Patent Trends on Reconfigurable Intelligent Surface

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Abstract—**Reconfigurable intelligent surface (RIS) is an emerging technology that enables operators intelligently manipulate propagation environments by utilizing refraction, reflection, and other natures of RIS. There has been an extensive study in academia and industry since its introduction and its effectiveness has been widely accepted. In this paper, we introduce trends on patent of reconfigurable intelligent surface.**

Index Terms—**Reconfigurable intelligent surface, Patents**

I. INTRODUCTION

Reconfigurable intelligent surface (RIS) is a surface that comprises electrically steerable elements. It has a capability of manipulating incident waves in various ways such as reflection, refraction, absorption, and others. Therefore, by utilizing those capabilities, RIS is expected to change hostile wireless environment into a favorable condition.

Due to its promising potentials, RIS has been attained wide interests across industry and academia and considered to be one of the core technologies for 6G communication systems. In academia, the basic natures of RIS such as wave propagation characteristics, performance gains, and its operational optimization has been extensively studied [1], [2]. While in industry, RIS proto-types are built and its performance gains are shown in real world situation [3]. At this point, it is beneficial to survey on the patents on RIS. It shall provide a guide to set up strategies for RIS future standardization activities.

A. Scope of Survey

In this patent survey, we have surveyed patent applications that are accessible by July of 2023 within major six countries: Korea, US, China, Japan, Europe, and PCT. Since RIS is a new born technology and RIS is expected to be adopted in future 6G standardization, the number of patent applications on RIS is still limited as of July 2023. The survey is also mainly focused on patents submitted by members of 3GPP, such as ZTE, Qualcomm, KDDI, and others. However, it is not limited to those companies if the applied patent addresses key technical issues of RIS.
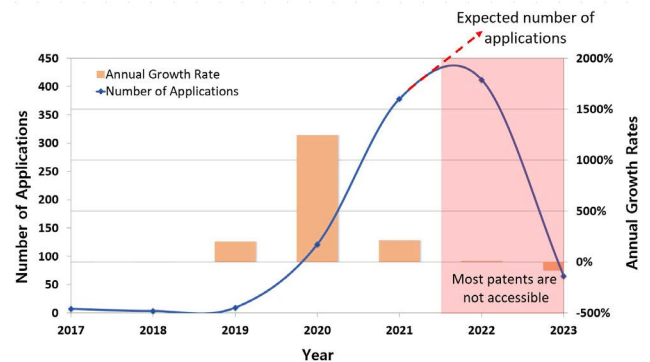
Figure 1. Number of RIS patent applications and its growth rate per year

II. SUMMARY OF RIS PATENT SURVEY

A. By Year

The number of patent applications on RIS has been identified as 995 as of July 2023. The number includes only publicly accessible patents, so the number would be larger if we can include classified patents. Fig. 1 shows the number of patents applications by year. It can be noted from Fig. 1 that the first patent on RIS is applied in 2017 [4] and the number of applications increases dramatically since then. The growth rate of the number of applications in 2020 is more than 1000% and it is expected to have the similar or higher rate by now.

It should be mentioned that the number of applications shown in Fig. 1 decreases after 2021. It does not reflect the real situation since most of the patent applications after 2022 are not accessible yet and those patent applications are not considered in this survey.[1] However, based on the trends in the previous years, the number of patents applications is expected to increase.

B. By Nation

We have also classified the country of patent applications as shown in Table I. We have observed that China has more than 50% of RIS patent applications where US and Europe follows.

