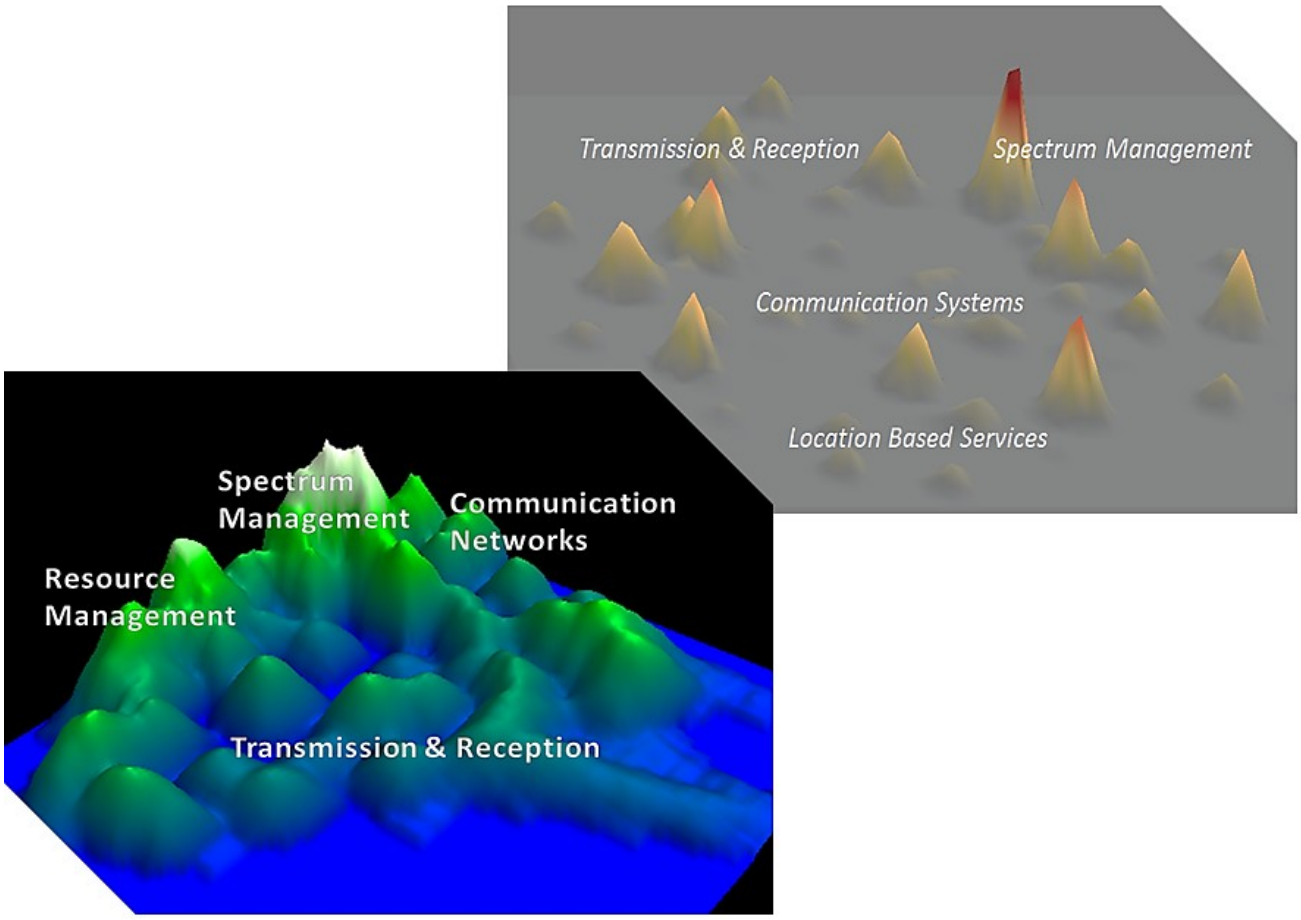
Tekes

Trial



Trial – Cognitive Radio Innovation Landscape

Author: Minna Suovirta

VTT

Contents

Tekes, the Finnish Funding Agency for Technology and Innovation

Tekes is the main public funding organisation for research, development and innovation in Finland. Tekes funds wide-ranging innovation activities in research communities, industry and service sectors and especially promotes cooperative and risk-intensive projects. Tekes' current strategy puts strong emphasis on growth seeking SMEs.

Tekes programmes – Tekes's choices for the greatest impact of R&D funding

Tekes uses programmes to allocate its financing, networking and expert services to areas that are important to business and society. Tekes programmes have been contributing to changes in the Finnish innovation environment for over twenty years.

1 Conclusions

The cognitive radio innovation landscape has been created for the Tekes Trial programme. The aim is to find application areas, trends and key organizations in cognitive radio research and business. To achieve this aim, patent and scientific publications are analysed.

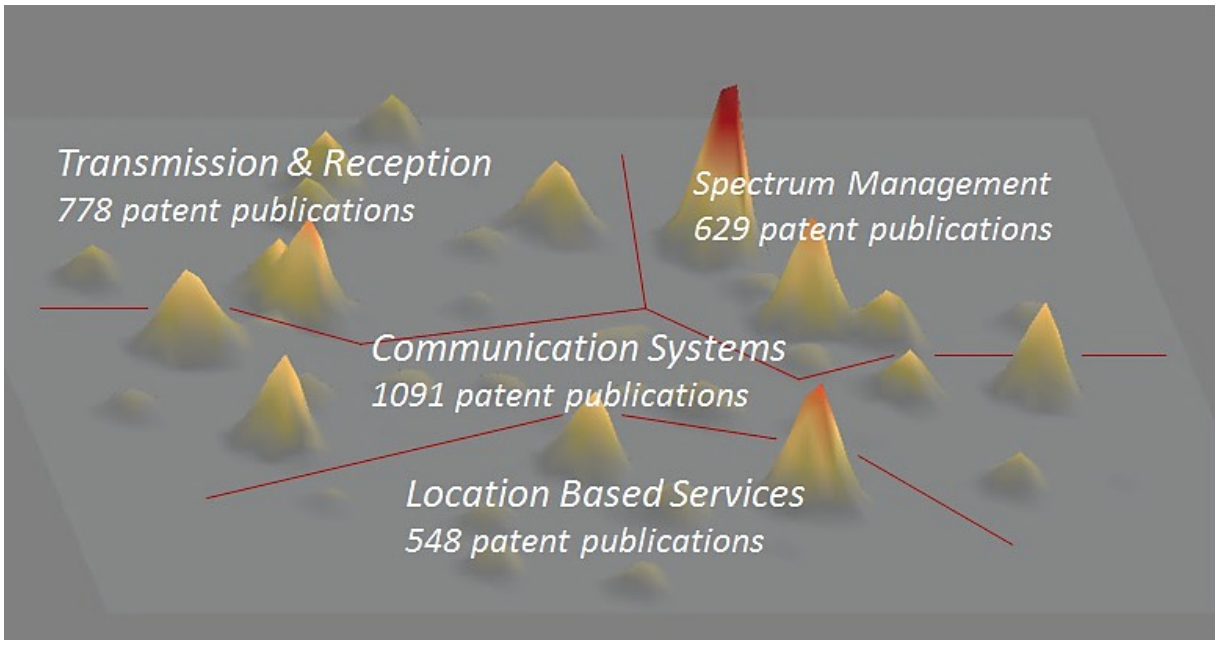


Figure 1 STN Anavist: Application areas of the patent landscape
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

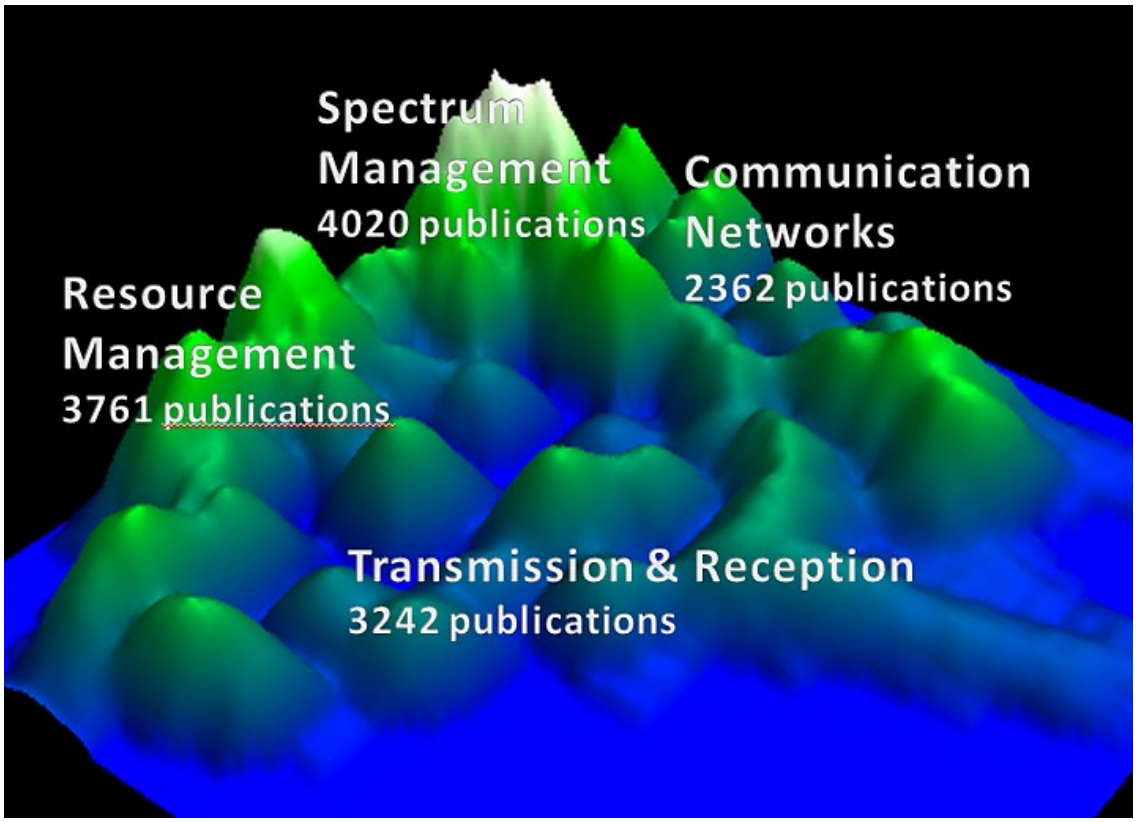


Figure 2 Omniviz: Application areas of the scientific publications landscape

In the patent landscape (Figure 1) and the scientific publications landscape (Figure 2), there are Transmission & Reception, Spectrum Management and Communication Systems/Networks application areas. In patent publications, there is also a Location Based Services area and in publications a more general Resource Management area.

The actual development period of cognitive radio started at the end of the 1990s. Until 1994, there were ten or fewer new patent applications per year. After that, the annual number of new cognitive radio innovations increased. In scientific publications, there were previously also only a few publications every year (fewer than 20 documents). Nowadays, the number of documents dealing with spectrum and resource management is increasing strongly.

In the cognitive radio area, Samsung has clearly made the biggest number of patent applications over the years. It has also been active in previous years. About half of LG's (2nd) patenting has been done in previous years, so it can now be said to be active in cognitive radio markets. NEC (3rd) is active, but over half of its patenting activity has been done before 2006. In the top group, Nokia, Electronics and Telecommunications Research Institute (ETRI), Motorola, Qualcomm, Beijing University of Posts and Telecommunications and Huawei were remarkably active, in relative terms, in 2006-2011.

In patenting, the USA is the most important business area, followed by the Asian countries: China, South Korea and Japan. The PCT and EP patenting routes are also much used. Germany is the most important individual European country. Finland is ranked 17th.

The most active organizations are from China, the USA and Singapore. They are Beijing University of Posts and Telecommunication, the University of California, Nanjing University of Post and Telecommunication, Virginia Polytechnic Institute and State University, Nanyang Technological University and Institute for Infocomm Research, A-Star. The top European organizations are the Polytechnic University of Catalonia and RWTH Aachen University, ranked 20th and 21st respectively. The top Finnish organization is Aalto University in 33rd place. The top company is Nippon Telegraph and Telephone (NTT) in 42nd place.

The patent analyses are presented in Chapter 2 and the scientific publication analyses in Chapter 3. Chapter 4 clarifies the search range in a patent and a publication database, the basics of visualization and some patent-specific matters, e.g. that patent applications are secret 18 months from the application data, so all patent publications are only available until the end of April 2011. Chapter 5 describes some of the patent-specific terms used in this report.

2 Patent Analyses

There are four regions in the patent landscape: Communication Systems, Transmission & Reception, Spectrum Management, and Location Based Services. The four highest peaks belong to localization matters in cognitive radio services, modulation of data transmission, spectrum sensing and spectrum distribution. The figures (Figure 3, Figure 4) also name other peaks with at least 100 documents.

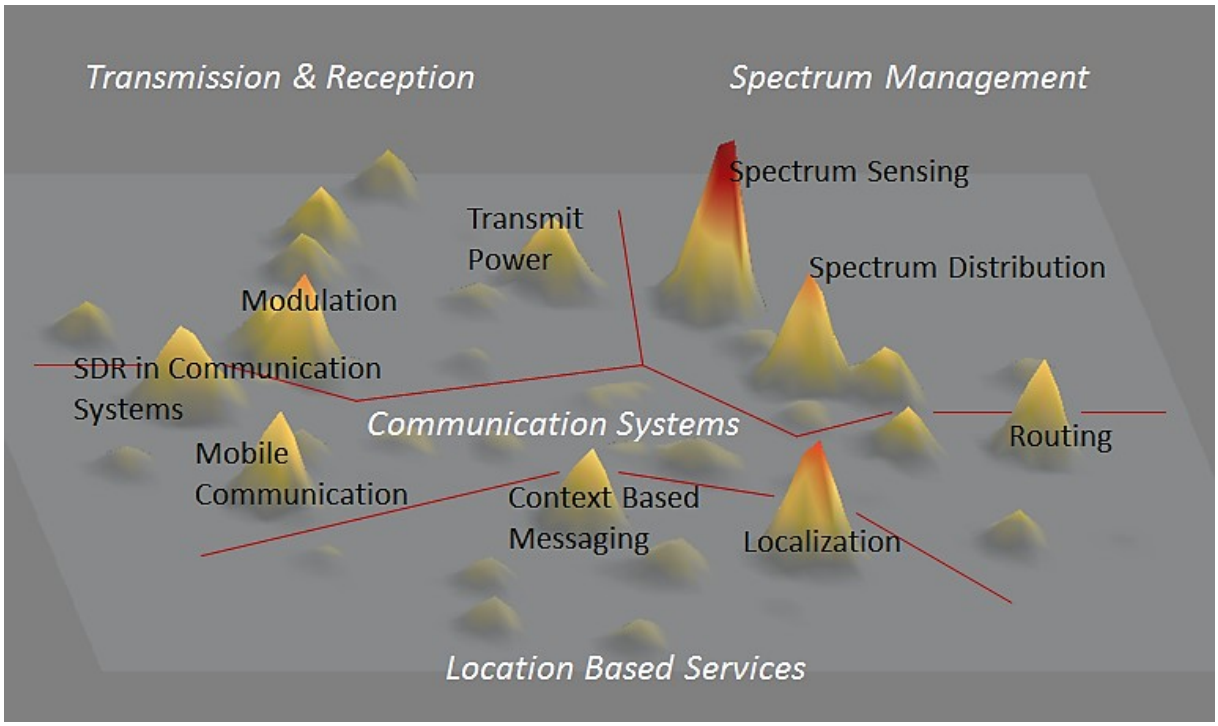


Figure 3 STN Anavist: Application areas and biggest peaks named in a 3D visualization (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The actual development period of cognitive radio started in the 1990s. Until 1994, there were ten or fewer new patent applications per year relating to cognitive radio. After that, the annual number of new cognitive radio innovations increased (Figure 29 on page 34).

In the cognitive radio area, Samsung has clearly made the biggest number of patent applications over the years. It has also been active in previous years (Figure 10 on page 15). About half of LG's (2nd) patenting has been done in previous years, so it can now be said to be active in cognitive radio markets. NEC (3rd) is active, but over half of its patenting activity has been done before 2006. In the top group, Nokia, Electronics and Telecommunications Research Institute (ETRI), Motorola, Qualcomm, Beijing University of Posts and Telecommunications and Huawei were remarkably active, in relative terms, in previous years (Figure 30 on page 35).

The organizations have different kinds of application area profiles (Figure 12 on page 17), e.g. SK Group and NTT focus on LBS and communication systems, and Samsung, LG, Nokia, Motorola and ETRI seem to have ideas in spectrum management.

The USA is the most important business area (Figure 31 on page 35), followed by the Asian countries: China, South Korea and Japan. The PCT and EP patenting

routes are also much used. Germany is the most important individual European country. Finland is ranked 17th.

The following sections investigate the application areas, key organizations, year trends and main patenting countries in more depth.

2.1 Application Areas

There are four regions in the patent landscape that concentrate more deeply on an application area. In descending order of number of patent documents, the application areas are Communication Systems, Transmission & Reception, Spectrum Management and Location Based Services (Figure 3, Figure 4).

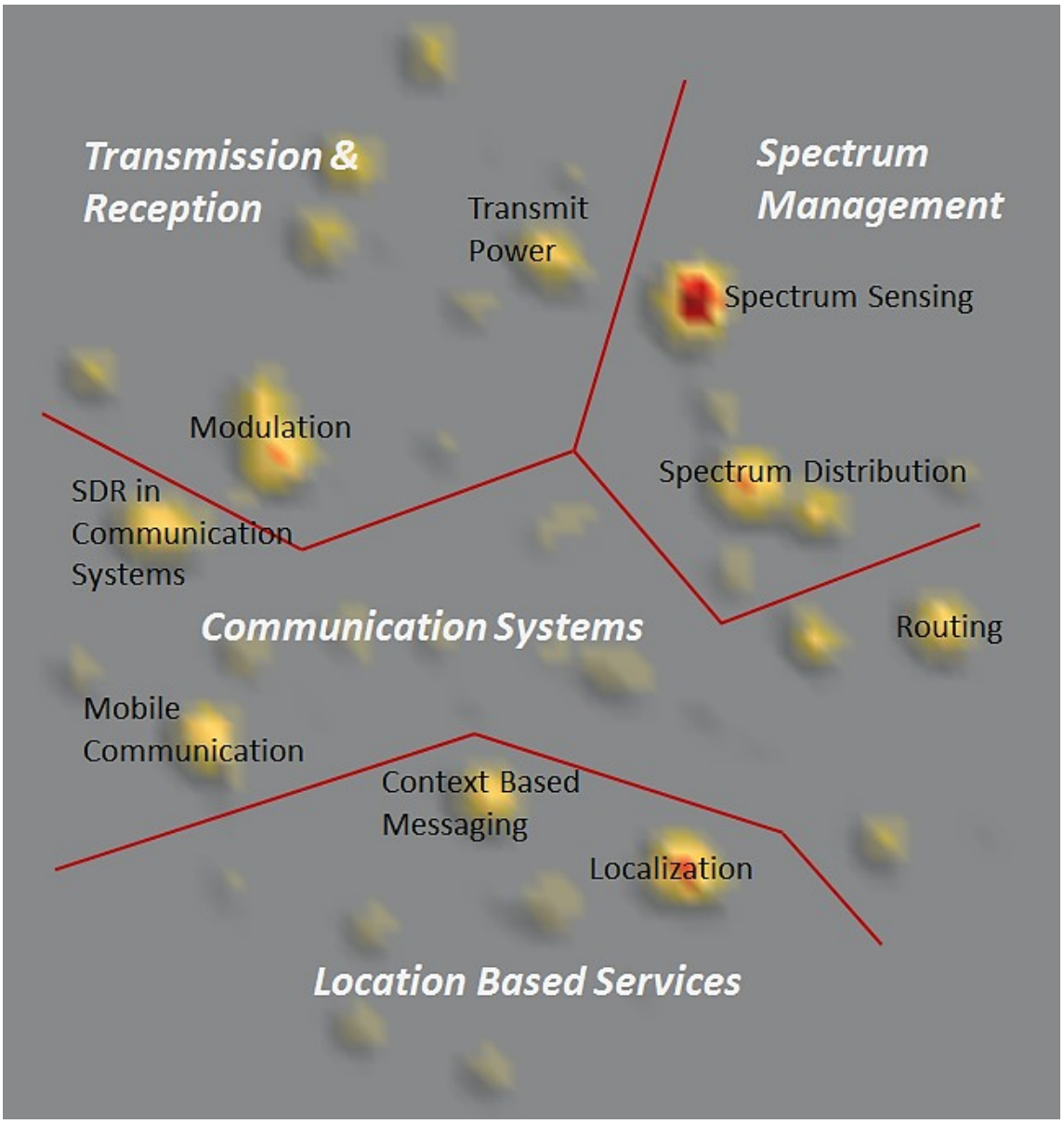


Figure 4 STN Anavist: Application areas of patent publications in a 2D visualization (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

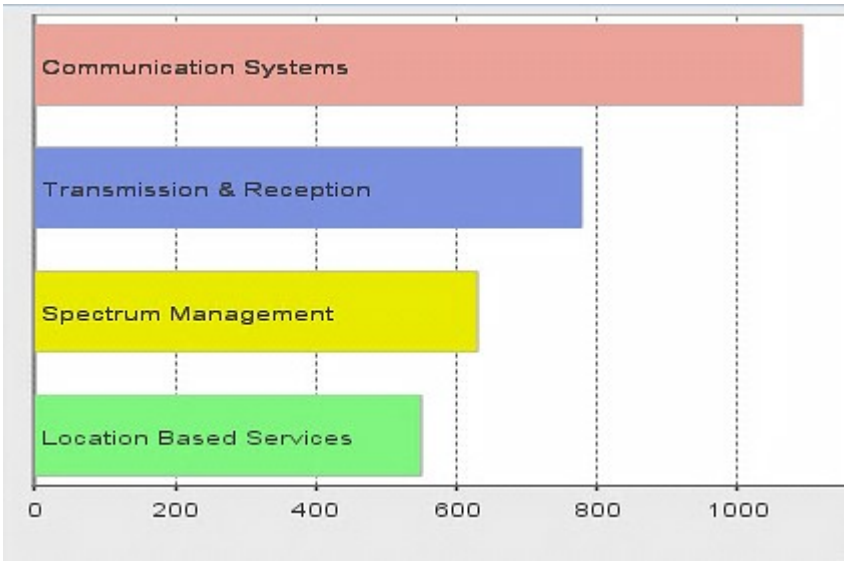


Figure 5 STN Anavist: Application areas and number of publications
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The following sections investigate the application areas separately. For each application area, there are diagrams for patent classifications, patent countries and priority years. Matters related to the application areas are also discussed in other chapters from the point of Key Organizations (p. 14) and Patenting Countries (p. 36).

2.1.1 Location Based Services

This application area has 548 patent publications that deal with situations that include base stations and mobile terminals, and adjusted data communication between them. Located matters could be base stations, terminals, or both.

