Chinese Patent Analysis for Foreign Object Detection in Wireless Charging

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Abstract: As wireless charging is one of the essential technologies of new energy vehicles, China has been keeping pace with the world in the commercial exploration of this emerging technology. This study employs patent analysis tools to analyze the output of Chinese patents on foreign object detection for wireless charging. Patent bibliometric methods are utilized to investigate the focus, hotspots, and frontiers of patent research in this scientific field, which helps researchers to understand the status and development trends of foreign object detection.

Keywords: Wireless Charging, Foreign Object Detection, Patent Analysis, Chinese Patent.

1 INTRODUCTION

As one of the essential basic technologies of new energy vehicles, China has been keeping pace with the world in the commercial exploration of wireless charging technology [2,5]. Domestic research institutions and universities represented by China Electric Power Research Institute, Chongqing University, Southeast University, Chinese Academy of Sciences, and Harbin Institute of Technology have accumulated more than a decade of experience in wireless charging theory and prototypes [1,6]. In addition, domestic companies, mainly represented by ZTE/ZTE New Energy Vehicles, have opened several commercial demonstration lines in more than a dozen domestic cities, such as Chengdu, Changsha, Zhengzhou, Shenzhen, and so on. In recent years, they have accumulated rich practices for the large-scale deployment of wireless charging systems. Foreign Object Detection (FOD) plays a significant role in commercializing wireless charging technologies because it highly determines the operating safety and reliability of the charging system [7-8].

Based on these applications, the local standards for wireless charging have also taken the lead. For example, led by ZTE/ZTE New Energy Vehicle, Shenzhen wireless charging local standards were officially released in 2015. These standards are the most complete and detailed electric vehicle specifications in the current global system. Furthermore, on April 28, 2020, the Standardization Administration of the People's Republic of China announced the release of four national standards for wireless charging systems for electric vehicles [4].

Through the patent analysis, the technology distribution, research trends, competition situation, and technical hotspots of Chinese patents on FOD are presented clearly, which is helpful to

BDEDM 2023, January 06-08, Changsha, People's Republic of China
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DOI 10.4108/eai.6-1-2023.2330330

evaluate the current technological development level in the wireless charging field in China from the objective perspective.

2 METHODS AND MATERIALS

2.1Description of Data Sources and Analysis Tools

IncoPat is a patent database provider from China with a collection of patents from 120 authorities and is updated daily. Using the IncoPat database, the data collection scope is before the search date in 2018 (the search date is up to July 6, 2018). The data type is "Chinese invention application."

2.2Search Process and Search Formula Development

The final search formula was determined as follows: ((IPC=((H02J5/00 OR H02J7/00 OR H02J7/02 OR H02J17/00 OR G01V3/10 OR G01V3/11 OR G01V3/12 OR G01V3/14))) OR (TIABC=((wireless or inductive or non-contact or remote)) AND TIABC=((charging or power supply or energy transmission or electrical transmission or energy emission or electrical emission or energy transmission or electrical reception or energy reception or electrical reception or coupling resonance or resonant coupling or electromagnetic induction or electromagnetic resonance or magnetic resonance or energy transfer or WPT)))) AND ((IPC=(G01V3/11)) OR (TIABC=((Foreign Object Detection OR Foreign Object Detection OR External Object Detection OR Special Object Detection OR Metal Detection OR Metal Object Detection OR FOD)))). Approximately 435 patents were retrieved.

3 PATENT TREND ANALYSIS RESULTS

3.1Trend Analysis

3.1.1Annual Change in the Number of Patent Applications

Figure 1 shows the trend of the patent application. Since 2011, the number of relevant patent applications in China has rapidly grown, reaching 83 in 2016. The average annual growth rate （PAGR） was 35.7% between 2011 to 2016 (see table 1 to check the calculation formula).

