science database, a total of at least 159 authors have had their names listed on published RIS research, with Liu Y. W. (39 documents), Li X. (38 documents), and Di Renzo, M. (36 documents), Alexandropoulos G. C. (35 documents), and Cui T. J. (33 documents) occupying the top five rankings.

RIS prototypes encompass various design types, utilizing a range of structural cell units, as documented in the survey literature. The scope of research extends beyond technical aspects to encompass diverse fields such as computer science, physics, material science, mathematics, science, decision science, and many more. The distribution of the published documents according to field of study is depicted in Figure 12, highlighting a predominant presence in the computer science category, with 37.9% of documents, followed by the engineering category, with 32.6% of documents. Additionally, 8.2% of documents are in physics, 6% in material science, and 5.7% in mathematics. As in Figure 13, from 4508 publications selected from the Web of Science Core Collection, 2352 belong to the engineering electrical electronic topic, 1729 to the telecommunications category, and 1083 to the computer science artificial intelligence.

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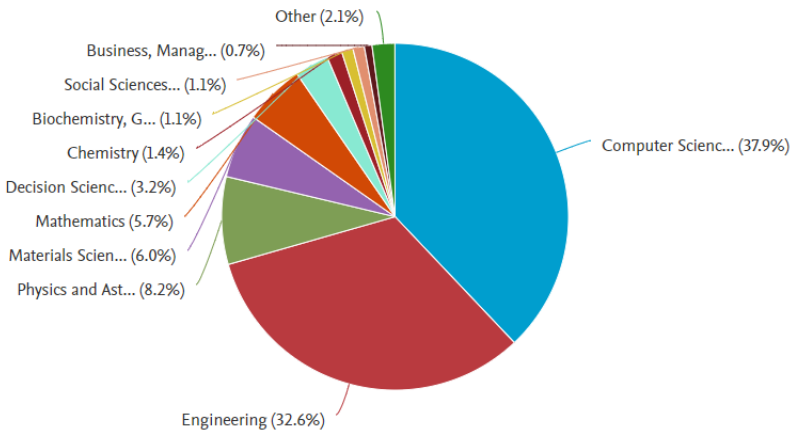

Fig. 12. Field of RIS study.

Fig. 13. Category of published RIS study according to Web of Science Core Collection.

Table 2. Countries with the highest number of published RIS works, according to Web of Science.

Country/Territory	Number of Documents
China	1763
United States	814
Germany	307
England	300
Japan	288
Canada	181
France	168
India	164
South Korea	160
Italy	128

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Researchers from various countries and territories worldwide actively contribute to the field of RIS. Table 2 presents the number of documents issued by the top 10 countries/territories. Additionally, Figure 14 provides a visualization depicting the network linkage of indexed keywords and title sources using the VOSviewer tool. Different keywords from the title sources, such as "*reconfigurable intelligent surface*," "*5G mobile communication system*," "*wireless sensor network*," "*internet of things*," and others, are represented by circles in the network. Lines connecting these circles signify the connections between keywords, with opaque colors, larger font sizes, and larger circle sizes, highlighting stronger relationships with RIS. In the subsection below, we discuss some of the keywords with the strongest relationships.