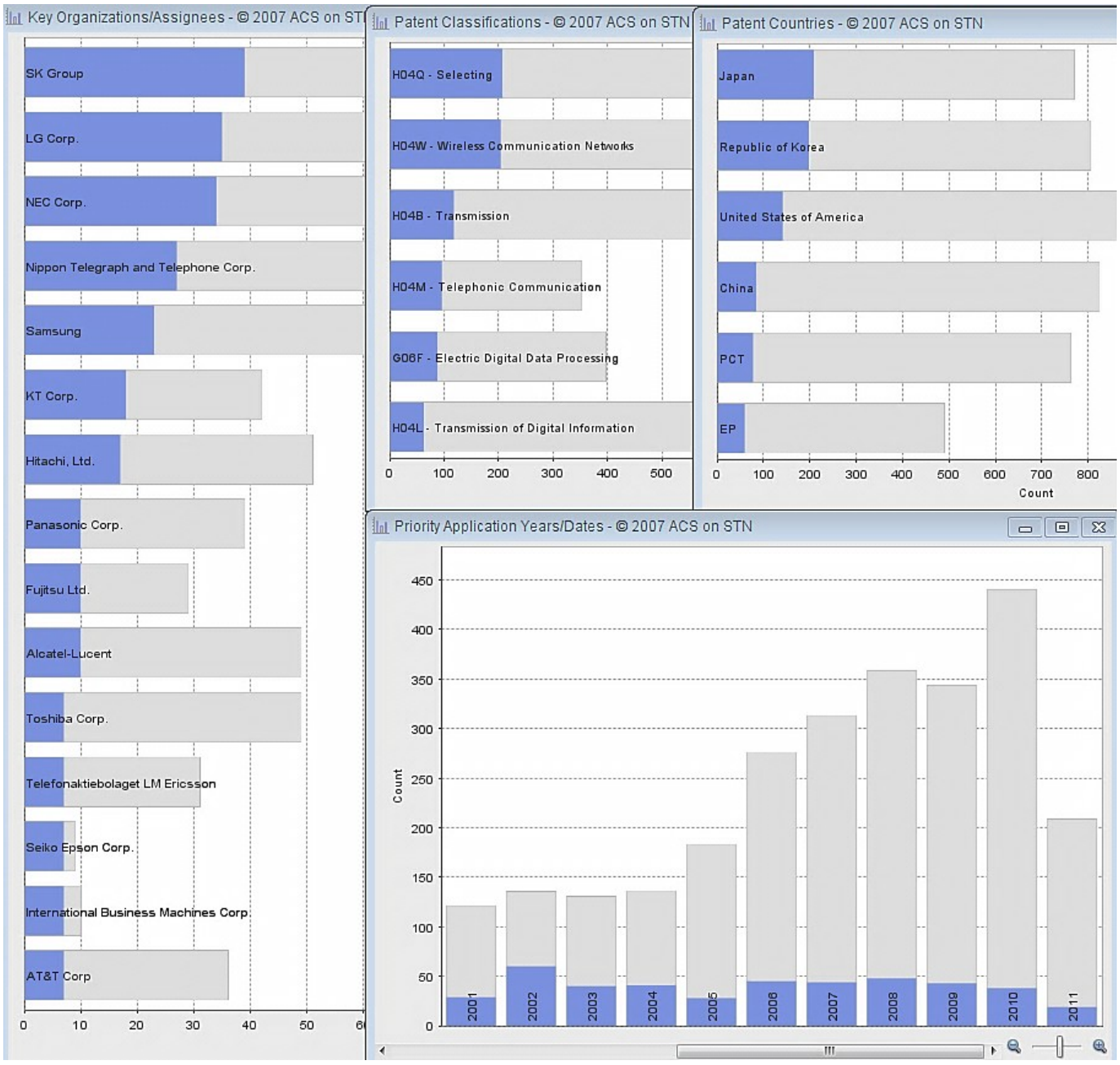


Figure 6 STN Anavist: The Location Based Services application area's top 15 organizations, main patenting countries, main patent classes and annual new innovations in 2001-4/2011 (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The key organizations in this application area are SK Group (39 documents), LG Corporation, NEC Corporation, Nippon Telegraph and Telecommunication Corporation (NTT) and Samsung Group. Japan (209 documents) and South Korea (198 documents) are the main patenting countries. In the last decade, patenting has been quite stable with approximately 40 patent applications per year. So far, 2002 has been a top year with 60 patent applications (Figure 6).

2.1.2 Communication Systems

This application area has 1091 patent publications that deal with wireless networks and communication systems. In the patent landscape, there are big peaks on both sides of the drawn boundary line with the Transmission & Reception application area, so these areas have a strong connection with each other (Figure 4), and documents near the boundary line discuss both communication systems, and transmission and reception matters.

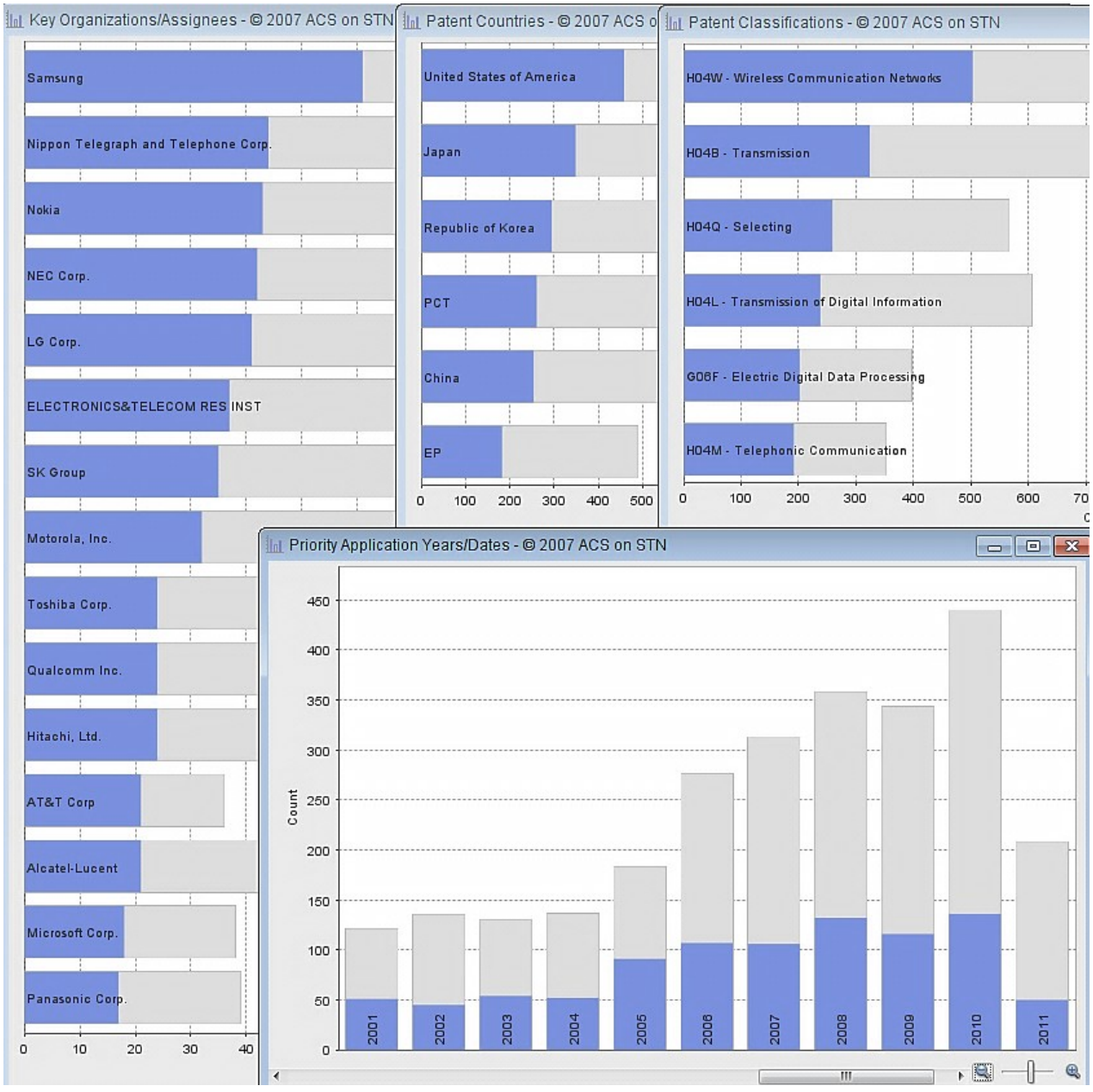


Figure 7 STN Anavist: The 'Communication Systems' application area's top 15 organizations, main patenting countries, main patent classes and annual new innovations in 2001-4/2011 (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The key organizations in this application area are Samsung Group (61 documents), Nippon Telegraph and Telecommunication Corporation (NTT), Nokia, NEC Corporation and LG Corporation.

The USA (458 documents) is the main patenting country, followed by Japan and South Korea.

Since 2006, there have been over 100 patent applications per year. So far, 2010 has been the most active year with 136 patent applications. It is likely that the number of patent applications will be at the same level or even higher in 2011, as 50 patent applications have already been filed in the first third of the year (Figure 7).

2.1.3 Transmission & Reception

This application area has 778 patent publications that deal with parameters, factors, systems and apparatuses in digital data transmission and reception. In the patent landscape, there are big peaks on both sides of the drawn boundary line with the Communication Systems application area, so these areas have a strong connection with each other (Figure 4), and documents near the boundary line discuss both transmission and reception, and communication systems matters.

The key organizations in this application area are Samsung Group (33 documents), Motorola, and Electronics and Telecommunications Research Institute (ETRI).

The USA (357 documents) is the main patenting country, followed by China and the PCT applications.

From 2006 to 2010, there have been 85-90 patent applications per year (except in 2009 when there were only 71). It is likely that the number of patent applications will be at the same level or even higher in 2011, as 50 patent applications have already been filed in the first third of the year (Figure 8).

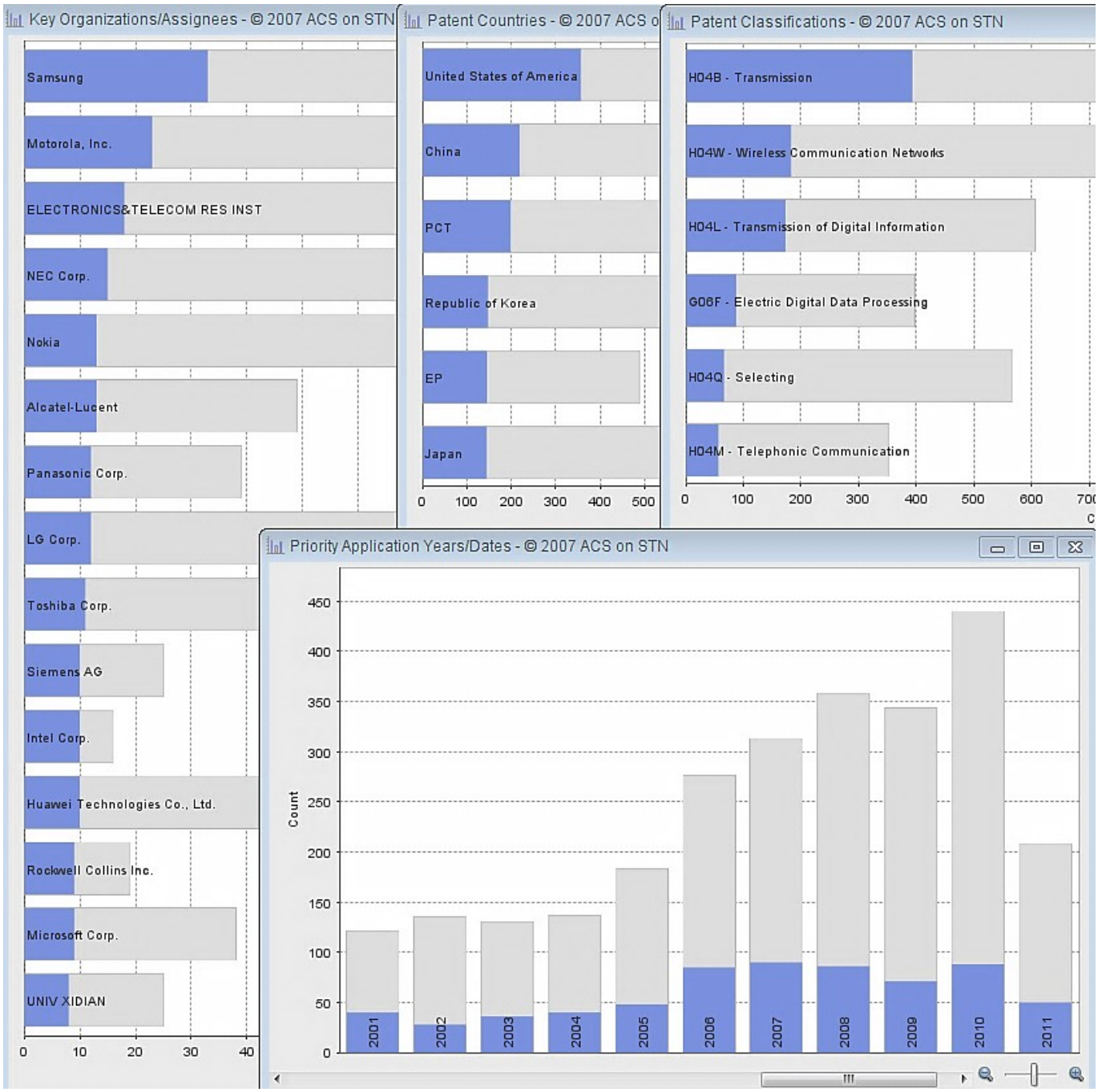


Figure 8 STN Anavist: The 'Transmission & Reception' application area's top 15 organizations, main patenting countries, main patent classes and annual new innovations in 2001-4/2011 (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

2.1.4 Spectrum Management

This application area has 629 patent publications that deal with spectrum management (sensing, distribution, allocation sharing, estimation, monitoring, etc.). The terms 'spectrum sensing' and 'spectrum distribution' dominate and also have own peaks in the patent landscape (Figure 3).

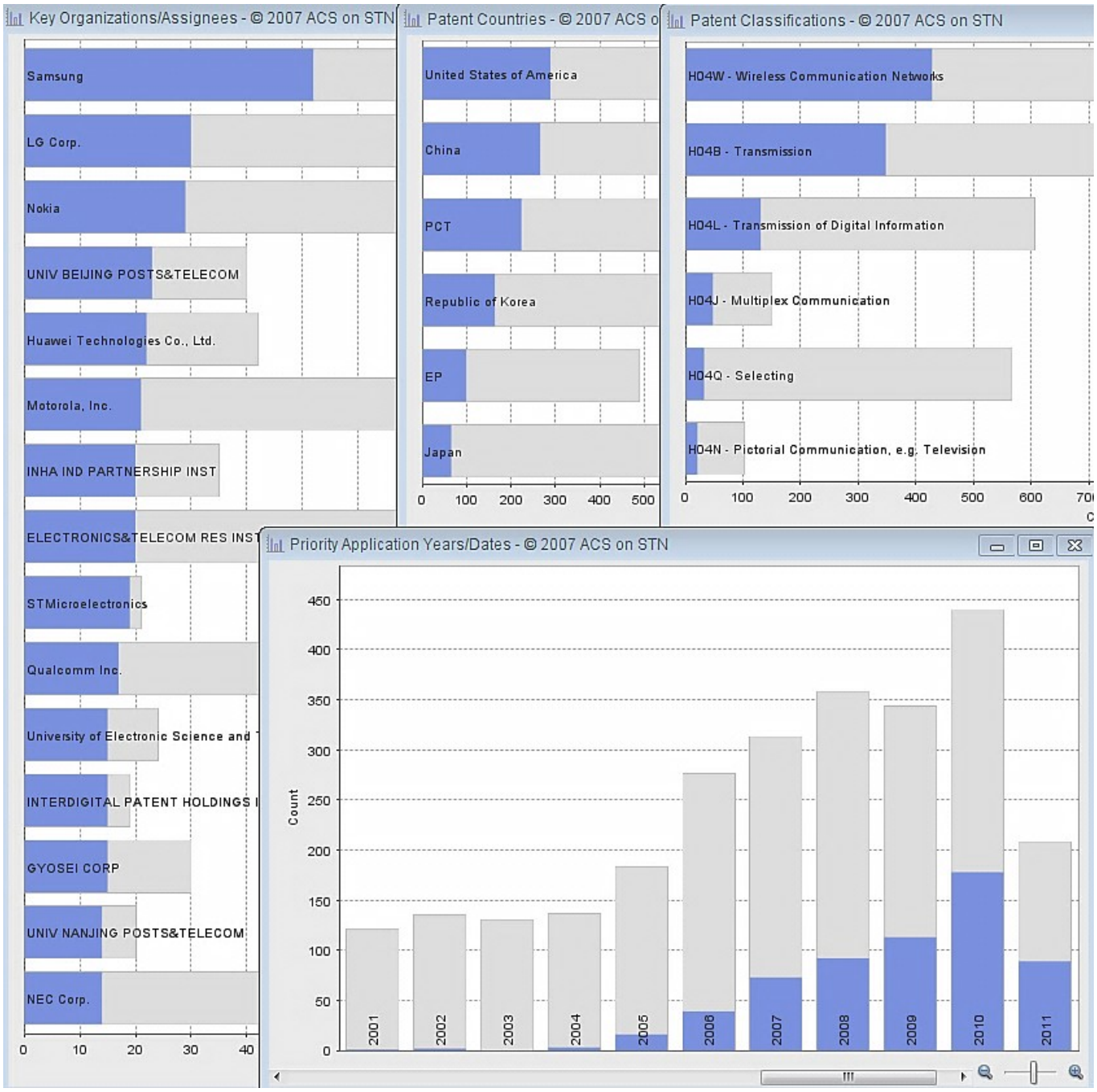


Figure 9 STN Anavist: The 'Spectrum Management' application area's top 15 organizations, main patenting countries, main patent classes and annual new innovations in 2001-4/2011 (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The key organizations of this application area are Samsung Group (52 documents), LG Group and Nokia.

The USA (289 documents) and China (266 documents) are the main patenting countries, followed by the PCT applications.

From 2004 to 2010, the number of annual patent applications increased from 3 to 178 documents. It is likely that the increase will continue in 2011 (Figure 9).

2.2 Key Organizations

Organizations protect their business by patenting their most valuable innovations. Patent assignee statistics represent the key organizations of a technology or application area. The cognitive radio technology area's key organizations are shown in Figure 10 and Figure 11.

Samsung has clearly made the biggest number of patent applications over the years. It has also been active in previous years. About half of LG's (2nd) patenting has been done in previous years, so it can now be said to be active in cognitive radio markets. NEC (3rd) is active, but over half of its patenting activity has been done before 2006. In the top group, Nokia, Electronics and Telecommunications Research Institute (ETRI), Motorola, Qualcomm, Beijing University of Posts and Telecommunications and Huawei were remarkably active, in relative terms, in previous years (Figure 30).

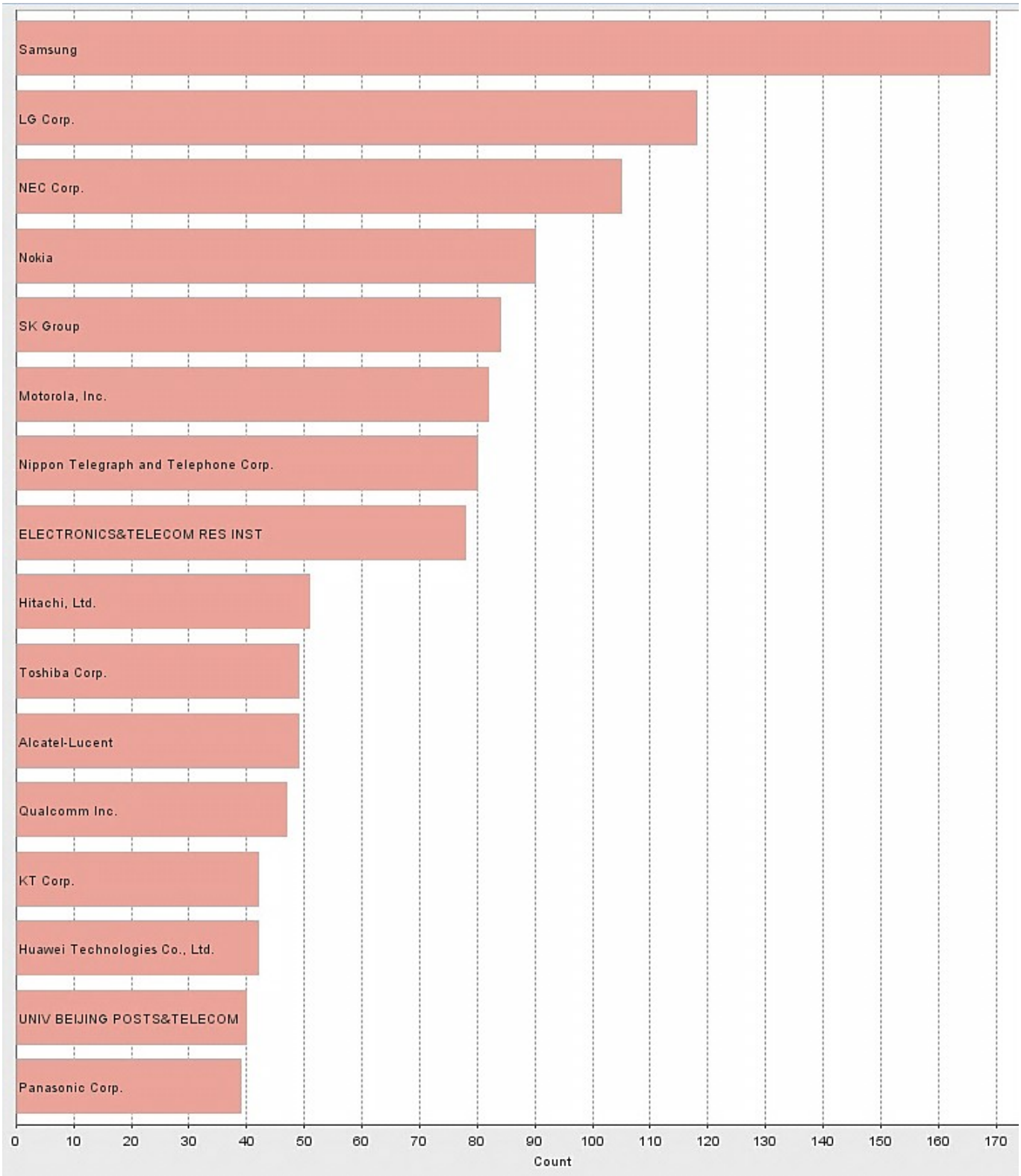


Figure 10 STN Anavist: Most active patenting organizations (1-16)
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