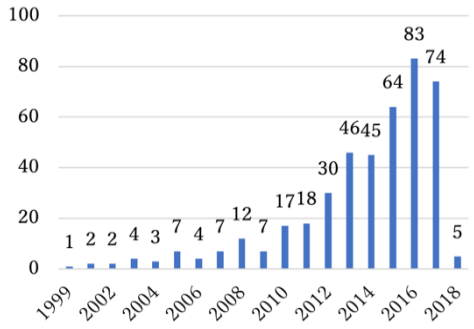

Figure 1. Annual change in the number of patent applications

Table 1. Analysis index and calculation formula of patent applications (Self-drawing)

Analysis index	Calculation formula
The average annual growth rate of patent applications （PAGR） Number of Patent Applications in start-up year（NYS） Number of Patent Applications at the end of the (NYE) Number of years between the start-up year to the end of the years(Y)	$PAGR = (\sqrt[Y-1]{NYE - NYS} - 1) * 100\%$

3.1.2Annual Changes in the Number of Patent Disclosures

Figure 2 shows the annual changes in the number of patent disclosure. The trend of the disclosure can understand the difference in the number of patent disclosure documents of the analyzed object in each period at the macro level. The number of patent disclosures has increased rapidly since 2012, reaching a maximum of 83 in 2017.

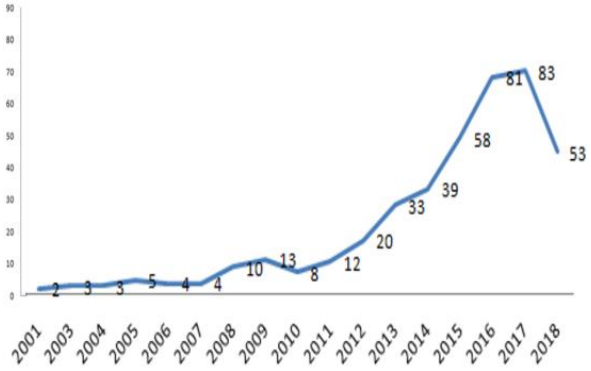

Figure 2. Annual changes in the number of patent disclosures

3.2Technical Analysis

3.2.1 Overview Analysis of Main Technology Types

From the perspective of the leading technology types of patents, patent technology applications related to FOD in wireless charging are mainly concentrated in the four categories, namely, G01V (geophysics; gravimetry), H02J (an electrical energy storage system), G01N (testing or analyzing materials), and B60L (electric vehicle power units). Among them, G01V and H02J have the most patents.

3.2.2Technology Application Trends

Figure 3 shows the distribution and development trend of patent applications in different technology directions of the analyzed objects. The result shows that the number of patent applications in G01V and H02J is overgrowing, with patent applications in G01V entering a period of rapid growth from 2010 and reaching a maximum of 59 in 2016. Patent applications in H02J entered a period of rapid growth from 2012 and earned a maximum of 35 in 2015.

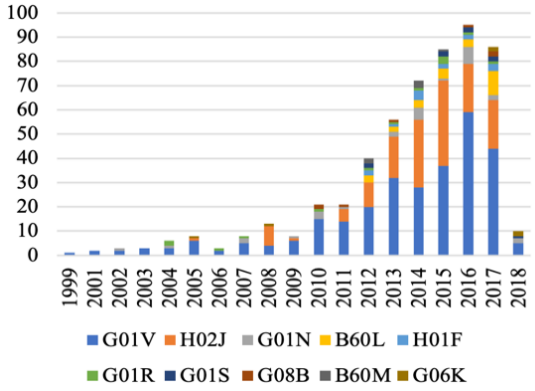

Figure 3. Technology Application Trends

3.3Technology Disclosure Trend

Figure 4 shows the distribution and development trends of the number of patent disclosures in different technical directions of the analysis object. It turns out that the number of patent disclosures in G01V has increased since 2009, reaching 51 in 2016 and 2017. The number of patent disclosures in H02J has increased since 2013, reaching 35 in 2017.