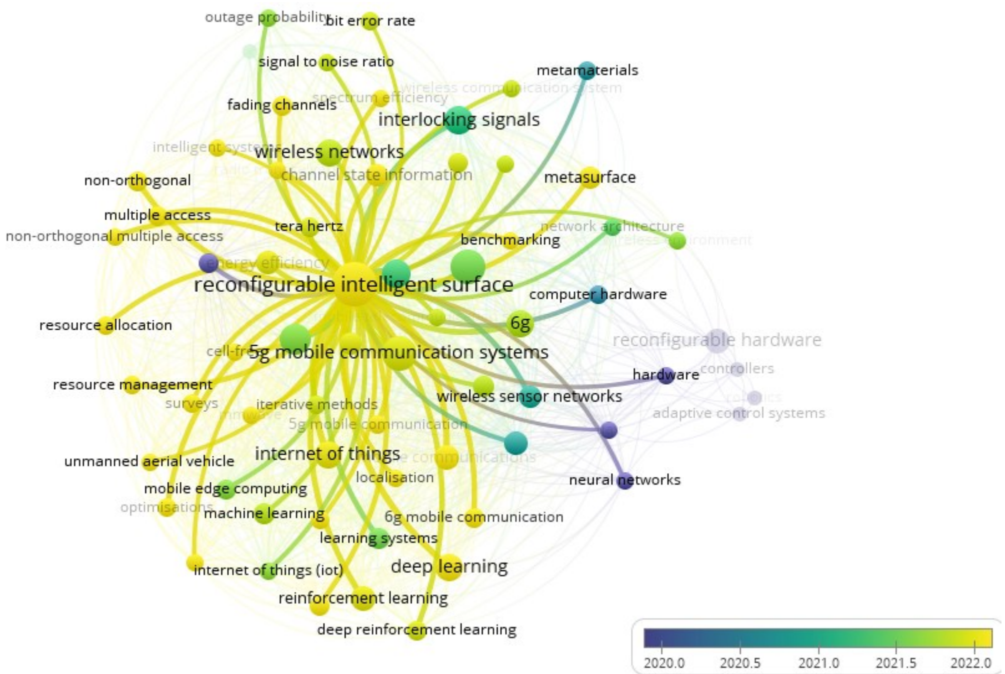

Fig. 14. Visualization describing network linkage of indexed keywords among published works on RIS topic.

A. 5G and 6G Mobile Communication Systems

RIS is poised to be a critical component in the evolution of 5G and the development of 6G mobile communication systems. In 5G networks, RIS can enhance signal strength, improve coverage, and increase energy efficiency by intelligently reflecting and modulating electromagnetic waves. As we transition to 6G, RIS technology is expected to play an even more significant role by enabling ultra-reliable, low-latency communications, and supporting new paradigms such as holographic beamforming and integrated sensing and communication. The ability of RIS to dynamically adapt the wireless environment will be key in meeting the stringent requirements of 6G, including higher data rates, massive connectivity, and improved spectral efficiency.

B. Internet of Things (IoT)

The integration of RIS into Internet of Things (IoT) networks can significantly enhance their performance and reliability. RIS can be employed to improve the connectivity and coverage of IoT devices, especially in dense urban environments where signal obstruction is common. By reconfiguring the propagation of wireless signals, RIS can ensure stable and robust communication links for a multitude of IoT devices, thereby reducing latency and increasing data throughput. This capability is crucial for the seamless operation of IoT applications, such as smart cities, industrial automation, and healthcare monitoring, where reliable and efficient communication is essential.

C. Machine Learning, Neural Networks, Reinforcement Learning, and Deep Learning

Machine learning (and its extended definitions) can be leveraged to optimize the performance of RIS in wireless communication systems. By employing machine learning algorithms, the configuration of RIS elements can be dynamically adjusted to adapt to changing wireless environments and user requirements. This adaptive control enables the RIS to enhance signal quality, reduce interference, and maximize overall network performance. Machine learning models can also be used to predict the optimal settings for RIS based on historical data and real-time inputs, thereby improving the efficiency and effectiveness of RIS deployment in complex and dynamic scenarios.

D. Wireless Sensor Networks (WSNs)

In Wireless Sensor Networks (WSNs), RIS can play a pivotal role in enhancing communication reliability and energy efficiency. By intelligently redirecting signals, RIS can mitigate the effects of fading and interference, which are common challenges in WSNs. This capability ensures more reliable data transmission between sensor nodes, extending the network's operational lifespan and improving its overall performance. Additionally, RIS can reduce the power consumption of sensor nodes by enhancing signal propagation, thus enabling more energy-efficient communication in WSNs. Furthermore, several studies have highlighted the RIS potential to aid simultaneous wireless information and power transfer (SWIPT).

E. Interlocking Signals

RIS technology can effectively manage and mitigate the issue of interlocking signals in wireless communication systems. By dynamically reconfiguring the phase and amplitude of reflected signals, RIS can minimize interference and enhance signal separation. This capability is particularly beneficial in environments with high signal density, such as urban areas and indoor settings, where multiple signals often overlap and cause performance degradation. The use of RIS to control interlocking signals ensures clearer communication channels and improved data integrity.

F. Metamaterials/Metasurface

RIS is closely related to metamaterials and metasurfaces, which are engineered materials designed to control electromagnetic waves. RIS leverages the unique properties of metasurfaces to dynamically alter the propagation of wireless signals. These surfaces can be programmed to change their electromagnetic response, enabling precise control over signal direction, reflection, and refraction. The

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use of metasurfaces in RIS allows for the creation of smart and adaptive communication environments, significantly enhancing the performance and flexibility of wireless networks.