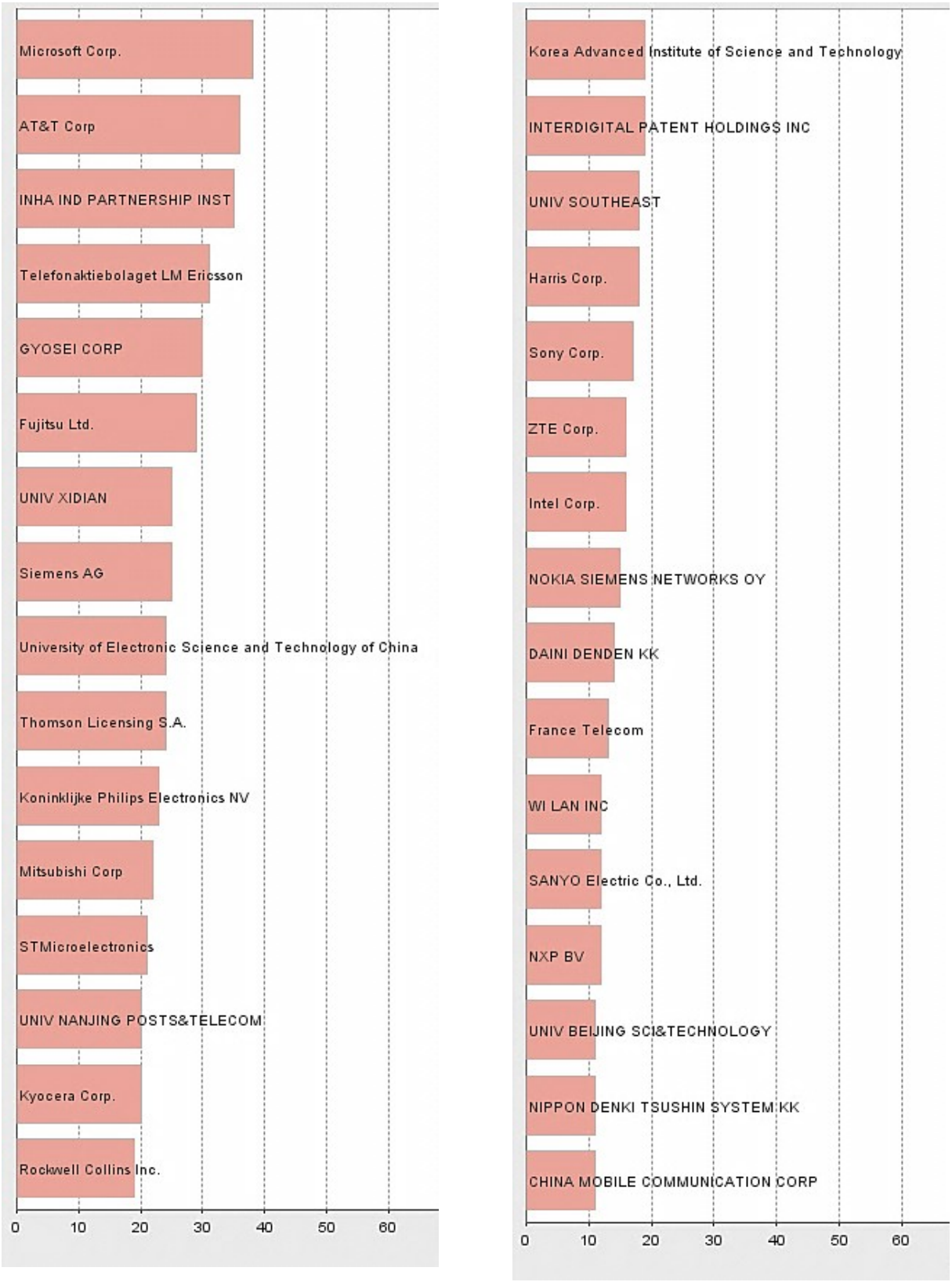


Figure 11 STN Anavist: Most active patenting organizations (17-48)
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The organizations have different kinds of application area profiles (Figure 12), e.g. SK Group and NTT focus on LBS and communication systems, and Samsung, LG, Nokia, Motorola and ETRI seem to have ideas in spectrum management.

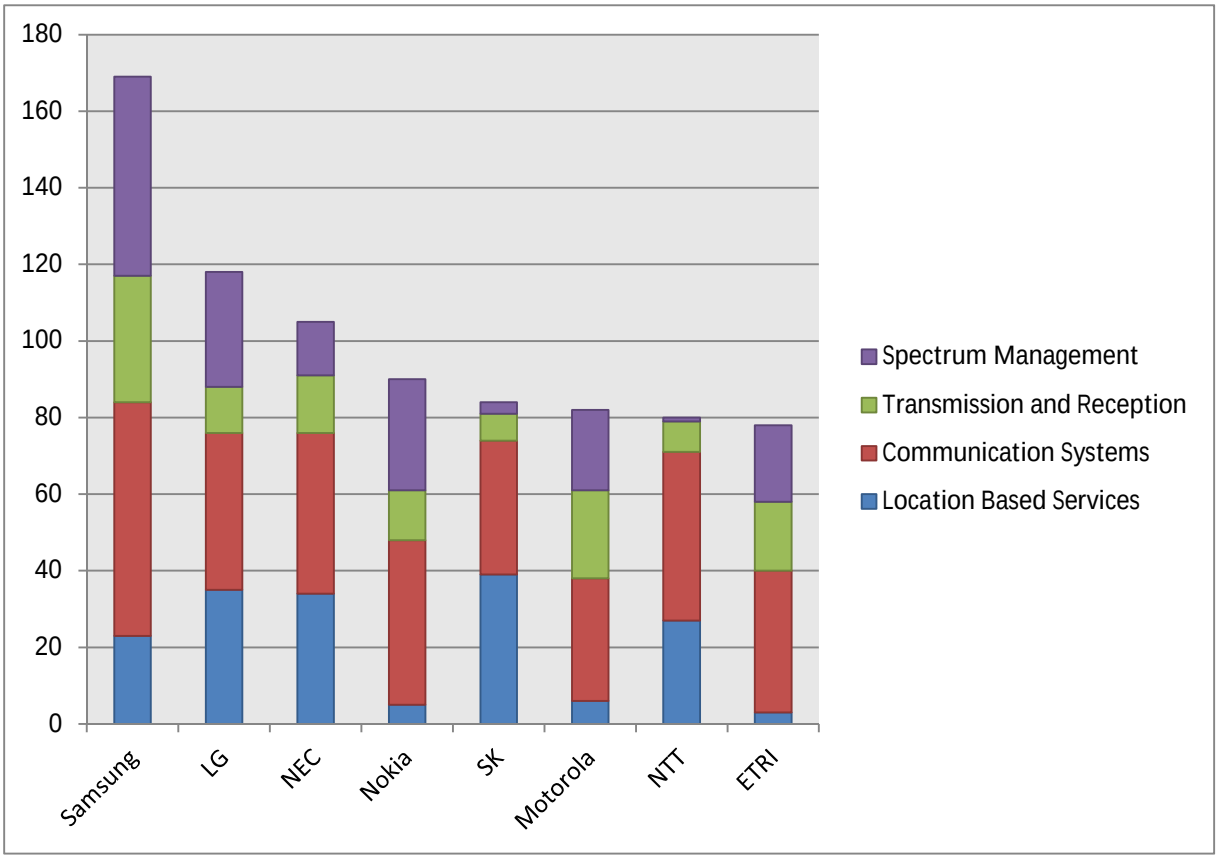


Figure 12 Application area distribution of the top 8 organizations
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The statistics in the figures (Figure 10, Figure 11) include all the patenting activity of organizations from 1971 to the most recent public patent publications. The chapter's figures therefore give the cumulative activity ranking of the organizations. If statistics are compiled for the previous years, the order of the organizations differs, as can be seen in Figure 30 in the chapter 'Year Trends' (p. 34).

The following sections investigate the most active key organizations separately. For each organization, there are diagrams for patent classifications, patent countries and main partners.

2.2.1 Samsung Group

Samsung is an international South Korean conglomerate. It is best known as a manufacture of consumer electronics (e.g. television sets, MP3 players, mobile phones).

Samsung has been active in patenting and has the highest number of patent publications (169) in the patent landscape. Its earliest patent application in the cognitive radio area was filed in 1998. The company has been active, especially in 2007-2008, with 36 patent applications per year (Figure 14). Its patenting now seems to be decreasing in this technology area.

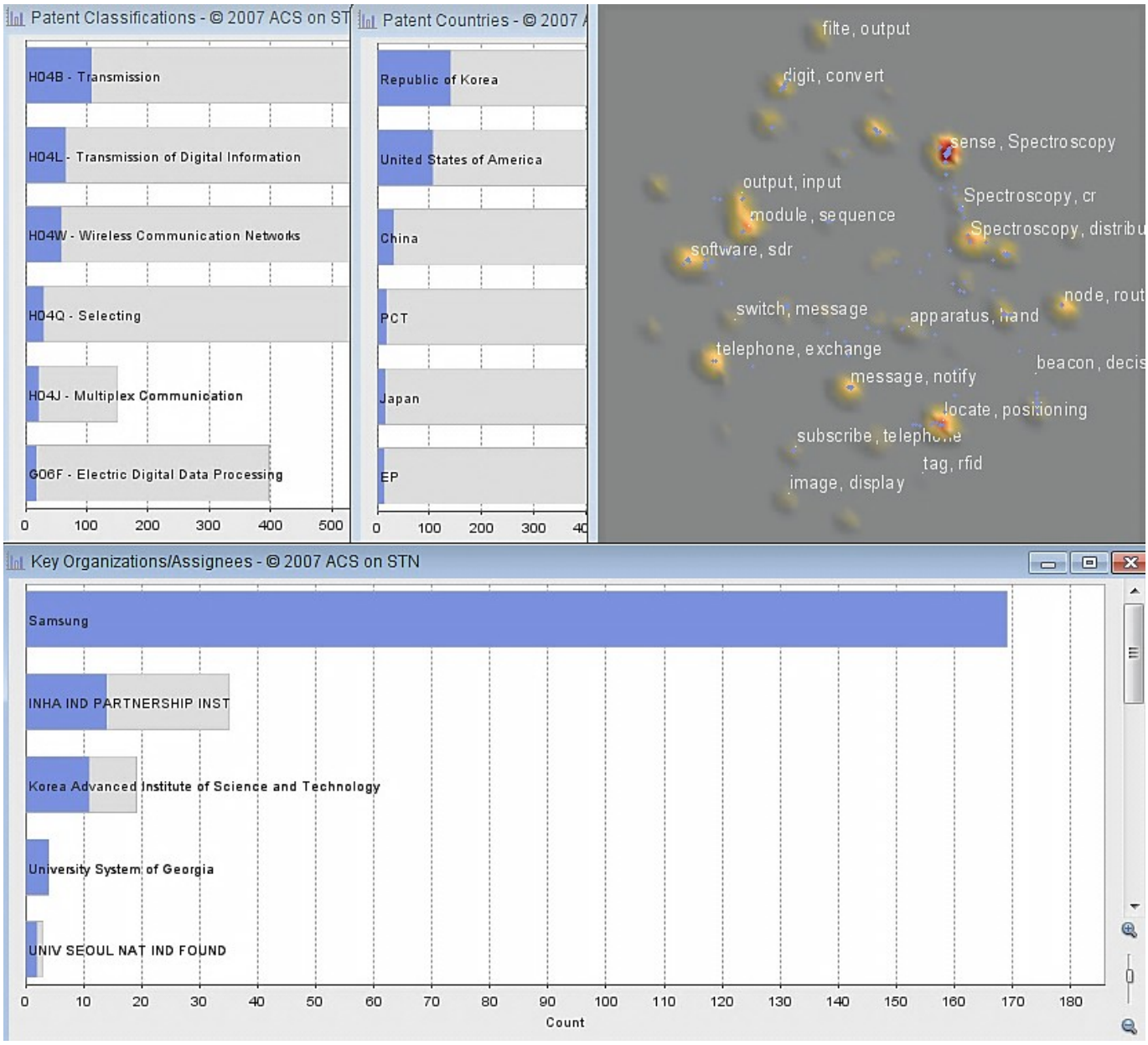


Figure 13 STN Anavist: Samsung Group's 169 patent publications in the landscape, patenting countries, four main partners and main patenting classes
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

Samsung collaborates in research and development with other organizations and has several co-patents with them. For most of its patents (141 documents) it has

applied in South Korea. The USA is also an important patenting country for Samsung. In Finland, it has applied for patents for nine innovations (Figure 13).

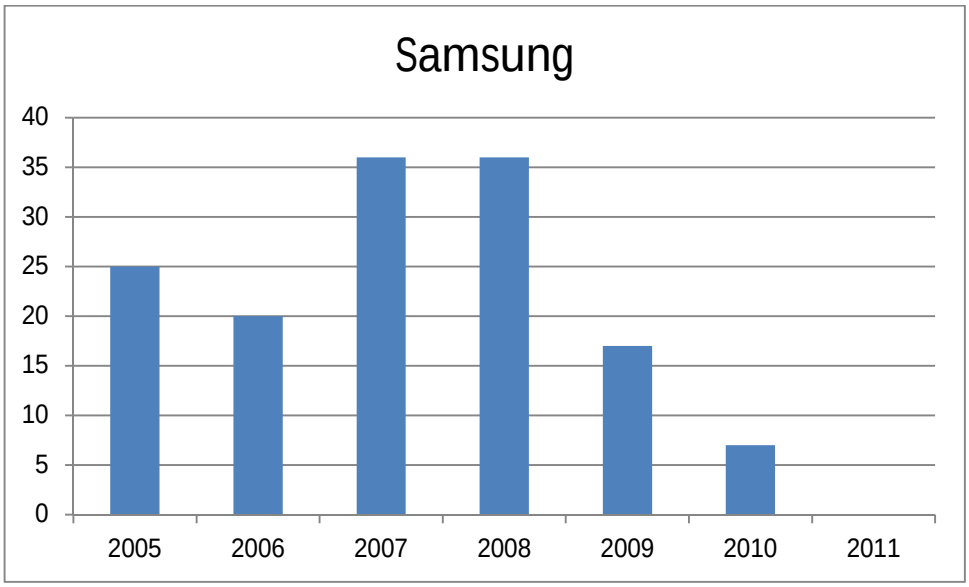


Figure 14 Samsung Group's yearly patenting from 2005 to now (Public patent publications, in general, to the end of April 2011)

Samsung has innovations in all application areas:

- Communication Systems (61 documents)
- Spectrum Management (52 documents)
- Transmission & Reception (33 documents)
- Location Based Services (23 documents)

2.2.2 LG Group

LG is an international South Korean conglomerate. The LG Group companies manufacture electronics, telecommunication and petrochemical products.

LG has the second highest number of patent publications (118) in the patent landscape. Its earliest patent application in the cognitive radio area was filed in 1999. In 2010, LG had a remarkable peak in patenting with 36 patent applications (Figure 16). It appears to have been less active in 2011, as in the first third of the year it had only applied for patents for two innovations.

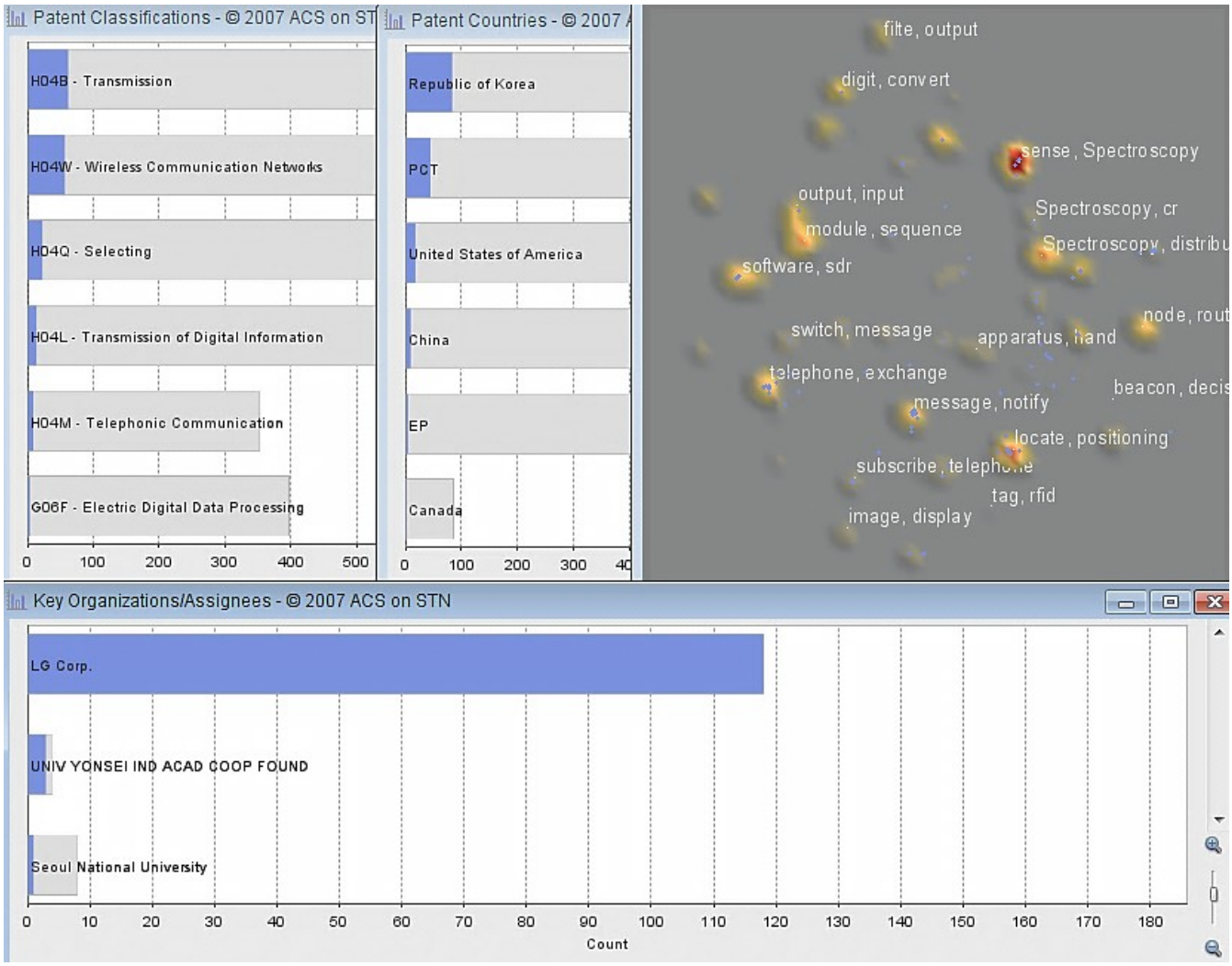


Figure 15 STN Anavist: LG Group's 118 patent publications in the landscape, patenting countries, partners and main patenting classes
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

LG collaborates in research and development with other organizations and has some co-patents with them. For most of its patents (84 documents) it has applied in South Korea. LG also favours PCT applications (with 45 documents) for an international search report for national phases (Figure 15).

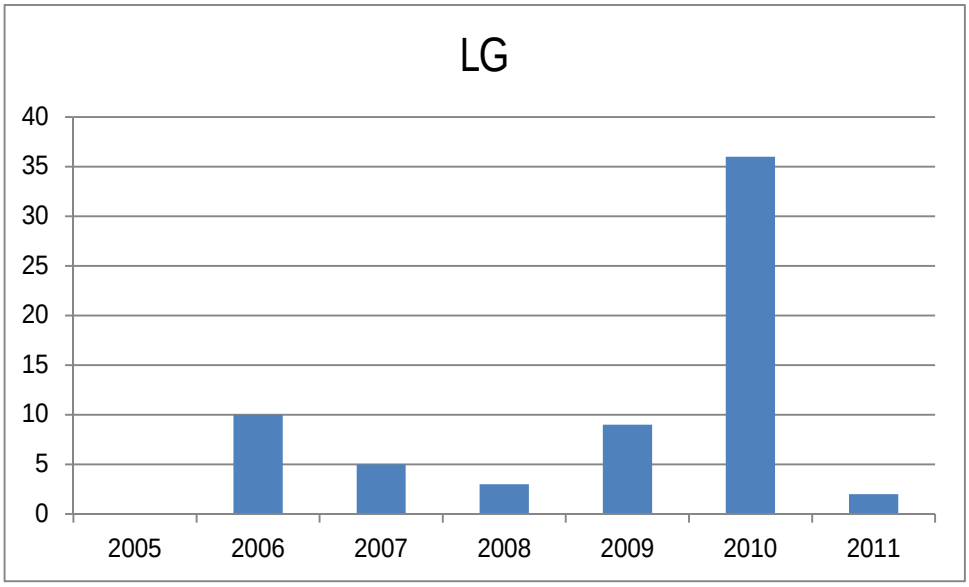


Figure 16 LG Group's yearly patenting from 2005 to now (Public patent publications, in general, to the end of April 2011)

LG has innovations in all application areas:

- Communication Systems (41 documents)
- Location Based Services (35 documents)
- Spectrum Management (30 documents)
- Transmission & Reception (12 documents)

2.2.3 NEC Corporation

NEC is an international Japanese information technology company.

NEC has the third highest number of patent publications (105) in the patent landscape. Its earliest patent application in the cognitive radio area was filed in 1988. In 2005-2010, its yearly patenting activity varied from 4 to 15 annual new patent applications (Figure 18). In general, its patenting seems to be increasing in the cognitive radio area.

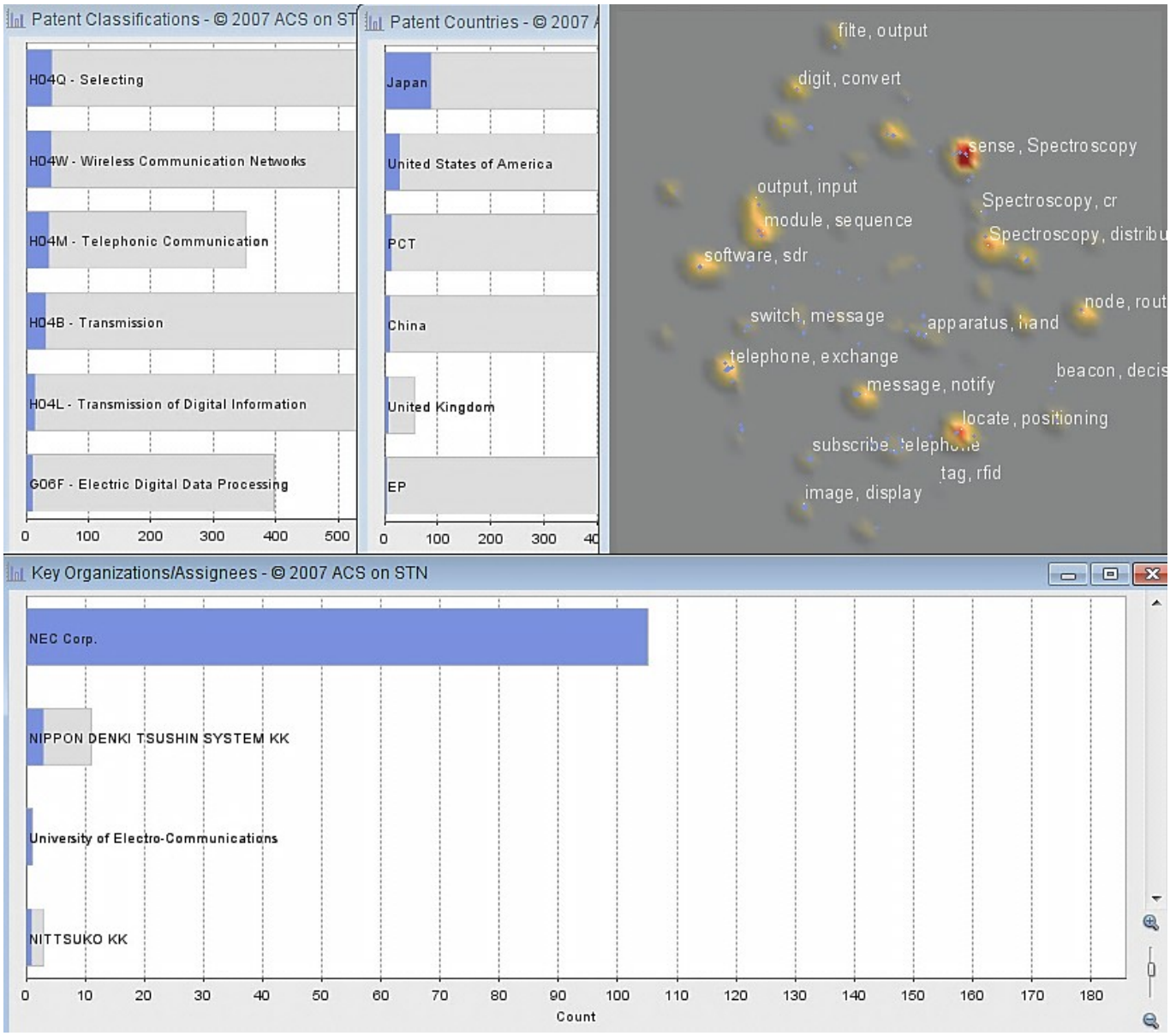


Figure 17 STN Anavist: NEC Corporation's 105 patent publications in the landscape, patenting countries, partners and main patenting classes.
(3046 documents retrieved from the "Derwent Word Patent Index" patent database 1971-2012)

NEC collaborates in research and development with other organizations and has some co-patents with them. For most of its patents (88 documents) it has applied in Japan. The USA is also an important patenting country. In Finland, it has applied for a patent for one innovation (Figure 17).