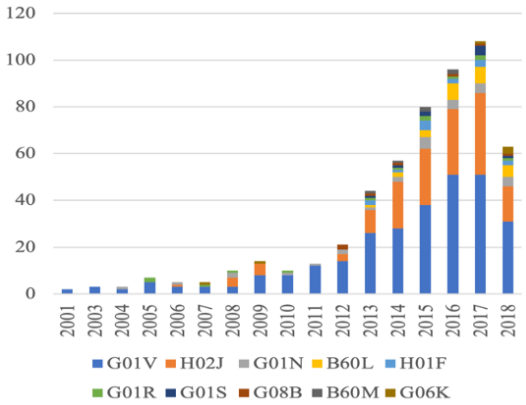

Figure 4. Technology Disclosure Trends

3.3.1Technology Distribution by Provinces and Cities in China

Figure 5 shows the quantitative distribution of each technical direction of the analysis object in different provinces. Through comparative analysis, it is possible to figure out the regions where important technical movements are concentrated. The relevant patents are mainly concentrated in Guangdong, Jiangsu, Beijing, Shanghai, Anhui, Zhejiang, and other places.

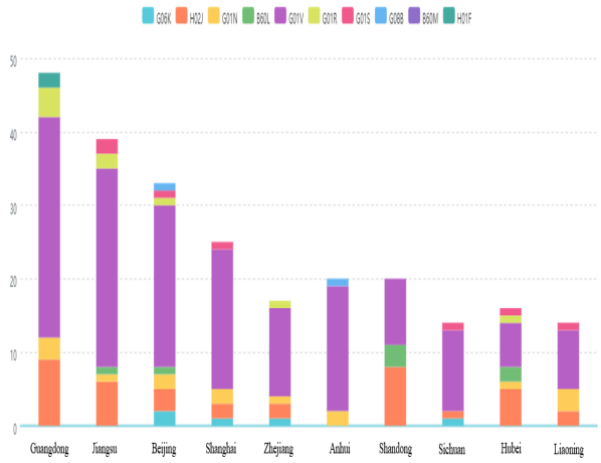

Figure 5. Technology Distribution by Provinces and Cities in China

3.3.2Technology Distribution by Regions in China

Figure 6 shows the quantitative distribution of each technical direction of the analysis object in different cities and only counts Chinese patents. The cities with the most relevant patent applications are Beijing, Shanghai, Shenzhen, and Chengdu.

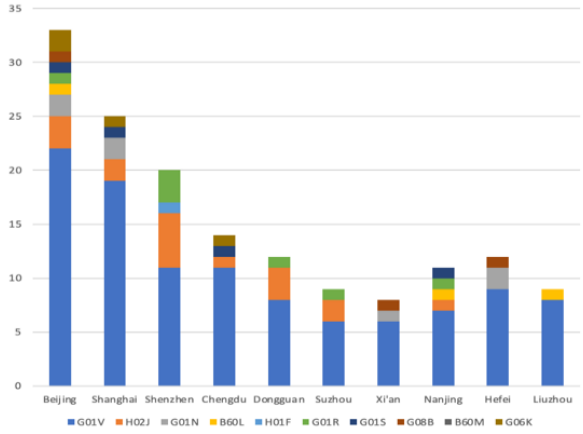

Figure 6. Technology Distribution by Regions in China

3.4Applicant Analysis

3.4.1Ranking of Applicants

The result shows that applicants of the enterprise type applied for the most significant number of patents, totaling 335. Figure 7 shows that the applicant with the most significant number of related patents is Sony Corporation (17), followed by Panasonic Intellectual Property Management Co., Ltd. (14) and Mettler Toledo Safety Line Co., Ltd. (10).