G. Non-Orthogonal Multiple Access (NOMA)

RIS can enhance the performance of Non-Orthogonal Multiple Access (NOMA) systems by improving signal quality and reducing interference among users. NOMA allows multiple users to share the same frequency spectrum by superimposing their signals, which RIS can help manage more effectively. By dynamically adjusting the reflection properties of the surface, RIS can optimize the signal-to-interference-plus-noise ratio (SINR) for each user, thereby increasing the overall capacity and efficiency of NOMA systems. This synergy between RIS and NOMA can lead to significant improvements in network throughput and user experience.

H. Resource Allocation

The deployment of RIS in wireless networks can significantly improve resource allocation strategies. By enhancing signal propagation and reducing interference, RIS can optimize the use of available spectrum and power resources. This capability allows for more efficient allocation of resources to users, improving overall network performance and user satisfaction. Additionally, RIS can enable dynamic and adaptive resource allocation based on real-time network conditions, ensuring optimal utilization of network resources and minimizing wastage.

I. Mobile Edge Computing (MEC)

RIS can enhance Mobile Edge Computing (MEC) by improving the communication link between edge servers and end-user devices. By optimizing signal strength and reducing latency, RIS can facilitate faster and more reliable data transmission, which is crucial for MEC's real-time processing capabilities. This improvement can support a wide range of latency-sensitive applications, such as augmented reality, autonomous driving, and real-time analytics, ensuring that computational tasks are efficiently offloaded to edge servers with minimal delay.

J. Outage Probability

RIS can significantly reduce outage probability in wireless communication systems by enhancing signal reliability and strength. Outage probability, which measures the likelihood of a communication link failing to meet a required signal quality threshold, can be mitigated through the intelligent use of RIS. By dynamically adjusting the phase and amplitude of reflected signals, RIS can ensure more stable and robust communication links, even in challenging environments with obstacles and interference. This capability is essential for maintaining high-quality communication in scenarios where consistent and reliable connectivity is critical.

Due to the page length limitation, we will not delve deeper into the aforementioned keywords. Additionally, several keywords depicted in Figure 14 cannot be discussed in detail here. For instance, channel state information (CSI) and fading are two keywords that have significant relationships with RIS. This is probably because RIS typically lacks radio frequency (RF) chains, making obtaining CSI for RIS-assisted systems challenging. This remains an open problem in the field. Furthermore, the absence of RF chains limits the practical gains achievable by RIS, which is further exacerbated by the multiplicative fading effect in RIS-aided systems. In such systems, signals must first travel to the RIS before being reflected to the transmitter-receiver, resulting in relatively higher propagation loss.

Another set of important keywords includes cell-free systems, localization, spectrum efficiency, and unmanned aerial vehicle (UAV). Many previous studies have demonstrated that RIS can be utilized to assist cell-free systems, achieve accurate wireless localization, and enhance spectrum efficiency. RIS can significantly improve these areas by dynamically reconfiguring the wireless environment to optimize signal propagation and reduce interference, thereby improving the overall performance of wireless networks. In addition, RIS-aided UAV communications and mobile RIS attached to UAVs have become two emerging topics in the last couple of years.

Table 3 presents the top five most cited publications related to RIS, including the year of publication, author(s), and journal title. One notable publication was authored by C. Huang et al. and published in IEEE Transactions on Wireless Communications in 2019. At the time of writing this paper, the article has been cited 2852 times by researchers. The paper delves into the theoretical performance of RIS for energy efficiency in wireless communications by utilizing mathematical techniques and explores potential applications in the next generation of wireless networks. Titled "*Reconfigurable Intelligent Surfaces for Energy Efficiency in Wireless Communication,*" the article validates a promising RIS potential for enhancing wireless communications efficiency. It encompasses various scenarios, leveraging insights from physics and the electromagnetic characteristics of RIS to enhance understanding and implementation.

Another key publication, titled "*Wireless Communications Through Reconfigurable Intelligent Surfaces*," provides a comprehensive overview of how RIS can transform wireless communication systems. The authors investigate various configurations and implementations of RIS, demonstrating its capability to manipulate electromagnetic waves to improve signal strength and coverage. This work, widely cited for its practical insights and theoretical advancements, underscores the significant role RIS can play in overcoming the limitations of traditional wireless networks.