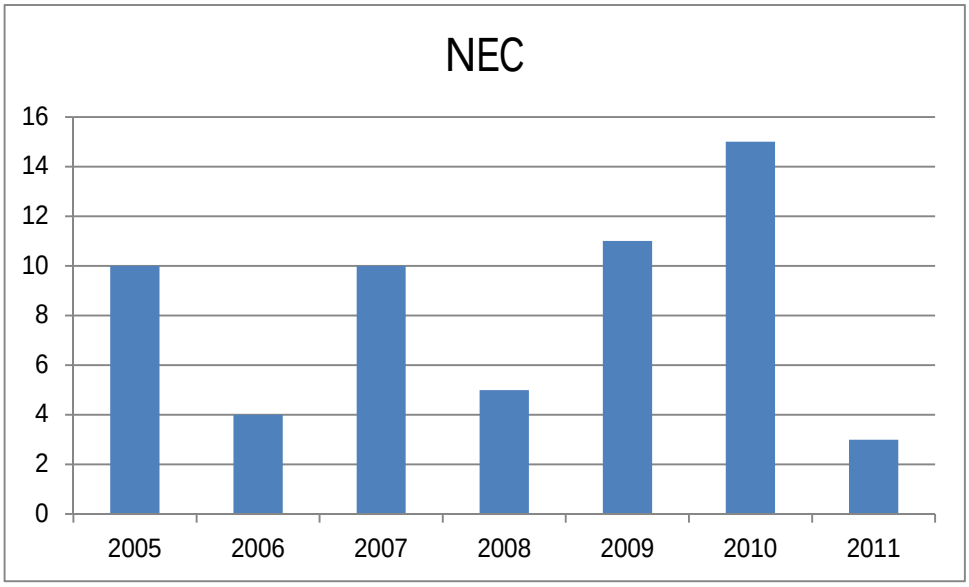


Figure 18 NEC Corporation's yearly patenting from 2005 to now (Public patent publications, in general, to the end of April 2011)

NEC has innovations in all application areas:

- Communication Systems (42 documents)
- Location Based Services (34 documents)
- Transmission & Reception (15 documents)
- Spectrum Management (14 documents)

2.2.4 Nokia Corporation

Nokia is an international Finnish telecommunication company.

Nokia has the fourth highest number of new innovations (90) in the patent landscape. Its earliest patent application in the cognitive radio area was filed in 1993. The company's patenting in the cognitive radio area seems to be increasing (Figure 20).

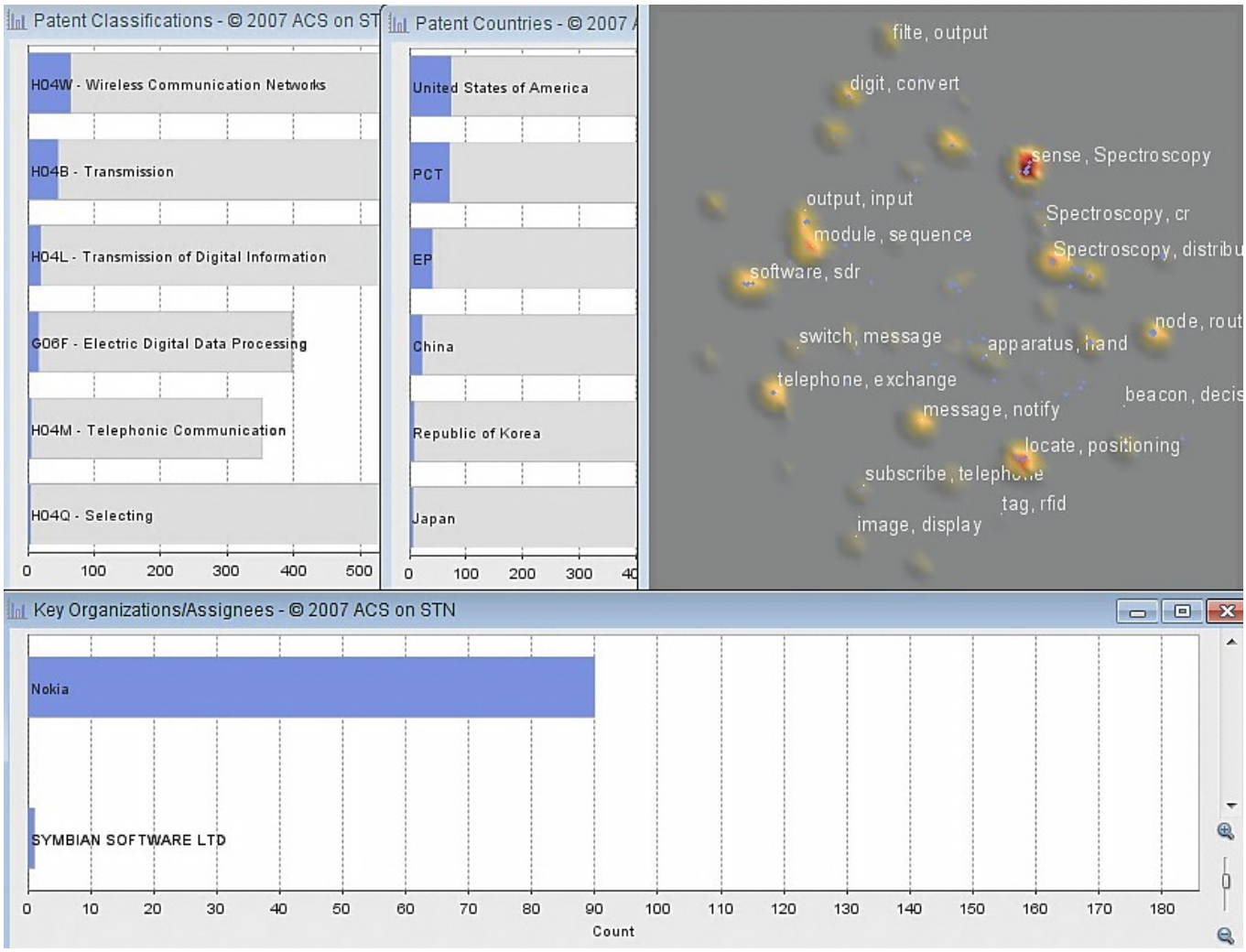


Figure 19 STN Anavist: Nokia Corporation's 90 patent publications in the landscape, patenting countries, partners and main patenting classes
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

Nokia has only one co-patent, with Symbian Software Ltd. For many of the innovations (74 documents) it has applied for patents in the USA. Nokia also favours PCT applications (with 71 documents) for an international search report for national phases (Figure 19).

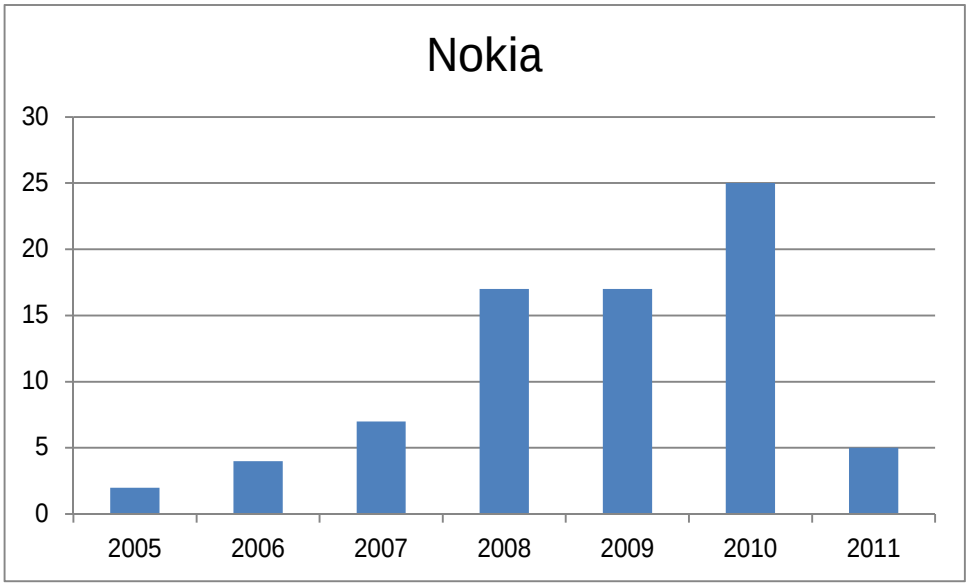


Figure 20 Nokia Corporation's yearly patenting from 2005 to now (Public patent publications, in general, to the end of April 2011)

Nokia has innovations in all application areas:

- Communication Systems (43 documents)
- Spectrum Management (29 documents)
- Transmission & Reception (13 documents)
- Location Based Services (5 documents)

2.2.5 SK Group

SK is an international South Korean conglomerate. Its lines of business include energy & chemicals, telecommunications, and trading & services.

SK has the fifth highest number of patent publications (84) in the patent landscape. Its earliest patent application in the cognitive radio area was filed in 2000. The company was especially active in 2006-2007 with 13 patent applications per year (Figure 22). It currently seems to be patenting about 5 applications per year.

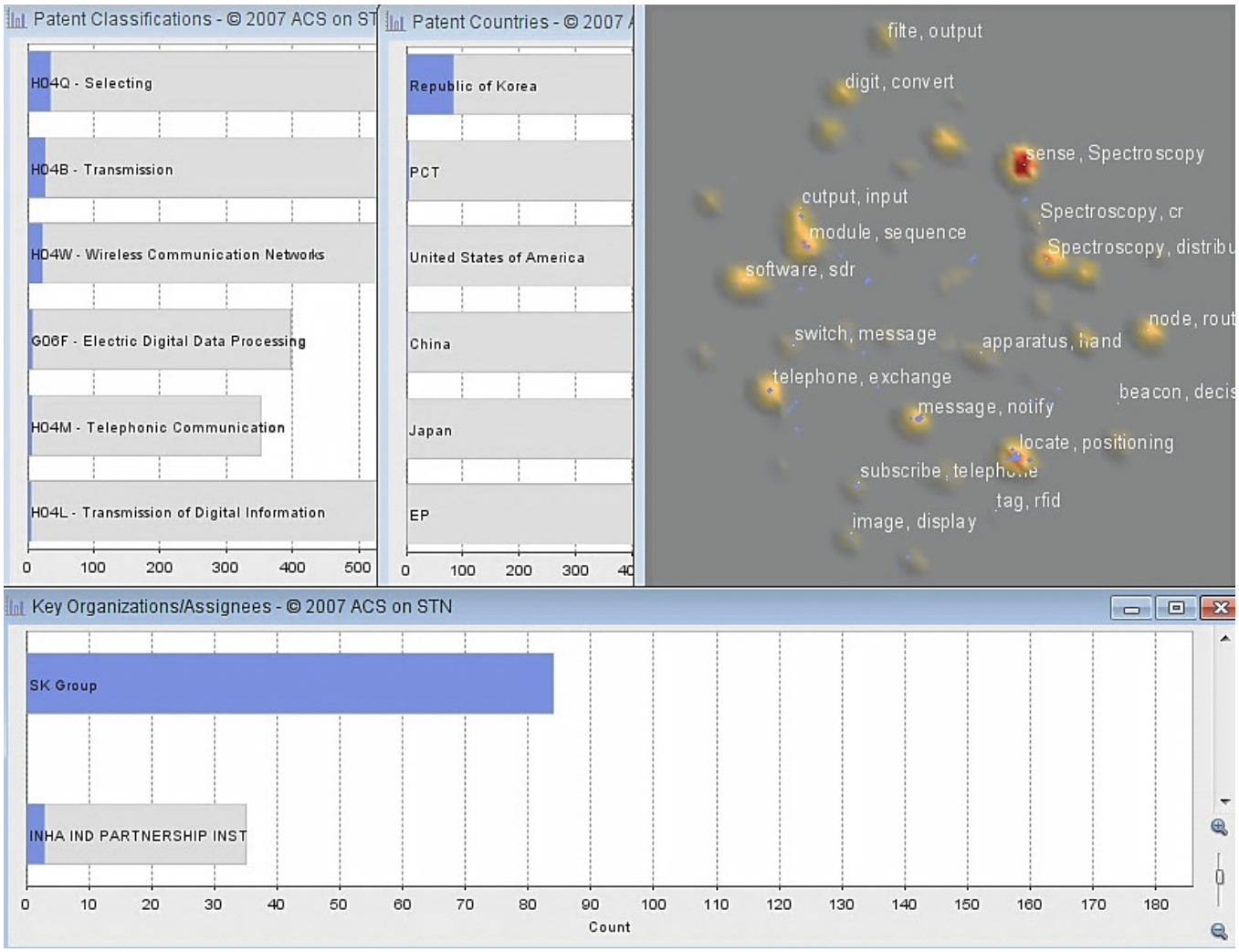


Figure 21 STN Anavist: SK Group's 84 patent publications in the landscape, patenting countries, partners and main patenting classes
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

SK has three co-patents with the Korean Inha-Industry Partnership Institute. So far, it has applied for patents for all its innovations in South Korea. It rarely applies for patents in other countries (Figure 21).

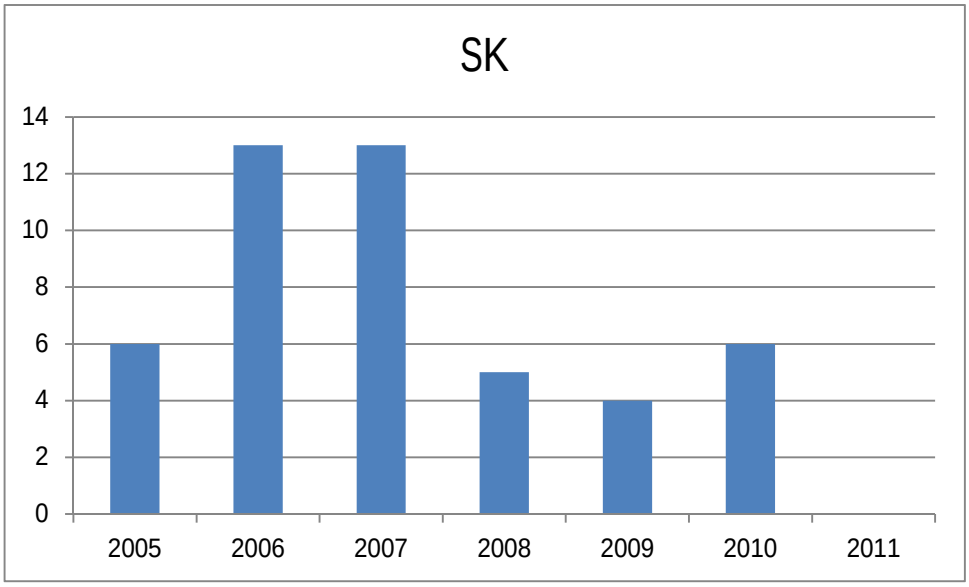


Figure 22 SK Group's yearly patenting from 2005 to now (Public patent publications, in general, to the end of April 2011)

SK has innovations in all application areas:

- Location Based Services (39 documents)
- Communication Systems (35 documents)
- Transmission & Reception (7 documents)
- Spectrum Management (3 documents)

2.2.6 Motorola Inc.

Motorola is an international American telecommunication company.

Motorola has the sixth highest number of patent publications (82) in the patent landscape. Its earliest patent application in the cognitive radio area was filed in 1988. Since its patenting peak in 2006, the company's patenting in cognitive radio has been decreasing (Figure 24).

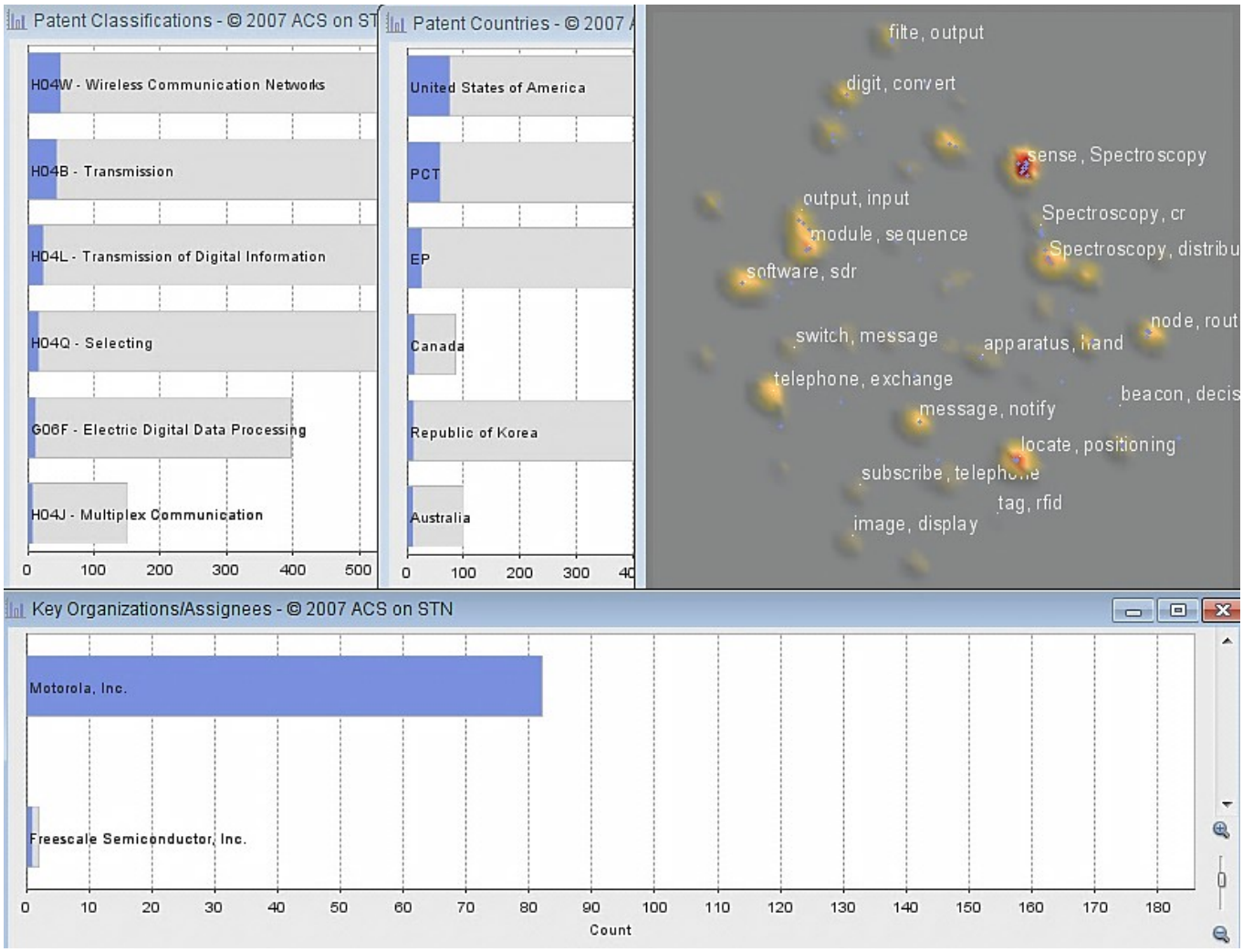


Figure 23 STN Anavist: Motorola Inc.'s 82 patent publications in the landscape, patenting countries, partners and main patenting classes
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

Motorola has one co-patent with Freescale Semiconductor Inc. For most of its patents (76 documents) it has applied in the USA. Motorola also favours PCT applications (59 documents) for an international search report for national phases. (Figure 23)

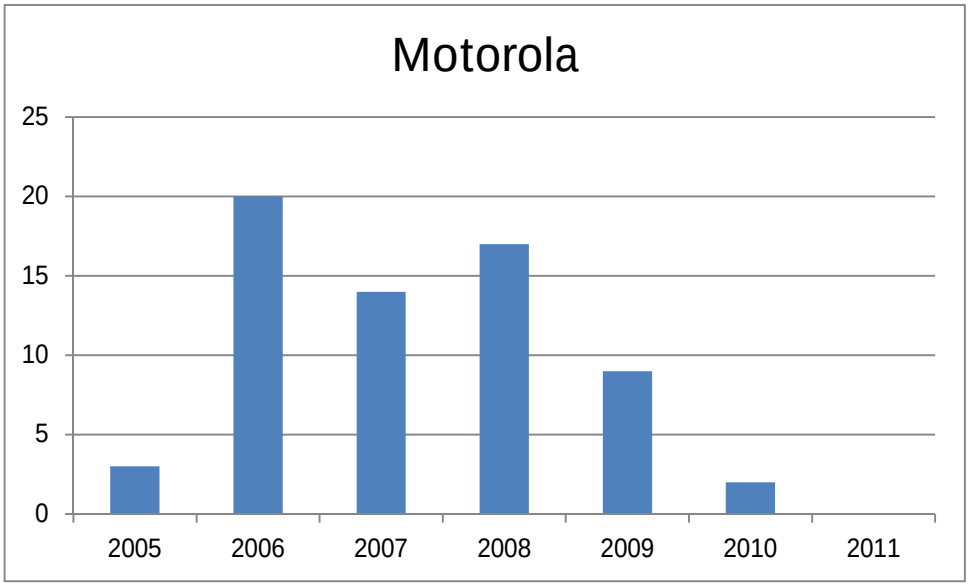


Figure 24 Motorola Inc.'s yearly patenting from 2005 to now (Public patent publications, in general, to the end of April 2011)

Motorola has innovations in all application areas:

- Communication Systems (32 documents)
- Transmission & Reception (23 documents)
- Spectrum Management (21 documents)
- Location Based Services (6 documents)

2.2.7 Nippon Telegraph and Telephone Corporation (NTT)

NTT is a Japanese telecommunication company.