C. By Nationality

Fig. 2 shows the nationality of patent applications in each country. It is observed that in Korea and China, most of

[1]Approximately 90% of patent applications in 2022 are classified

Table I
NUMBER OF RIS PATENT APPLICATIONS BY COUNTRY

Country	KR	US	EP	CN	PCT	Total
Num. applications	6	97	30	627	235	995
Share (%)	≤ 1	10	3	63	24	100
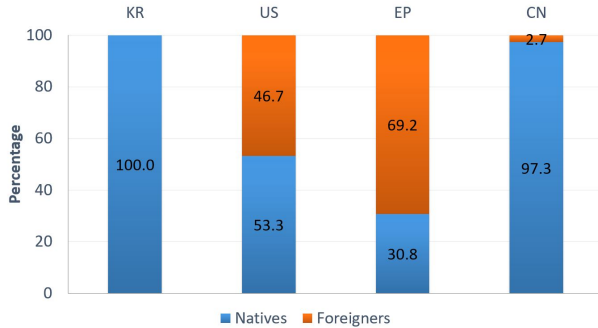
Figure 2. Nationality of patent applications in four regions

Figure 3. Top 15 affiliations with RIS patent applications

Table II
PATENT APPLICATIONS ON RIS BY TECHNICAL CATEGORIES

Category	Description	%
RIS control singaling	Resource on/off control, RIS cofficient control	25
RIS beamforming	Transmit/Receive beam control, Analog elelment beamforming	17
RIS phase control	Maximum transmit gain, beamforming phase control	16
Positioning	Optimal RIS positioning, UE tracking, Positiong RS	12
RIS structure	Structure, material, elements of cells comprising RIS	10
Channel estimation	RIS channel estimation	6
RIS identification	Link identification between RIS-RIS or RIS-UE	4
RIS scheduling	Time/Frequency resource allocation and its signaling including RIS	3
Initial access	Random access, synchronization signal on RIS	2
RIS modulation	Data modulation with RIS	1

the patents are applied by natives while in US and Europe, about half of the applications are applied by foreigners. The high ratio of foreigners in those regions indicates that related companies are targeting US and Europe as their major market for RIS. On the other hand, in Korea all the patents are applied by Koreans. The cause might be the small market size compared to other countries. One interesting case is China. China has a huge market but only a few applications are submitted by foreigners. It is conjectured that due to unfavorable regulations in China, foreign companies are reluctant to enter China market.

D. By Affiliation

We have analyzed the affiliations of the inventors. Fig. 3 illustrates the top 15 institutes with most applications. It can be noted that Qualcomm has applied the most patents while China companies and universities take most of the possessions. To be specific, within top 15 affiliations 12 institutes are from China while the rest of three positions are shared by US, Japan, and Korea companies, respectively. As shown in Sec. II-B, China has the most patent applications and also various companies/universities are working on RIS.

E. By Technical Tree

We have also classified what technical issues are addressed in patents. For that 94 patents applications among the full patent list are selected and its technical claims are categorized. Table II shows the technical categories, its description, and share sorted in descending order. As in academic papers, many RIS papers focuses on its phase design and control aspects.

III. CONCLUDING REMARKS

In this paper, we have summaried a survey result on RIS patent applications. It is witnessed that as growing interests of RIS in academia and industry, the trends on the patent also reflects that as well. The survey result gave a clue where
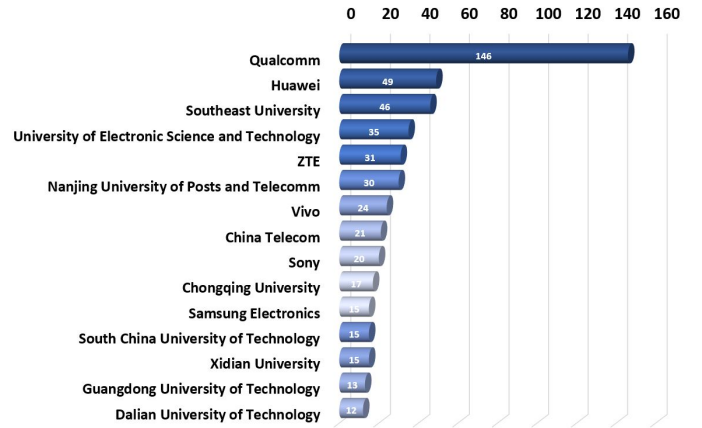
research is most focused and also a guide to future research directions such as for standardization of RIS.

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