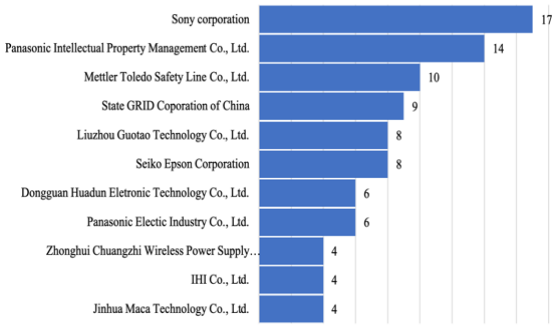

Figure 7. Ranking of applicants

3.4.2Patent Application Trend of Applicants

Figure 8 shows the development trend of the number of patent applications filed by each applicant. The result shows that the number of related patent applications of Seiko Epson Co., Ltd. reached the highest value in 2008 (7), the number of Sony Corporation reached the highest value (9) in 2013, and Liuzhou Guotao Technology Co., Ltd. reached the highest value in 2016 (8).

Figure 8. Patent Application Trend of Applicants

3.4.3Patent Disclosure Trends of Applicants

Figure 9 shows the development trend of the patent disclosure volume of each applicant. In 2014, the three applicants, Panasonic Intellectual Property Management Co., Ltd., Liuzhou Guotao Technology Co., Ltd., and Dongguan Huadun Electronic Technology Co., Ltd., all achieved the highest number of patent disclosures, with 8, 8, and 6, respectively.

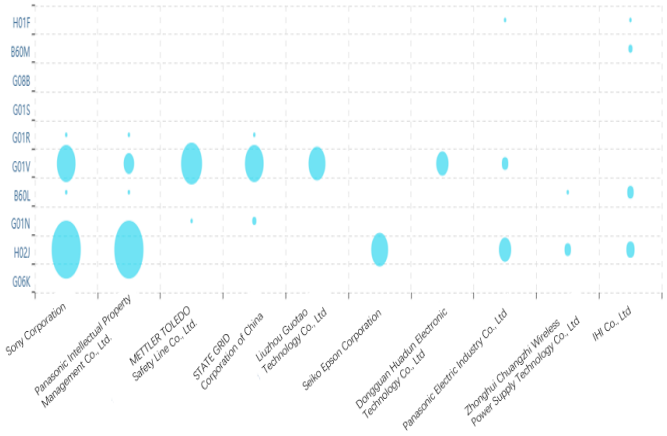

Figure 9. Patent disclosure trends of applicants

3.4.4Patent Value of Applicants

Patent value degree is a comprehensive evaluation index about the value of a patent after analyzing the patent regarding more than 20 parameters in three aspects: technical stability, technical advancement, and protection scope. Therefore, studying the distribution of the value degree score of the applicant's patent can provide a macro understanding of the applicant's patent quality and thus objectively evaluate an applicant's competitive strength in terms of patents. Figure 10 shows the distribution of each applicant's patent value degree score. Different colors represent different patent values. It can be seen from figure 10 that Seiko Epson Corporation has the most patent value of 10 points, with six patents. Panasonic Electric Industrial Co., Ltd. amounted to 4, while Mettler-Toledo Safety Line Co., Ltd. and Sony Corporation have two each. In addition, Sony Corporation has 11 patents with a value of 9 points. In contrast, the only Chinese company with the highest score patent is State Grid Corporation of China, with three 7-point patents.