NTT has the seventh highest number of new innovations (80) in the patent landscape. Its earliest patent application in the cognitive radio area was filed in 1990. Since its patenting peak in 2008, the company's patenting in the cognitive radio area has been decreasing (Figure 26).

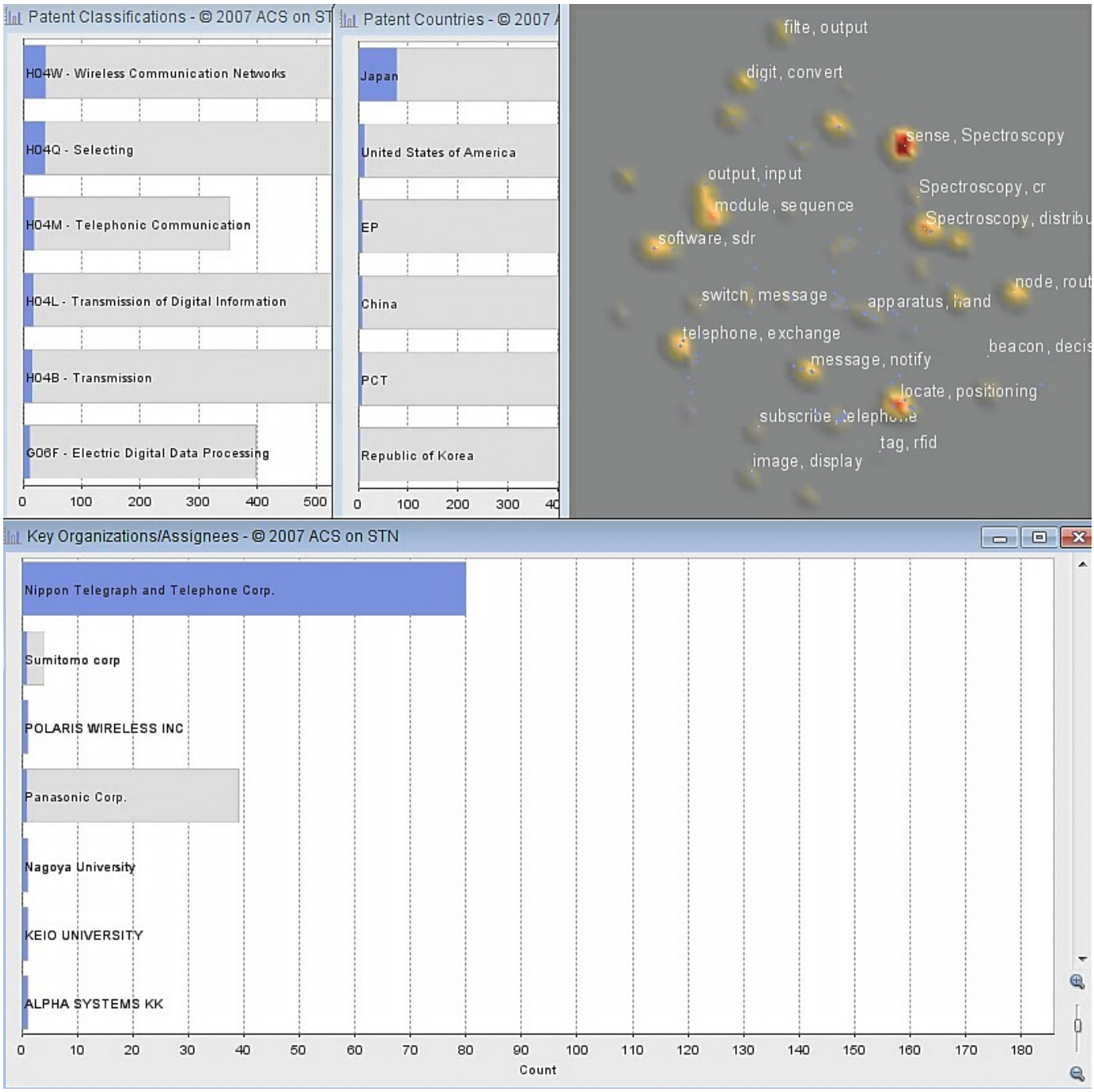


Figure 25 STN Anavist: NTT's (Nippon Telegraph and Telephone Corporation) 80 patent publications in the landscape, patenting countries, partners and main patenting classes (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

NTT collaborates with other organizations in research and development and has one co-patent with the organizations mentioned in the figure above. For most of its innovations (78 documents) it has applied for patents in Japan (Figure 25).

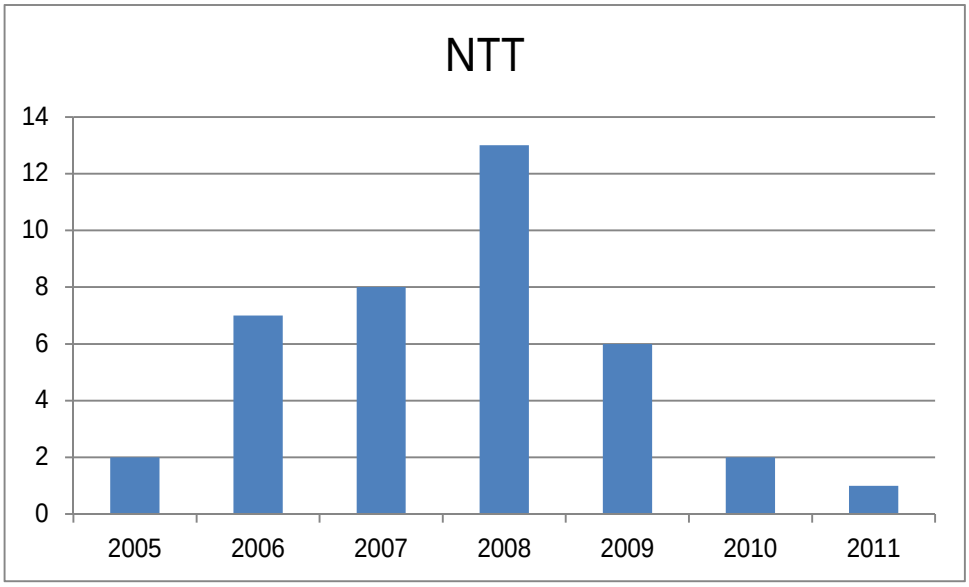


Figure 26 NTT's (Nippon Telegraph and Telephone Corporation) yearly patenting from 2005 to now (Public patent publications, in general, to the end of April 2011)

NTT has innovations in all application areas:

- Communication Systems (44 documents)
- Location Based services (27 documents)
- Transmission & Reception (8 documents)
- Spectrum Management (1 documents)

2.2.8 Electronics and Telecommunications Research Institute (ETRI)

ETRI is a government-backed South Korean research institute. Its fields of research are electronics and information technology.

ETRI has the eighth highest number of patent publications (78) in the patent landscape. Its earliest patent application in the cognitive radio area was filed in 2002. Since its patenting peak in 2008, the company's patenting in the cognitive radio has decreased (Figure 28).

Figure 27 STN Anavist: ETRI's (Electronics and Telecommunications Research Institute) 78 patent publications in the landscape, patenting countries, three main partners and main patenting classes (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

ETRI collaborates with several organizations in research and development. The main partners with two or more co-patents are listed in the figure above. For almost all of its innovations (77 documents) it has applied for patents in South Korea. The USA is also an important patenting country for ETRI (52 documents) (Figure 27).

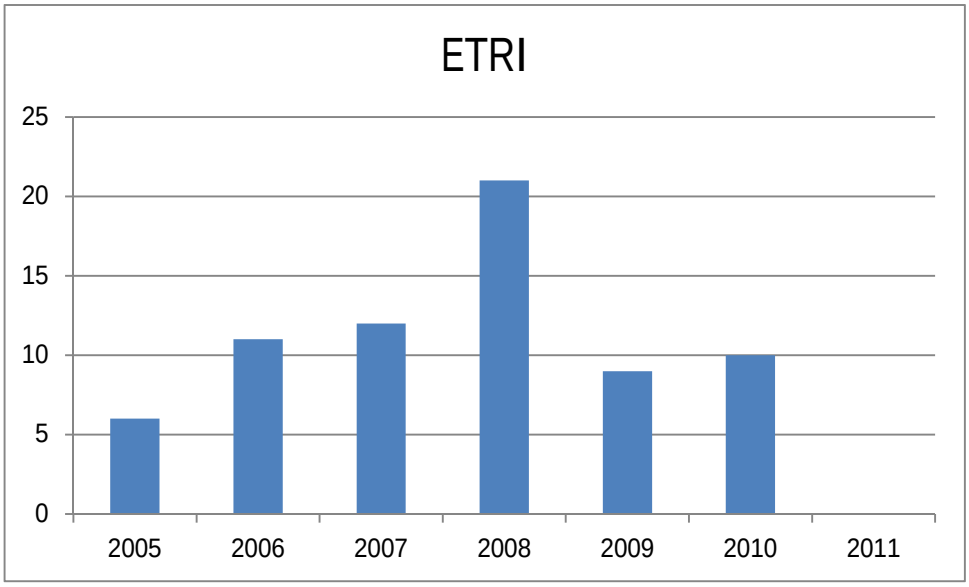


Figure 28 ETRI's (Electronics and Telecommunications Research Institute) yearly patenting from 2005 to now (Public patent publications, in general, to the end of April 2011)

ETRI has innovations in all application areas:

- Communication Systems (37 documents)
- Spectrum Management (20 documents)
- Transmission & Reception (18 documents)
- Location Based Services (3 documents)

2.3 Year Trends

The actual development period of cognitive radio started in the 1990s. Until 1994, there were ten or fewer new patent applications per year relating to cognitive radio. After that, except 2003-2004, the annual number of new cognitive radio innovations increased. In 2010, there were 440 patent applications. By the end of April 2011 (the first third of the year), there had already been 208 new public patent applications, so it is likely that the patenting activity will continue to increase (Figure 29).

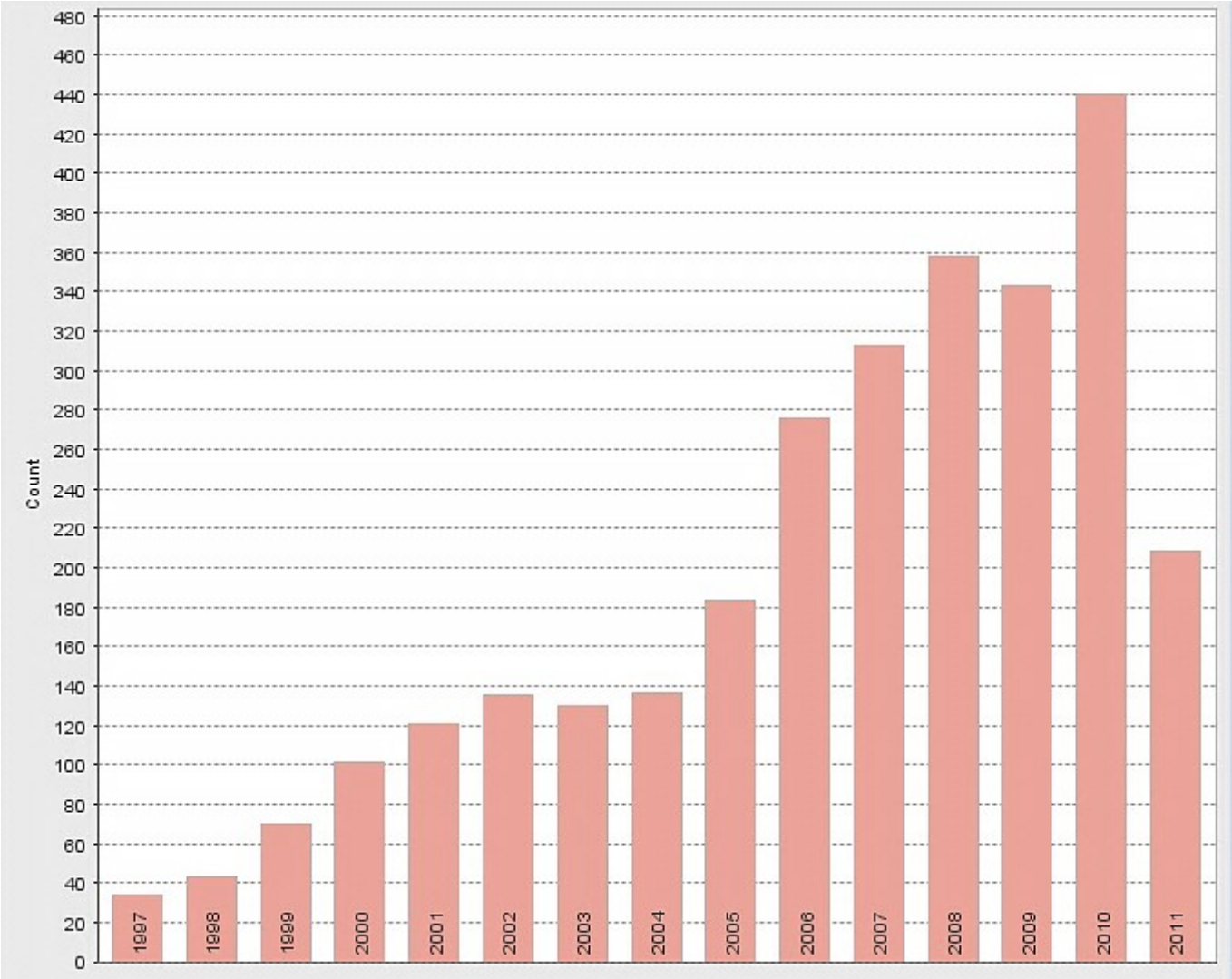


Figure 29 STN Anavist: Annual patent applications in 1997-4/2011
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

*Figure 30 STN Anavist: Key organizations and patenting countries in previous years, 2006-2012. Years **2006-2007 in yellow**, years **2008-2009 in blue** and years **2010- in red**.*
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The order of the most active organizations varies for different years and year periods. In Figure 30, the previous years from 2006 to now are highlighted. As can be seen, the order of the top organizations differs from the whole cumulative order of organizations presented in Figure 10 (page 15).

Samsung has clearly made the highest number of patent applications and continues its active patenting. From the cumulative top organizations (Figure 10), Nokia, Electronics and Telecommunications Research Institute (ETRI), Motorola, Qualcomm, Beijing University of Posts and Telecommunications, and Huawei were remarkably active, in relative terms, in previous years. It is also noticeable that 60 per cent of the Gyosei Corporation's patenting was in 2010 or later.

2.4 Patenting Countries

The USA is the most important business area (Figure 31), followed by the Asian countries: China, South Korea and Japan. The PCT and EP patenting routes are also much used. Germany is the most important individual European country. Finland is ranked 17th.

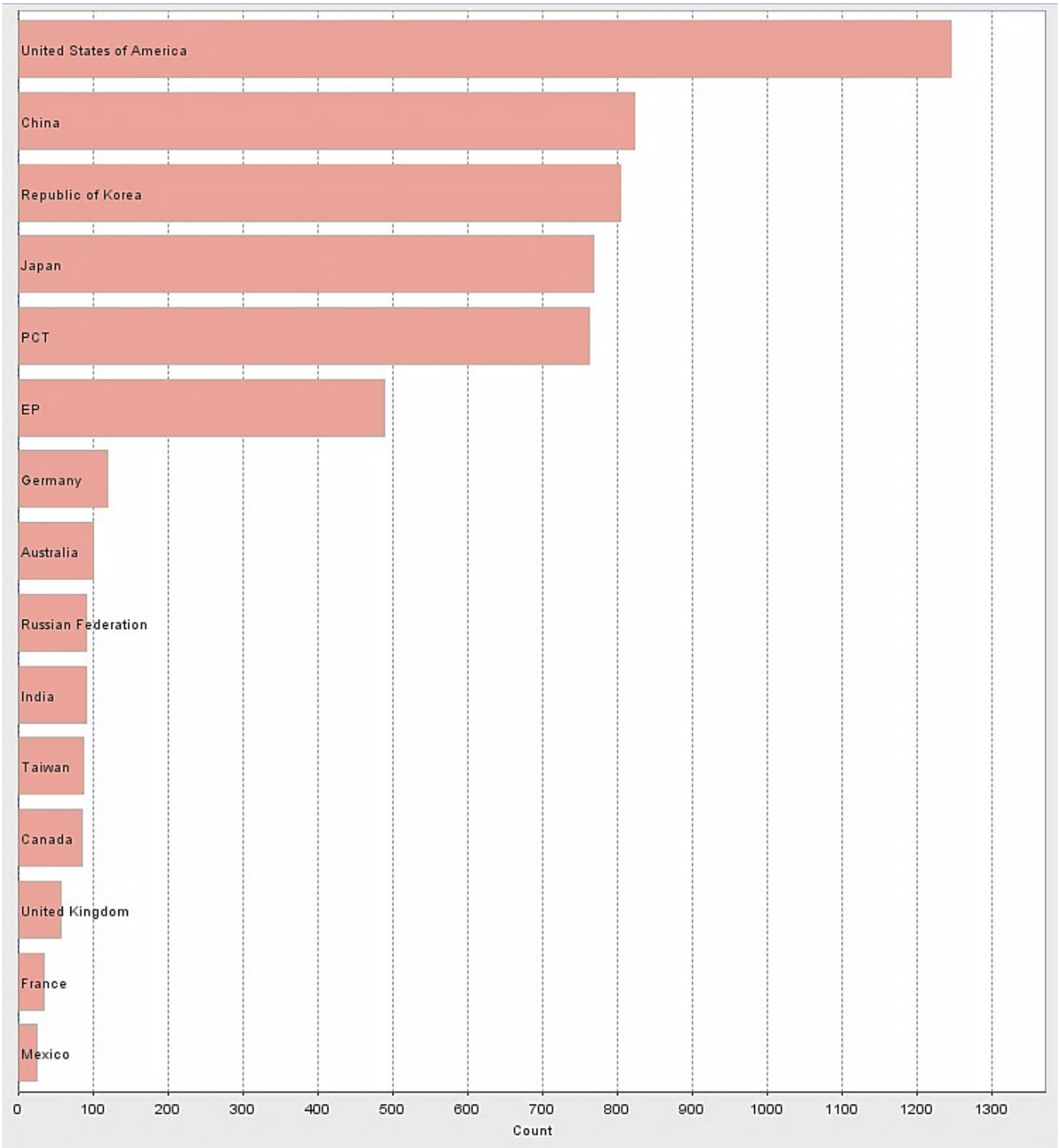


Figure 31 STN Anavist: Top 15 patenting countries (Public patent publications, in general, to the end of April 2011)
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

Patenting countries are countries in which patent applications have been filed for the invention. They indicate where the company intends to profit from the invention by using it in production there, by importing goods prepared using the invention, or by wanting to harass the competitors active in that country.

Application Area	Total	USA	China	South Korea	Japan	EP
Communication Systems	1091 *36 %*	458 *37 %*	254 *31 %*	295 *37 %*	349 *45 %*	183 *37 %*
Transmission & Reception	778 *26 %*	357 *29 %*	219 *27 %*	148 *18 %*	145 *19 %*	146 *30 %*
Spectrum Management	629 *21 %*	289 *23 %*	266 *32 %*	164 *20 %*	66 *9 %*	100 *20 %*
Location Based services	548 *18 %*	142 *11 %*	85 *10 %*	198 *25 %*	209 *27 %*	60 *12 %*
	3046	1246	824	805	769	489

Figure 32 The application areas' patent publication numbers and percentage values from the USA's, China's, South Korea's, Japan's and EP's patenting system's patenting totals
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

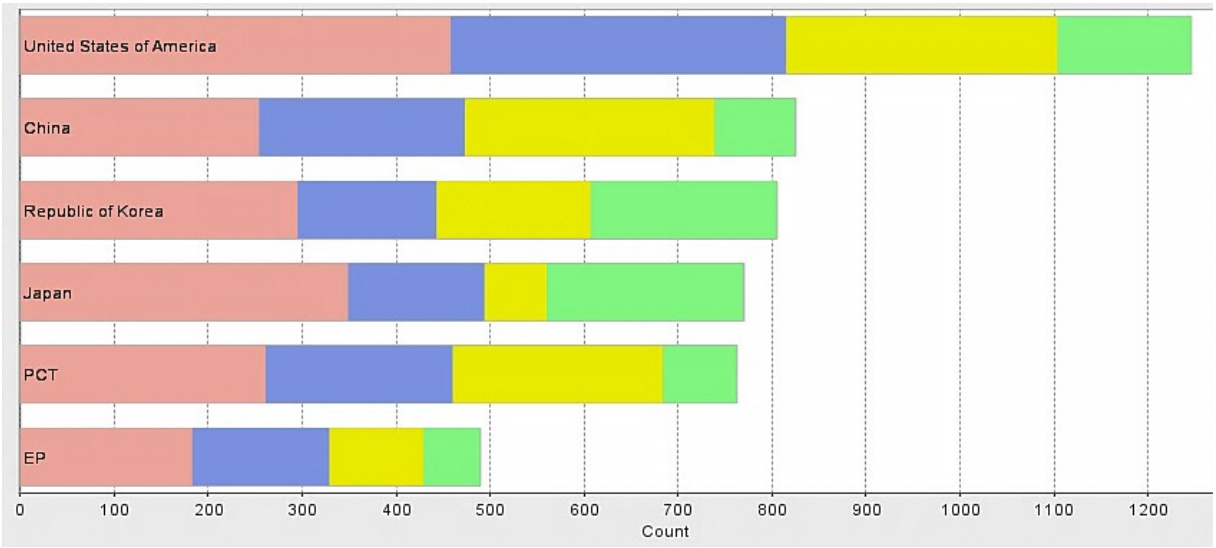


*Figure 33 STN Anavist: The application area distribution of patenting in the USA, China, South Korea, Japan and EP patenting system. Documents from the **Communication Systems** area are coloured red, **Transmission & Reception** area blue, **Spectrum Management** area yellow and **Location Based Services** area green.*
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

The emphasis on technology areas varies between countries and patenting systems (Figure 32, Figure 33). On the whole, the application areas, in order of magnitude, are Communication Systems, Transmission & Reception, Spectrum Management and Location Based Services. The patenting in the USA follows this order, though there is less emphasis on Location Based Services. In the same way, the patenting in the EP patent system essentially follows this general order. In China, there is relatively more (32 %) patenting that deals with Spectrum Management and less

emphasis on Location Based Services. In South Korea, there is relatively more emphasis on Location Based Services and less emphasis on Transmission & Reception. In Japan, there is more emphasis on communication technologies and Location Based Services and less on Transmission & Reception and Spectrum Management.

The following sections investigate the main patenting countries and Finland separately. For each country, there are diagrams of other patenting countries, key organizations and year trends.

2.4.1 The USA

The USA is the most important business area. The USA has applied for 1246 patents. For 30 % of the innovations it only applied for patents in the USA.