In the study "*Wireless Communications with Reconfigurable Intelligent Surface: Path Loss Modeling and Experimental Measurement*," the authors focus on the empirical aspects of RIS. They conduct extensive experiments to model path loss and validate their findings with real-world measurements. This publication stands out for bridging the gap between theoretical models and practical applications, offering valuable data and analysis that support the feasibility and effectiveness of RIS in enhancing wireless communication systems.

The paper "*Weighted Sum-Rate Maximization for Reconfigurable Intelligent Surface Aided Wireless Networks*" delves into optimizing the performance of wireless networks aided by RIS. The authors propose techniques to maximize the weighted sum-rate, a critical performance metric in wireless communications. This research highlights the optimization potential of RIS, providing a framework for achieving higher data rates and more efficient resource allocation in wireless networks.

The publication "*Reconfigurable Intelligent Surface-Based Index Modulation: A New Beyond MIMO Paradigm for 6G*" introduces a novel concept of integrating RIS with index modulation techniques. This groundbreaking work explores the next-generation wireless technologies beyond MIMO, presenting RIS as a pivotal element in the development of 6G networks. The authors provide detailed theoretical analysis and simulation results, demonstrating how RIS can enhance data transmission rates and spectral efficiency in future wireless systems.

Table 3 shows that the most cited publications are all about various aspects of RIS, including its application in wireless communications, path loss modeling, experimental measurements, and novel paradigms such as index modulation for 6G. These works highlight the significant interest and rapid development in RIS research, showcasing its potential to revolutionize wireless networks by improving energy efficiency, optimizing sum-rate performance, and introducing innovative techniques beyond traditional MIMO systems. The diversity and depth of these studies underscore the versatility and transformative potential of RIS in shaping the future of wireless communications.

Table 3. Most cited RIS articles.

No.	Document Title	Authors	Year of Publication	Journal Title	Citation Count
1.	Reconfigurable Intelligent Surfaces for Energy Efficiency in Wireless Communication	C. Huang, A. Zappone, G. C. Alexandropoulos, M. Debbah and C. Yuen	2019	IEEE Transactions on Wireless Communications	2852
2.	Wireless Communications Through Reconfigurable Intelligent Surfaces	E. Basar, M. Di Renzo, J. De Rosny, M. Debbah, M. -S. Alouini and R. Zhang	2019	IEEE Access	2549
3.	Wireless Communications with Reconfigurable Intelligent Surface: Path Loss Modeling and Experimental Measurement	W. Tang et al.,	2020	IEEE Transactions on Wireless Communications	1153
4.	Weighted Sum-Rate Maximization for Reconfigurable Intelligent Surface Aided Wireless Networks	H. Guo, Y. -C. Liang, J. Chen and E. G. Larsson,	2020	IEEE Transactions on Wireless Communications	727
5.	Reconfigurable Intelligent Surface-Based Index Modulation: A New Beyond MIMO Paradigm for 6G	E. Basar	2020	IEEE Transactions on Communications	716

Conclusion

This study employed bibliometrics as a robust methodological approach to delve into the statistical landscape of RIS research. The utilization of bibliometrics, in tandem with the analysis of data retrieved from prominent scholarly databases such as Google Scholar and Web of Science, enabled a comprehensive quantitative examination of the evolving trends and dynamics within the RIS domain.

The findings of this study reveal a notable surge in the volume of scholarly works dedicated to RIS in recent years, underscoring the growing significance and relevance of this field in the realm of wireless communications. This trend underscores the escalating interest among researchers and practitioners alike in exploring the intricacies and potential applications of RIS in advancing wireless communication technologies.

Furthermore, this paper employs sophisticated visualization techniques to unravel the intricate network linkages between key indexed keywords pertinent to RIS, including "*5G mobile communication system*," "*wireless network*," "*wireless sensor network,*" and several other keywords. Leveraging the VOSviewer tool, this visualization not only elucidates the interconnections among various research themes within the RIS domain but also offers valuable insights into emerging trends and focal points of scholarly inquiry.

In essence, this bibliometric analysis serves as a compass for researchers navigating the vast expanse of RIS studies. By pinpointing gaps in existing research and elucidating prominent areas of interest, bibliometric studies play a pivotal role in guiding researchers toward more targeted and impactful research endeavors. By aligning research objectives with the prevailing trends and emerging research frontiers within the RIS landscape, scholars can harness their efforts more effectively to foster innovation and drive advancements in wireless communication technologies.

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