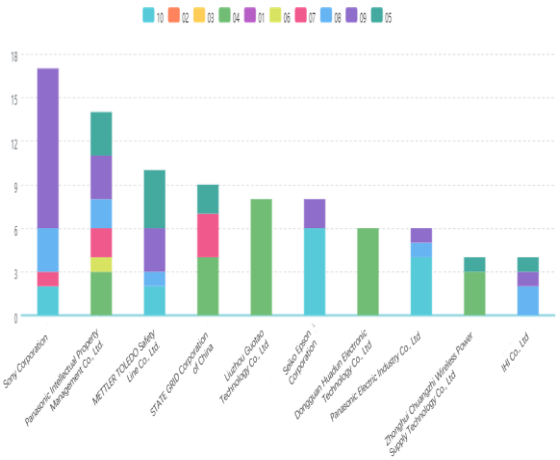

Figure 10. Patent Value of Applicants

3.5 Legal and Operational Analysis

3.5.1Transfer Trend

Figure 11 shows an overall upward trend in the transfer of related patents. This analysis is used to understand the trend of the technology cooperation, transformation, application, and promotion of the analyzed object in different periods and to reflect on the operation and implementation of the technology. In addition, by analyzing the changes in the amount of technology transformation, it is possible to understand the direction and popularity of the results of the subject of analysis in different periods, and then predict the development direction and future market application prospects of the technology.

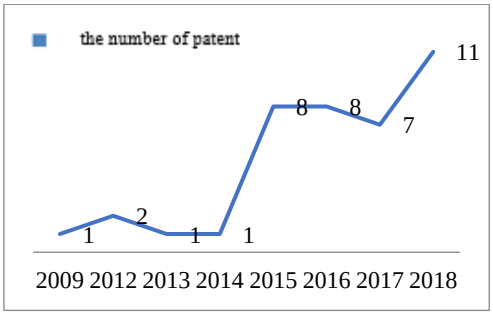

Figure 11. Transfer Trend

3.5.2Ranking of Assignors

Table 2 shows the ranking of patent holders according to the number of patents that have been transferred. This analysis identifies the technology export activities of each innovation agent and provides a reference for finding technology holders for transfer. In addition, changes in the direction of technological development or market operations can be inferred.

Table 2. Ranking of Assignors

Patent holders	No. of patents
Panasonic Electric Industry Co., Ltd	4
POSTECH Co., Ltd	4
ADT Services, LLC	3
Sensor Electronics LLC	3
SPACON Corporation	2
Jitong International Limited	2
Bauerbai Proxi GmbH	2
Wan Jiasheng	1
Dongguan Tianguan Energy Saving Technology Co., Ltd	1
Zhonghui Chuangzhi Wireless Power Supply Technology Co., Ltd	1

3.5.3Ranking of Assignees

Table 3 shows the ranking of patent assignees according to the number of patents that have been transferred. This analysis reveals the technology introduction of each assignee and predicts the direction of its next technology and market deployment.

Table 3. Ranking of Assignees

Patent holders	No. of patents
Panasonic Electric Industry Co., Ltd	4
General Electric Hybrid Technology LLC	4
ADT Services, LLC	3
Tyco Fire & Safety Limited	3
POSTECH Co., Ltd	3
STATE GRID Corporation of China	2
Apple Inc.	2
Philips Intellectual Property Enterprises Ltd	2

3.5.4Composition of Technology Transfer

Table 4 shows the distribution of technology fields in which patents have been assigned. By analyzing and understanding which technology directions are hot spots for promotion, achievement transformation, and patent operation, determining market maturity, and predicting future development trends. The specialized fields with the most significant number of transferred patents are G01V (21) and H02J (16).

Table 4. Composition of technology transfer

Technical fields	Patent numbers	Technical fields	Patent numbers
G01V	21	H01F	1
H02J	16	H01M	1
G01R	4	H02H	1
G08B	2	H04B	1
G01D	1	H05B	1
G01N	1		

4 CONCLUSION

Since 2010, Chinese patent applications for FOD in wireless charging have shown a rapid growth trend. From the perspective of the main technology types of patents, the G01V and H02J categories have the most patents, and the number of patent applications has increased rapidly. This study helps researchers to understand the status and development trends of scientific research in FOD for wireless charging.

Acknowledgment: This work was supported by The China Postdoctoral Science Foundation (No. 2019M650803, No.2020T130637) and the Guangdong Province Intellectual Property Project of Collaboratively Enhancing Academic Patent Transfer Achievement (No.HT-2022-CJ-ZY-004). Hongshen Pang is the corresponding author.

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