Annual patenting increased until 2008. Since then it has decreased. Key organizations in USA patenting are Samsung, Motorola, Nokia, ETRI, Qualcomm, Microsoft and AT&T (Figure 34). USA patenting covers all application areas (Figure 32).

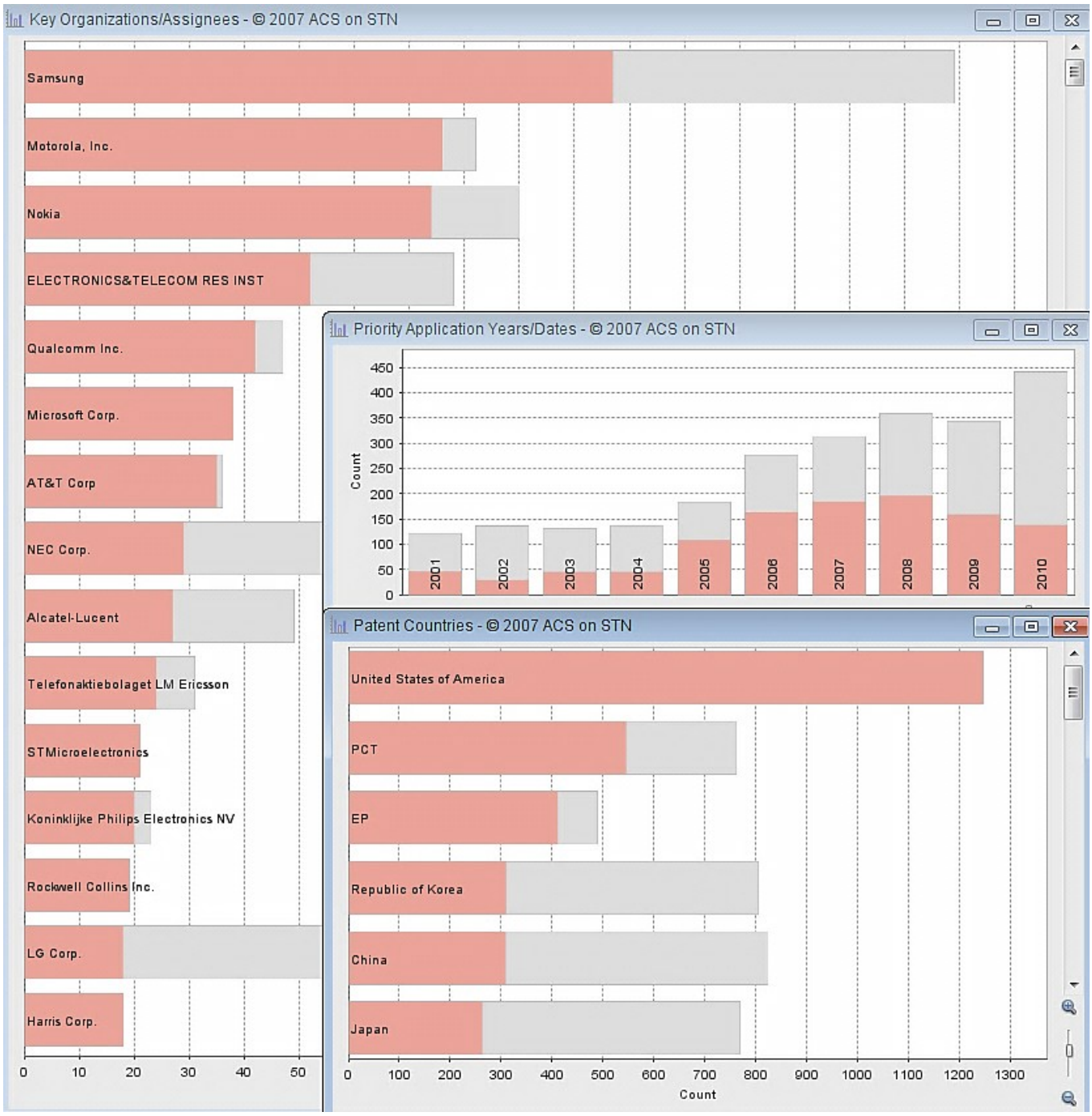


Figure 34 STN Anavist: The USA patent publications' key patenting organizations, annual numbers of patent applications and top 5 other patenting countries
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

2.4.2 China

China is the second most important business area with 824 patent publications. Of these, 58 % were only applied for in China, so the Chinese are concentrating, at least at first, on the domestic markets. The Chinese are now making so many patent applications that it detracts statistically the importance of other countries as business areas.

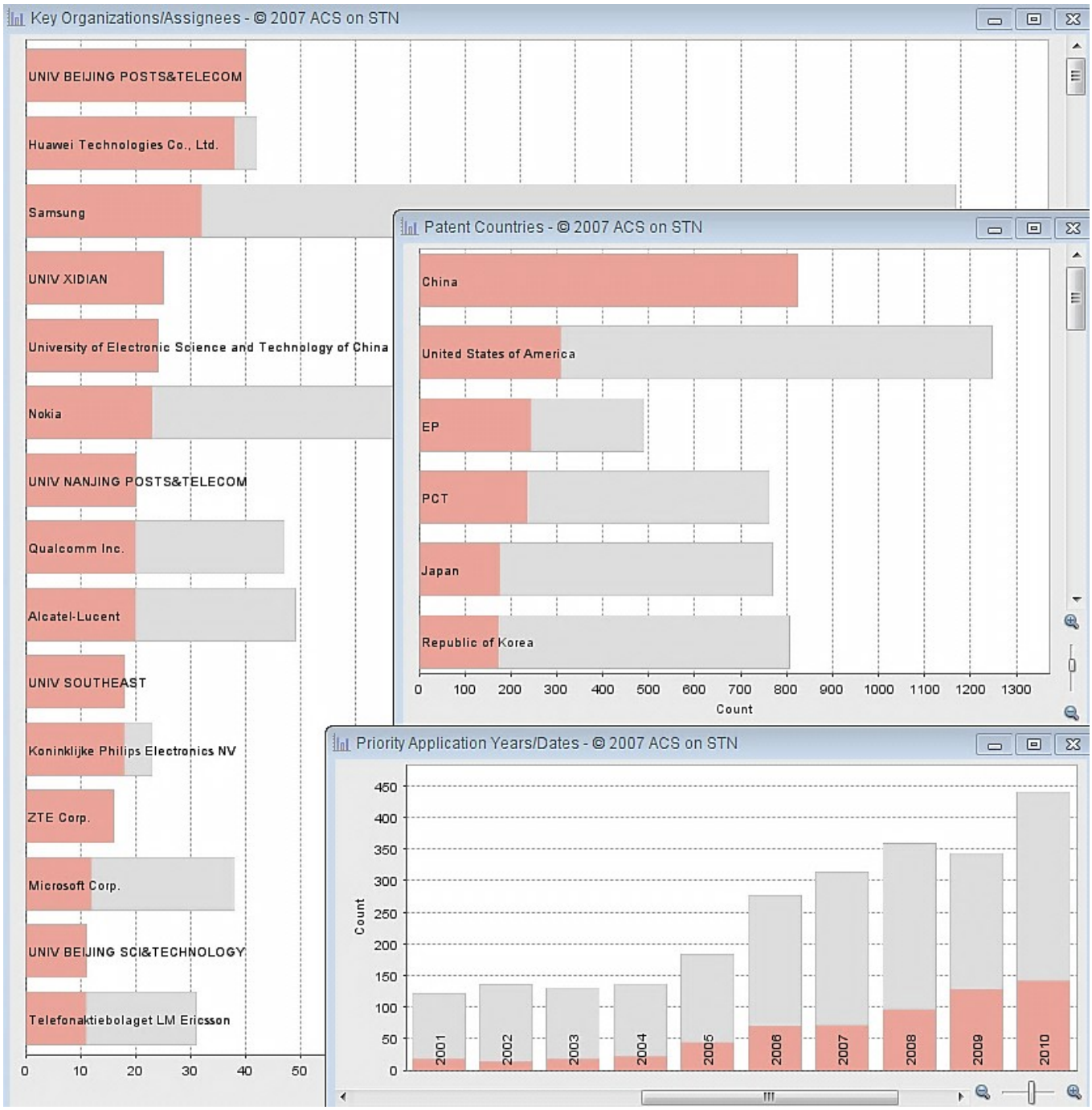


Figure 35 STN Anavist: China's patent publications' key patenting organizations, annual numbers of patent applications and top 5 other patenting countries
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

Annual patenting is increasing. The number of public applications in (the first third of) 2011 is already two higher than the number of patent applications in 2010 (122 documents), so the increase in patenting will continue (Figure 35).

Key organizations in China's patenting are Beijing University of Posts and Telecommunications, Xidian University, University of Electronic Science and Technology of China, Nanjing University of Posts and Telecommunications, Huawei and Southeast University (Figure 35). China's patenting covers all application areas (Figure 32).

2.4.3 South Korea

South Korea is the third most important business area with 805 patent publications. Of these, 58 % were only applied for in South Korea, so the Koreans are concentrating, at least at first, on the domestic markets.

Annual patenting increased until 2007. Since then, annual patenting has decreased. Key organizations in South Korea patenting are Samsung, SK Group, LG Group, ETRI, KT Corporation and Inha-Industrial Partnership Institute (Figure 36). South Korea patenting covers all application areas (Figure 32).

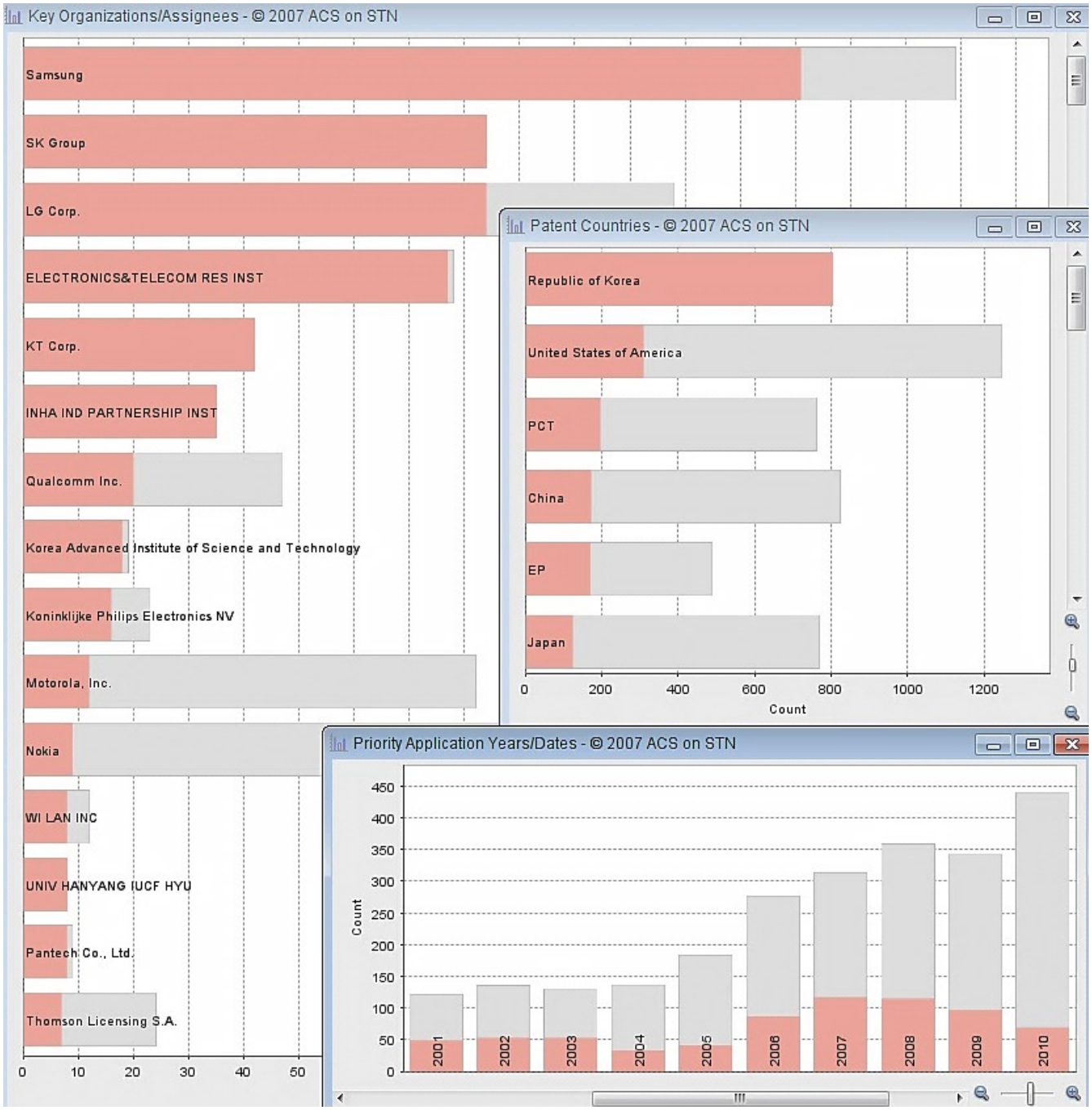


Figure 36 STN Anavist: South Korea's patent publications' key patenting organizations, annual numbers of patent applications and top 5 other patenting countries
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

2.4.4 Japan

Japan is the fourth most important business area with 769 patent publications. Of these, 62 % were only applied for in Japan, so the Japanese are concentrating, at least at first, on the domestic markets.

Annual patenting in 2002-2010 has varied between 30 and 50 patent applications per year. Key organizations in Japan's patenting are NEC, NTT, Hitachi, Toshiba, Panasonic and Gyosei (Figure 37). Japan's patenting covers all application areas (Figure 32).

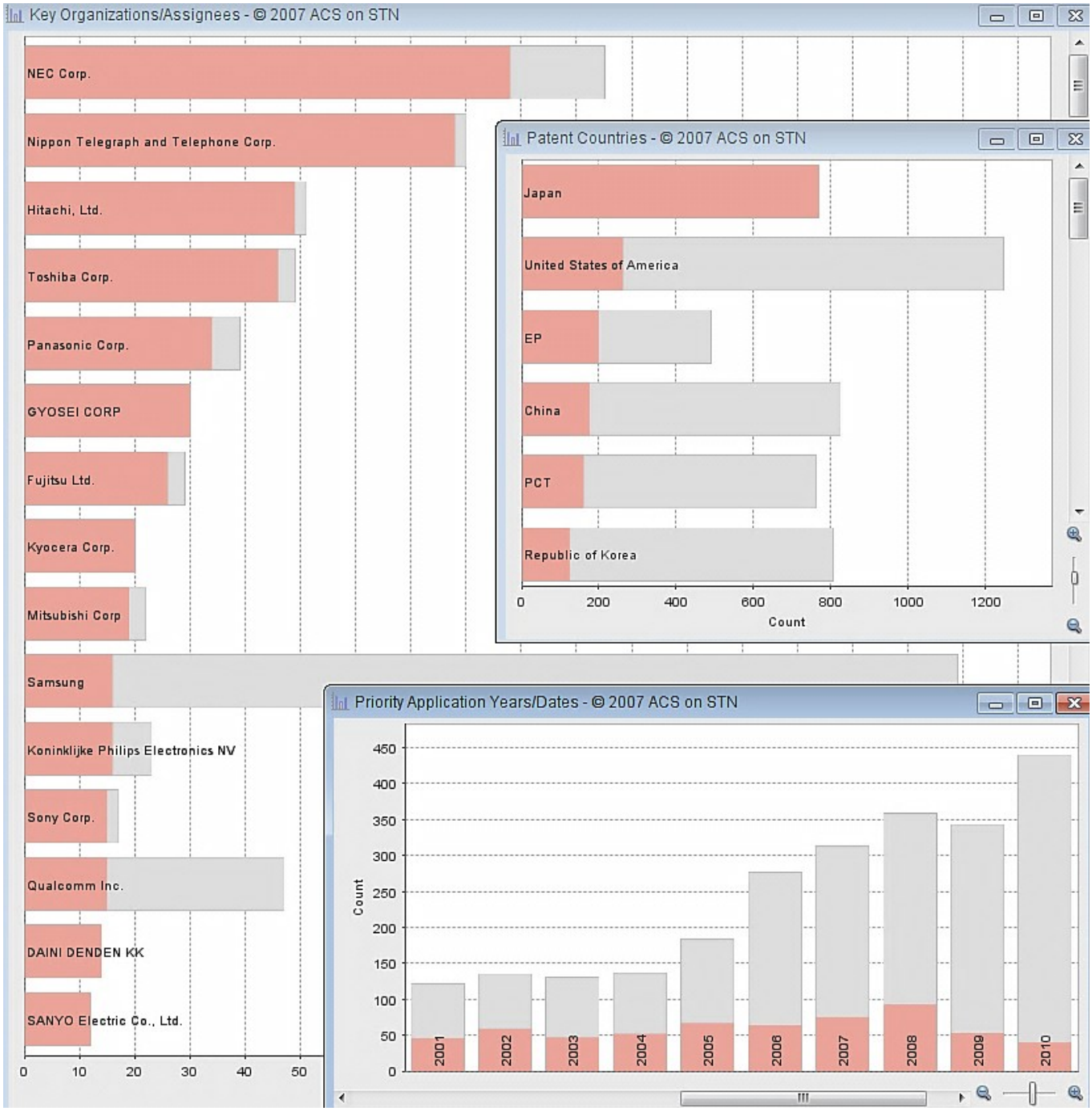


Figure 37 STN Anavist: Japan's patent publications' key patenting organizations, annual numbers of patent applications and top 5 other patenting countries
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

2.4.5 European Patent Organisation

Members of the European Patent Organisation are the fifth most important business area with 489 patent publications. Of these, only 4 % were applied for patent in the EP, so for almost all of the innovations, patents have also been applied for in other countries.

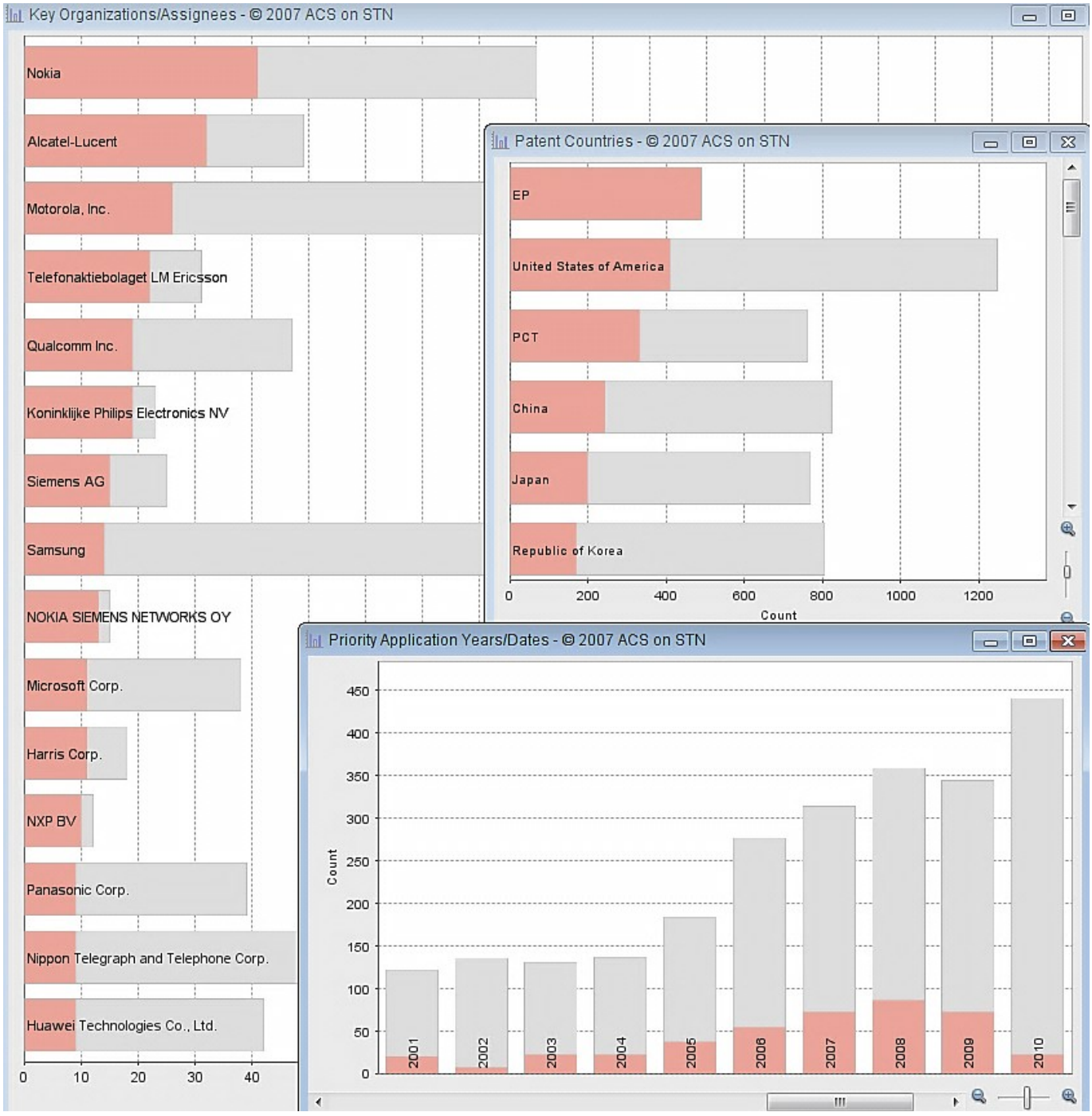


Figure 38 STN Anavist: The European Patent Organisation's patent publications' key patenting organizations, annual numbers of patent applications and top 5 other patenting countries (3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

Annual patenting increased until 2008. Since then, annual patenting has decreased. Key organizations in EP patenting are Nokia, Alcatel-Lucent,

Motorola, Ericsson, Qualcomm and Philips (Figure 38). The EP patenting covers all application areas (Figure 32).

2.4.6 Germany

Germany is the sixth most important business area with 120 patent publications. Of these, only 8 % were applied for only in Germany, so for almost all of the innovations, patents have also been applied for in other countries.

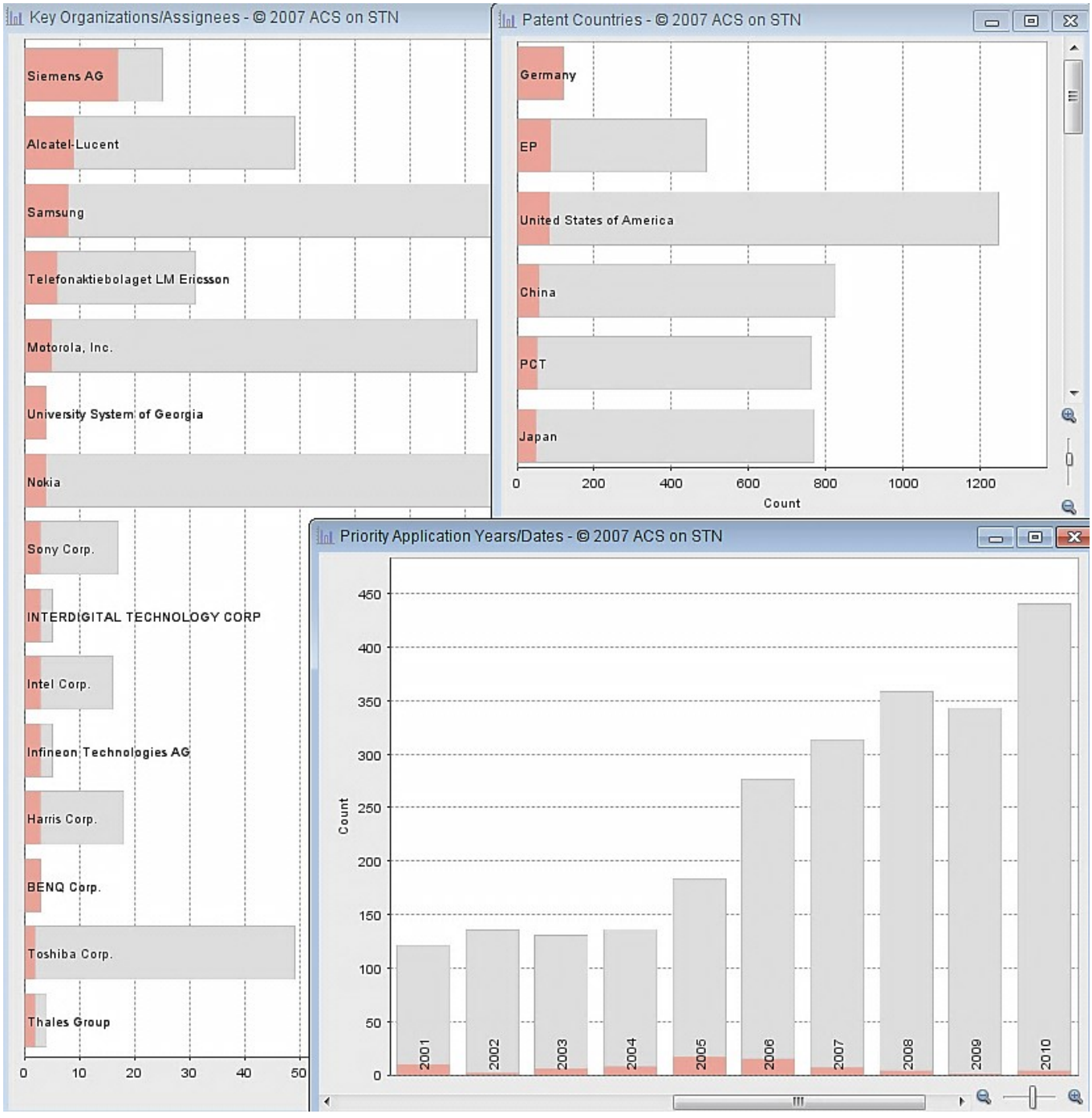


Figure 39 STN Anavist: German patent publications' key patenting organizations, annual numbers of patent applications and top 5 other patenting countries
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

Annual patenting was highest in 2006 (9 % of all the year's innovations). Since then, annual patenting has decreased. Key organizations in German patenting are Siemens, Alcatel-Lucent and Samsung. There is only a difference of a couple of documents between the numbers of patent applications per organization after Siemens (Figure 39).

German patenting covers all application areas:

- Communication Systems (48 documents)
- Transmission & Reception (43 documents)
- Location Based Services (17 documents)
- Spectrum Management (12 documents)

2.4.7 Finland

Finland is the seventeenth most important business area with 19 patent publications. Of these, three were applied for only in Finland. The previous patent applications are from 2005 (3 documents), 2006 (6 documents) and 2007 (3 documents).

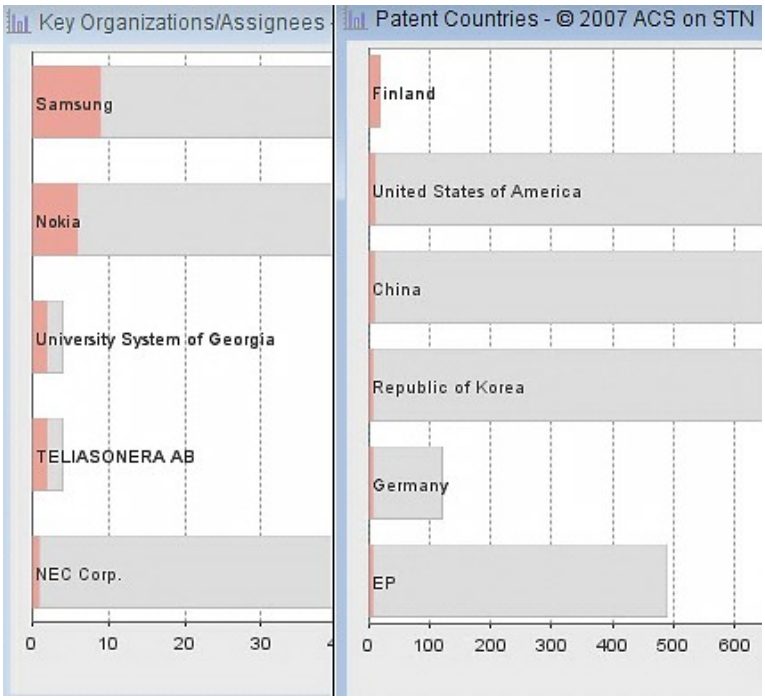


Figure 40 STN Anavist: Finland's patent publications' key patenting organizations and top 5 other patenting countries
(3046 documents retrieved from the 'Derwent Word Patent Index' patent database 1971-2012)

Patent assignees in the Finnish patents area are Samsung partly with University System of Georgia, Nokia, TeliaSonera and NEC (Figure 40).

Finnish patenting covers all application areas:

- Communication Systems (7 documents)
- Spectrum Management (6 documents)
- Transmission & Reception (4 documents)
- Location Based Services (2 documents)

3 Scientific Publication Analysis

In the scientific publications landscape (Figure 41), there are 13,400 publications from 1970 to the end of August 2012. At that point in 2012, over one-third of the publication number for 2011 had been reached. The year figures in this chapter cover previous years, 1995-2011.

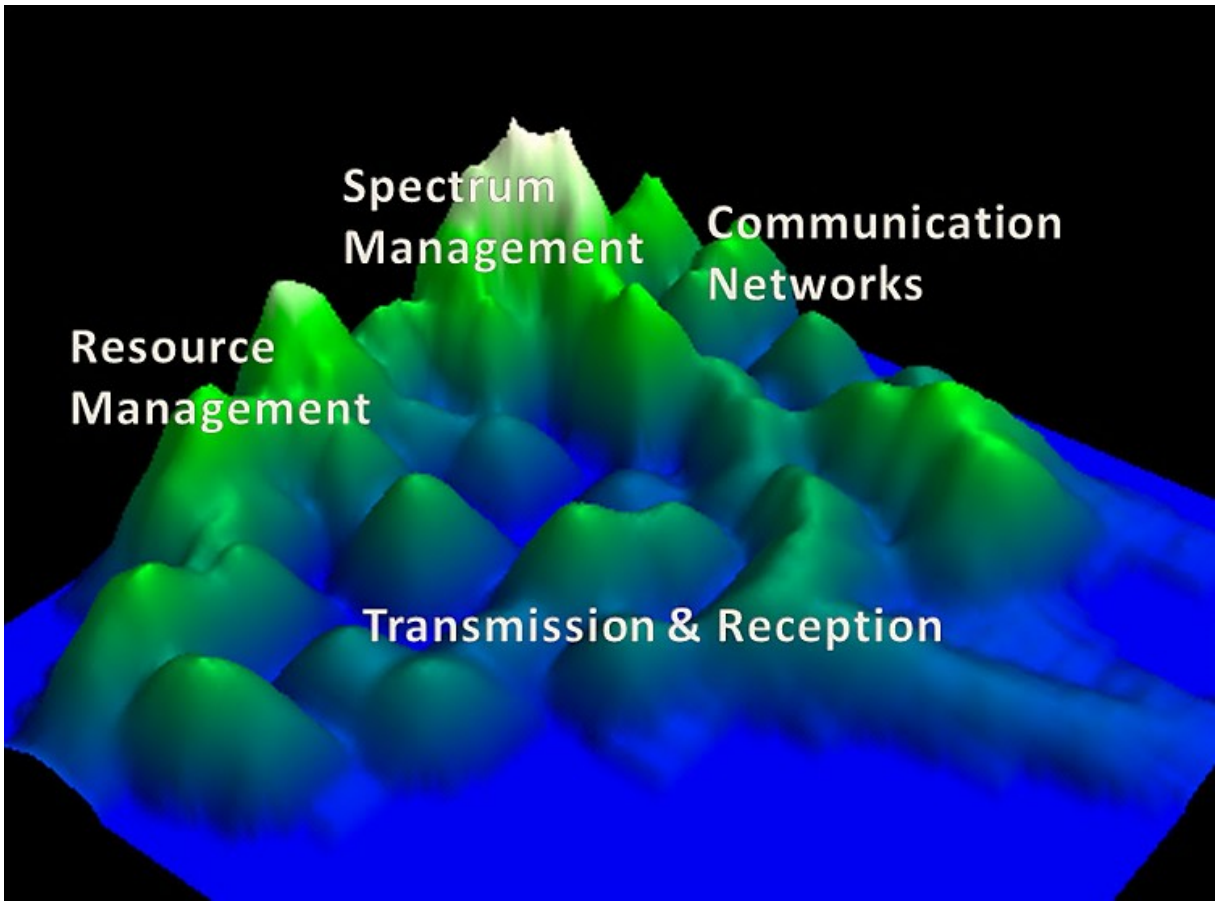


Figure 41 Omniviz: Cognitive radio 3D publication landscape

There are four application areas in the publication landscape (Figure 41, Figure 42). The biggest application area is Spectrum Management with the highest peaks, so there are many similar kinds of documents. Resource Management is a broader area, which, in addition to Spectrum Management, deals with other kinds of resources in a radio system. Transmission & Reception is a broad area that goes through the landscape, filling almost half of its surface area. The main viewpoint of the documents at one end is on transmission and at the other end on reception. The Communication Networks area handles networks in cognitive radio systems.

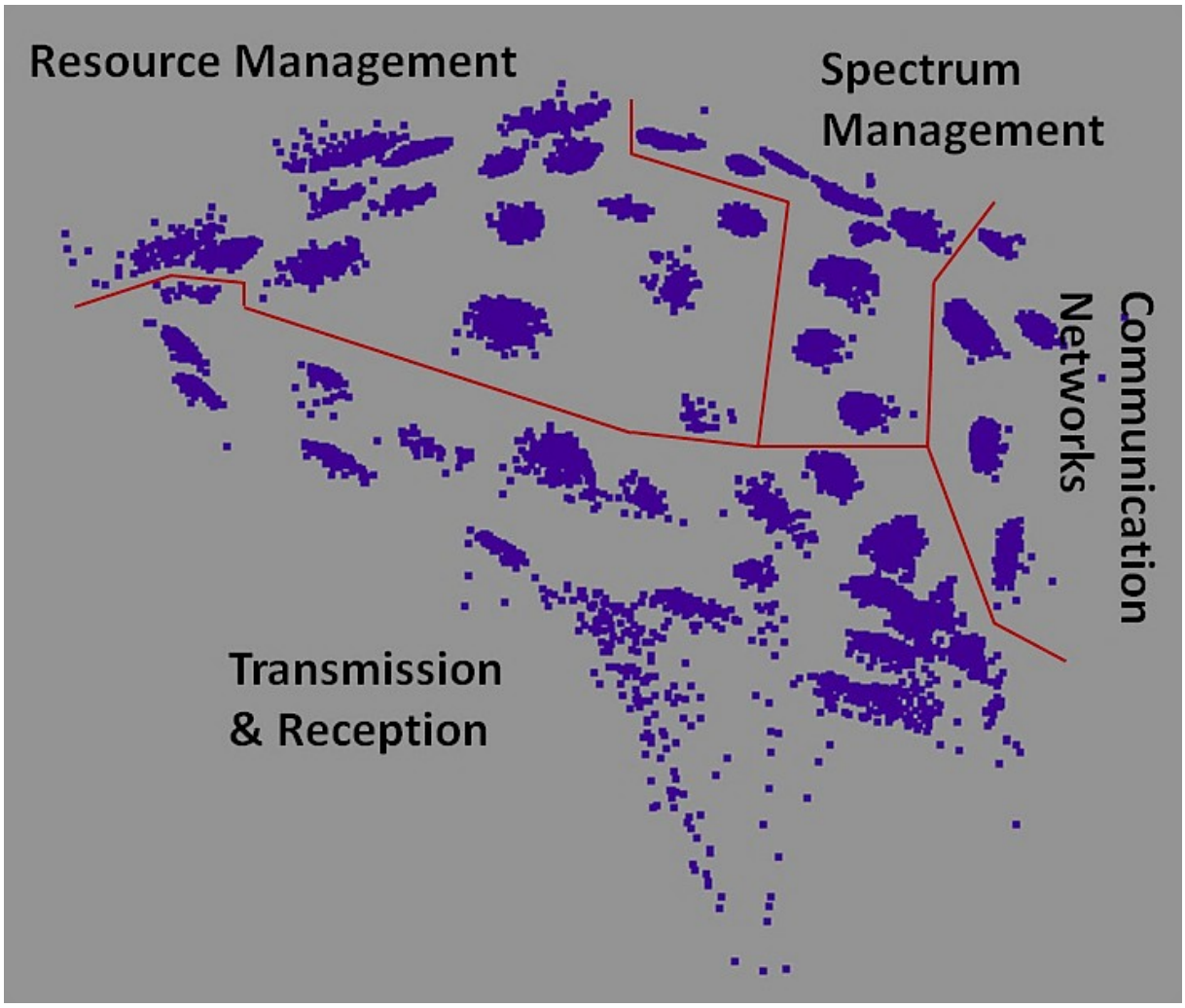


Figure 42 Omniviz: Cognitive radio 2D publication landscape.

Amount of publications starts its increase at the end of the 1990s (Figure 59 on page 61). Before that, there were only a few publications per year (less than 20 documents). From 2005 to now, the number of documents dealing with spectrum and resource management has and is increasing strongly (Figure 60 on page 61).

The most active organizations (top 6 before IEEE) are from China, the USA and Singapore (Figure 56 on page 58). They are Beijing University of Posts and Telecommunication (China), University of California (USA), Nanjing University of Post and Telecommunication (China), Virginia Polytechnic Institute and State University (USA), Nanyang Technological University (Singapore) and Institute for Infocomm Research, A-Star (Singapore). The top European organizations are Polytechnic University of Catalonia (Spain) and RWTH Aachen University (Germany), ranked 20th and 21st respectively. The top Finnish organization is Aalto University in 33rd place. The top company is Nippon Telegraph and Telephone (NTT) in 42nd place.

3.1 Application Areas

The publication landscape has four application areas: Spectrum Management, Resource Management, Transmission & Reception and Communication Networks (Figure 41, Figure 42).

In the following sections, the application areas are investigated separately. For each application area, there is a map with the locations of the application area's documents along with diagrams for the publication years.

3.1.1 Transmission & Reception

The Transmission & Reception area has had 3242 publications since 1970. Documents at one end of the area have their main viewpoint on transmission and at the other end on reception. Antennas are also included in this area.

The area's yearly publication numbers start to increase at the end of the 1990s (Figure 43).

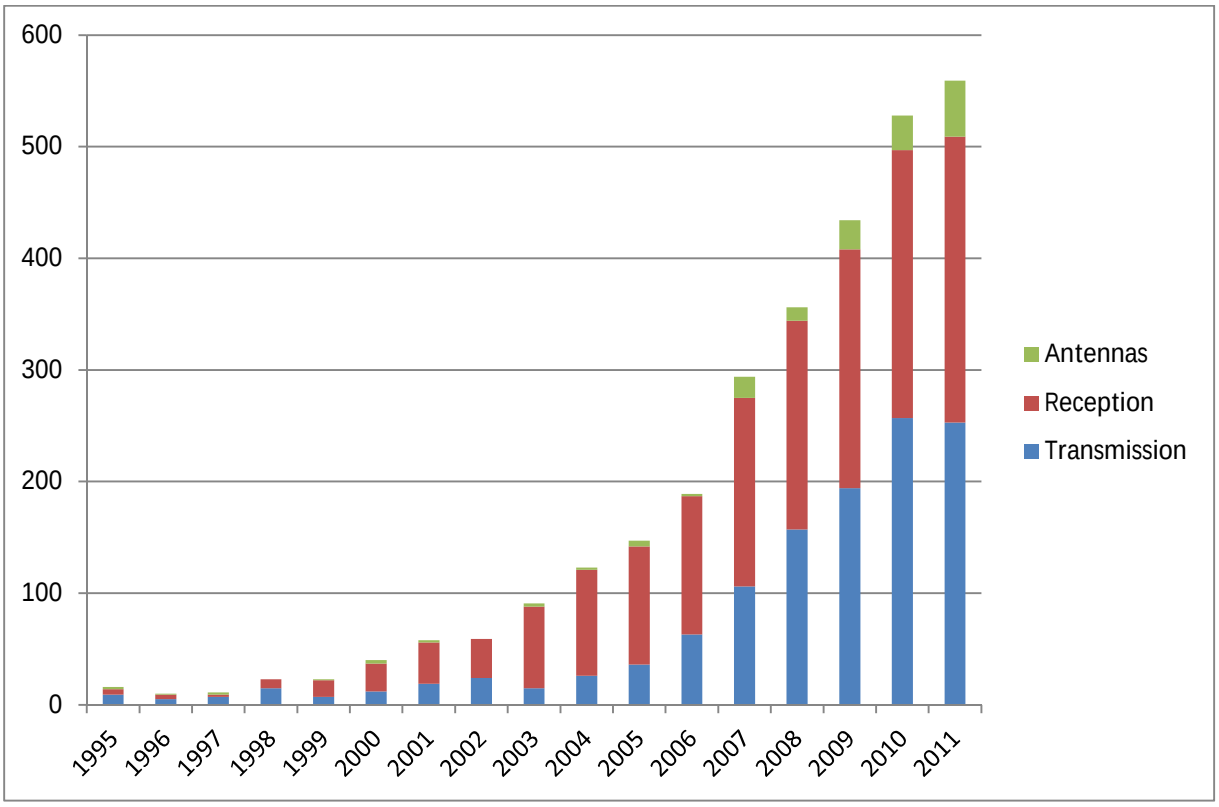


Figure 43 Cognitive radio documents dealing with transmission and reception in 1995-2011

In the following sections, the sub-areas are investigated separately.

3.1.1.1 Transmission

The Transmission area (Figure 44) has had 1351 publications since 1973. The documents' main point is transmission and transmitters but, naturally, close matters and terms such as receivers, transceivers, amplifiers, interferences, white spaces and widebands are also mentioned.

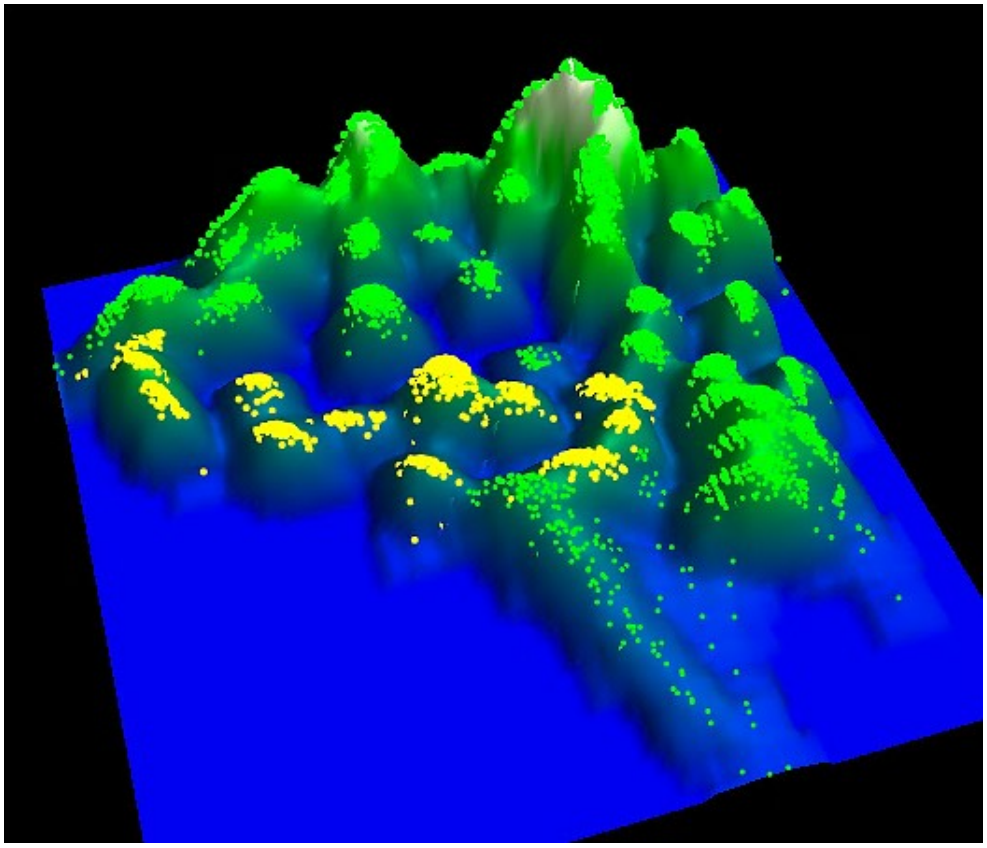


Figure 44 Omniviz: Cognitive radio documents dealing mainly with transmission matters in the 3D publication landscape

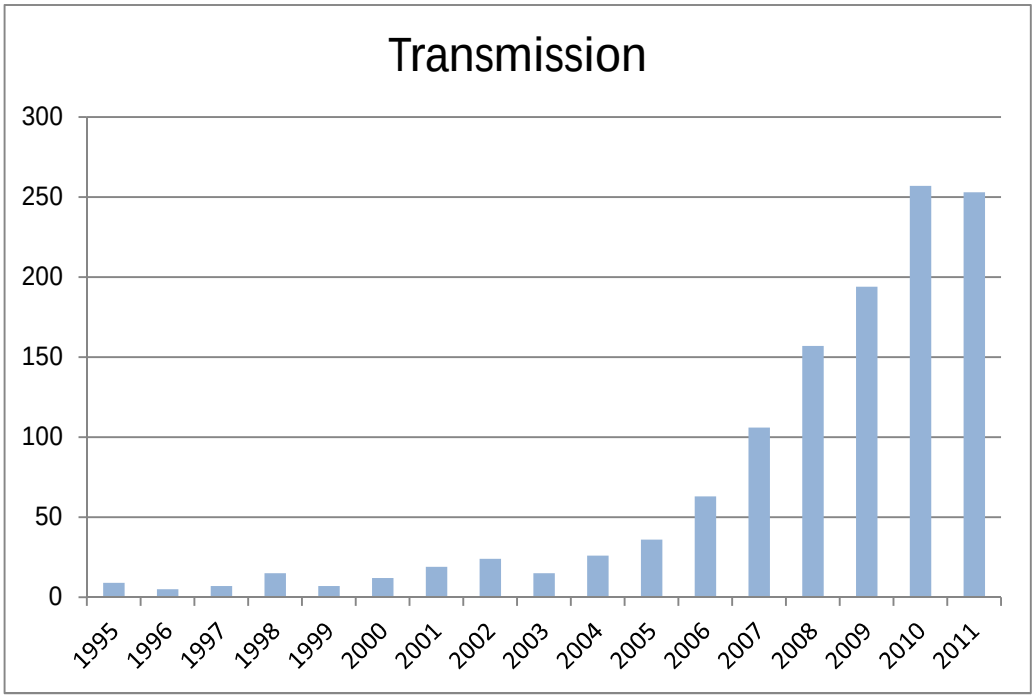


Figure 45 Cognitive radio documents dealing mainly with transmission matters in 1995-2011

In the year trend graph (Figure 45), it seems that the increase in the number of publications is subsiding. The publication numbers for 2011 may still reach the number for 2010 via late supplements to the publication database.

3.1.1.2 Reception

The Reception area (Figure 46) has had 1699 publications since 1970. The documents' main point is receivers and receiving data but, naturally, close matters and terms such as transmitters, transceivers, filters and converters are also mentioned.

The year trend graph (Figure 47) shows that the annual publication numbers in the area are increasing.

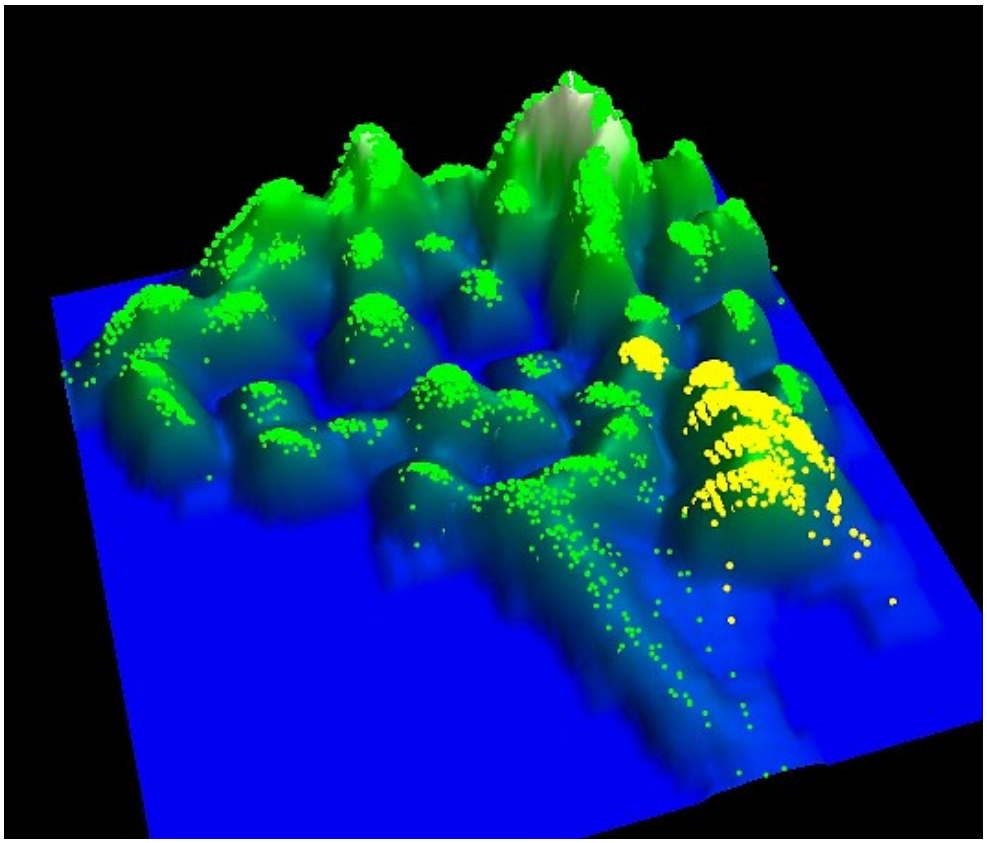


Figure 46 Omniviz: Cognitive radio documents dealing mainly with reception matters in the 3D publication landscape

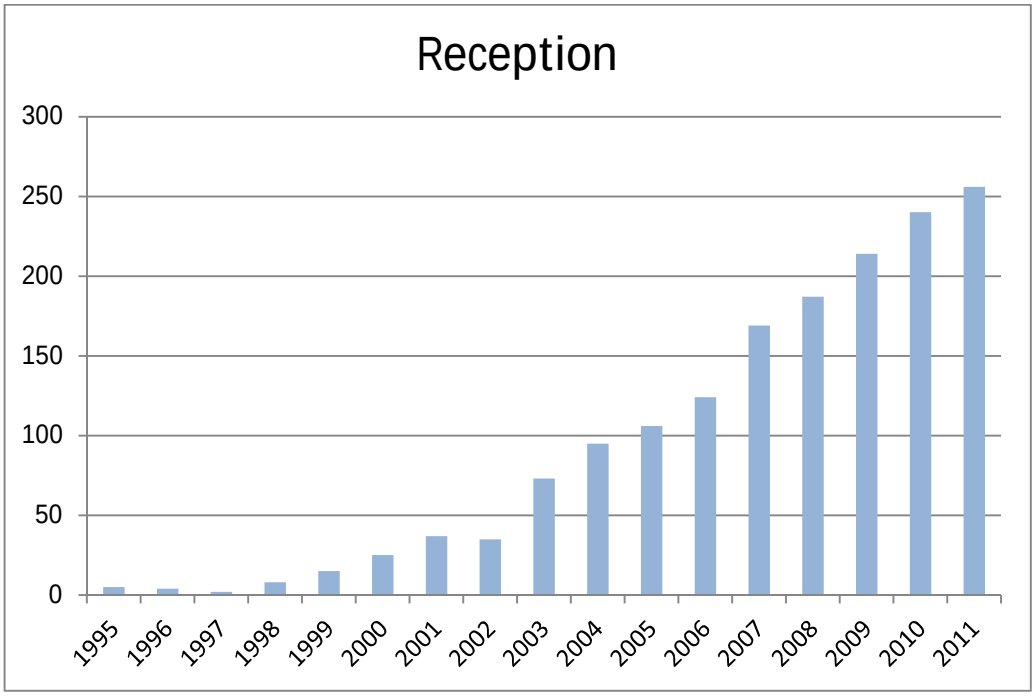


Figure 47 Cognitive radio documents dealing mainly with reception matters in 1995-2011

3.1.1.3 Antennas

The Antenna area (Figure 48) has had 192 publications since 1984. The year trend graph (Figure 49) shows that there has been a 60 % increase (from 31 documents to 50 documents) in publication numbers from 2010 to 2011.

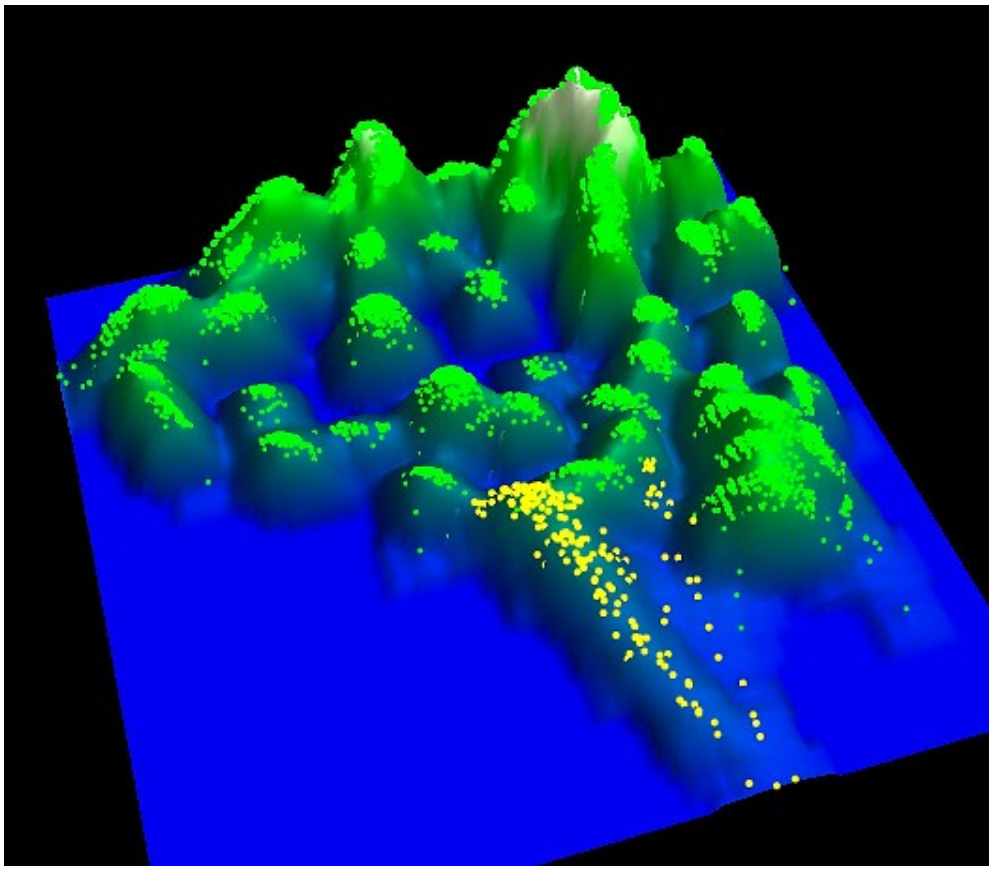


Figure 48 Omniviz: Cognitive radio documents dealing with antennas in the 3D publication landscape

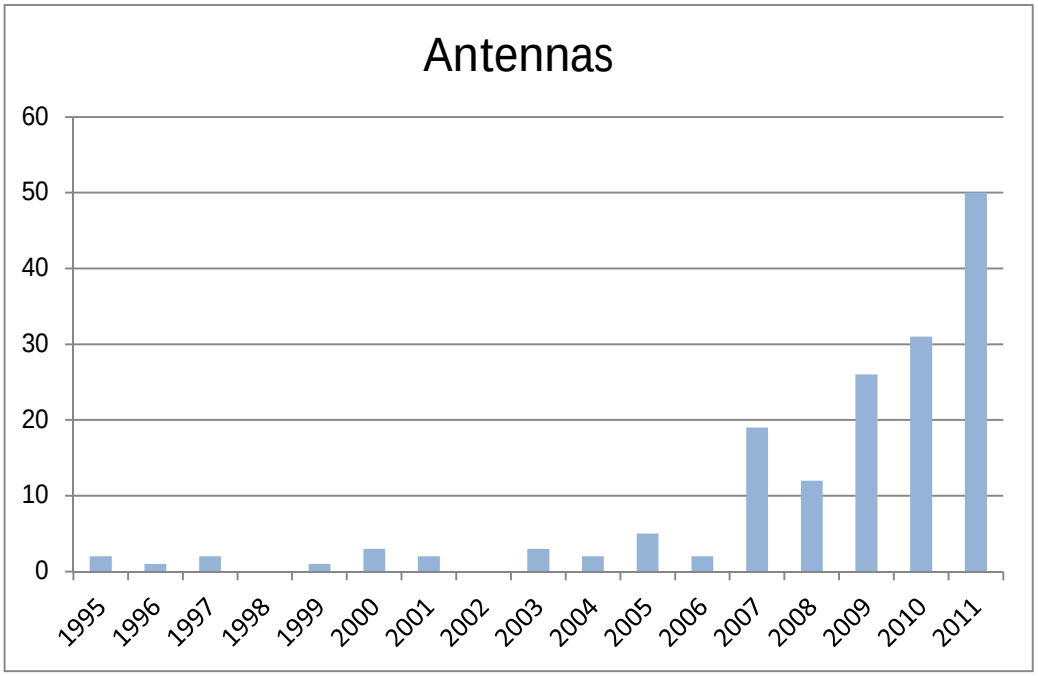


Figure 49 Cognitive radio documents dealing with antennas in 1995-2011

3.1.2 Communication Networks

The communication networks area (Figure 50) has had 2362 publications since 1983. Documents in the communication networks area discuss communication networks, architectures and systems.

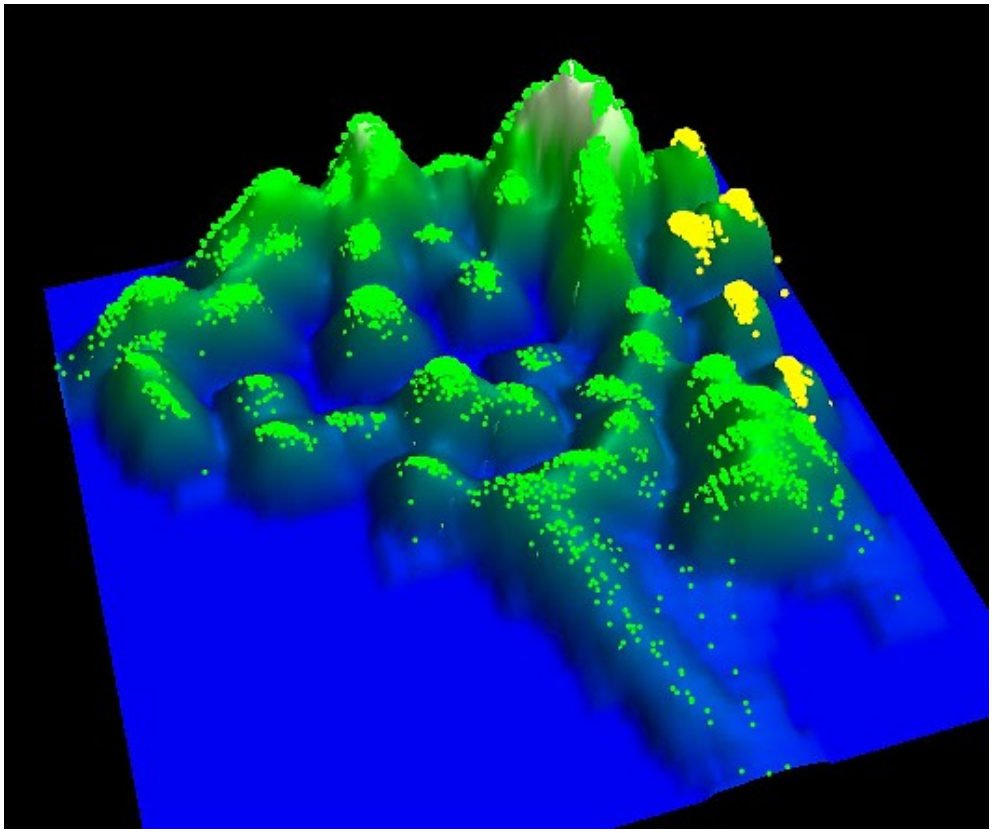


Figure 50 Omniviz: Cognitive radio documents dealing with communication networks in the 3D publication landscape

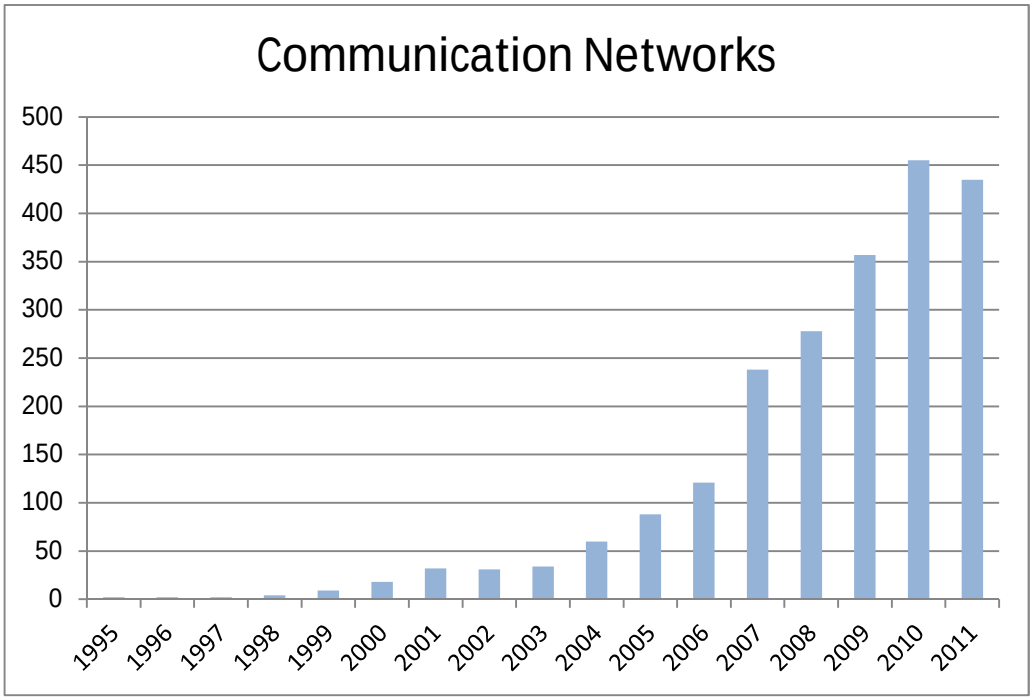


Figure 51 Cognitive radio documents dealing with communication networks in 1995-2011

The year trend graph (Figure 51) shows that the yearly increase in publication numbers has ended.

3.1.3 Spectrum Management

The Spectrum Management area (Figure 52) has had 4020 publications since 1991. The documents' main point is spectrum management, sensing, access and allocation. The area consists of a big peak with its near neighbourhood, so the area consists of many similar kinds of documents.

The spectrum management discussion started later than the other areas of the publication landscape. The yearly publication numbers remarkably started to increase in 2007. From 2005 to 2011 there was an almost 21-fold increase in the annual publication numbers (Figure 53).

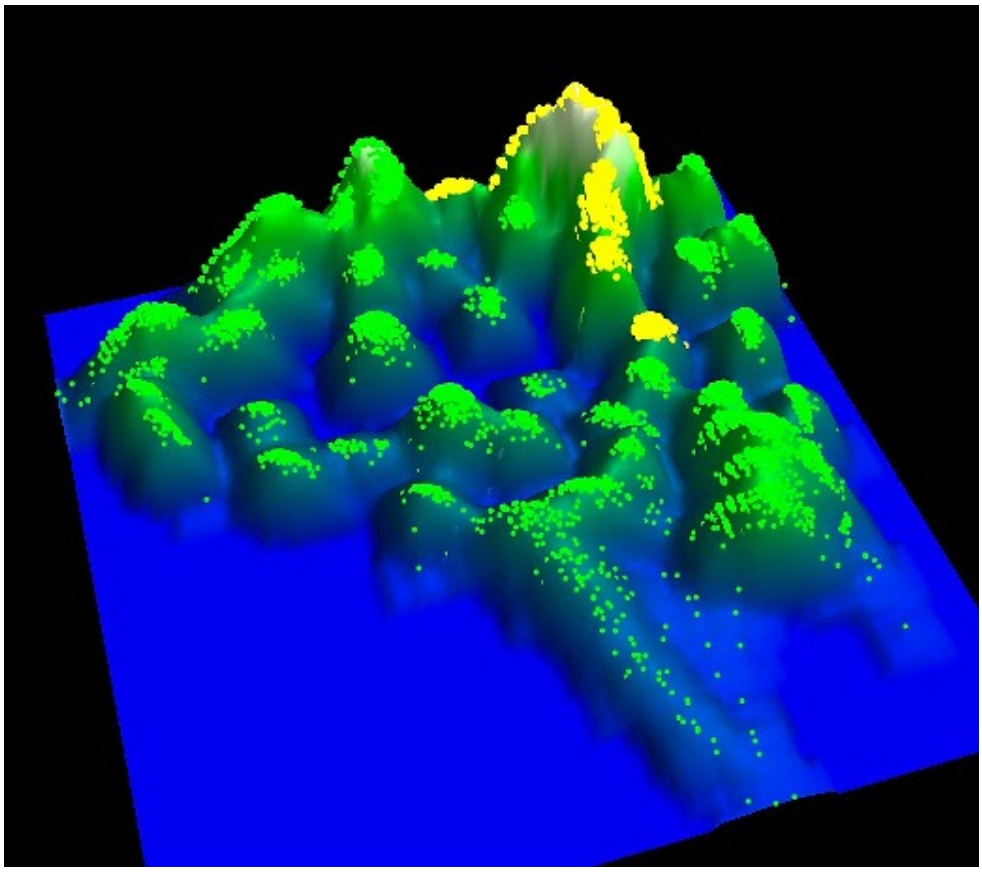


Figure 52 Omniviz: Cognitive radio documents dealing with spectrum management in the 3D publication landscape

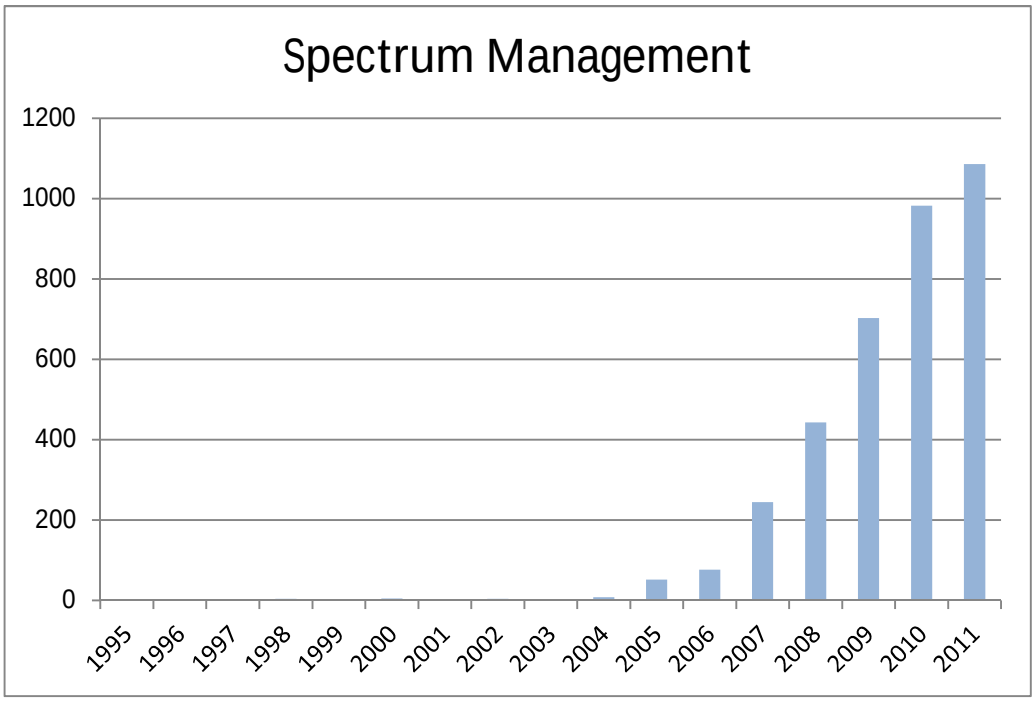


Figure 53 Cognitive radio documents dealing with spectrum management in 1995-2011

3.1.4 Resource Management

The resource management area (Figure 54) has had 3761 publications since 1986. The documents' main points are resource management, allocation, optimization, reconfiguration, control and sharing. The managed resources are in most cases power, spectra or channels.

The yearly publication numbers remarkably started to increase in 2007. From 2005 to 2011 there was an almost 19-fold increase in the annual publication numbers (Figure 55).

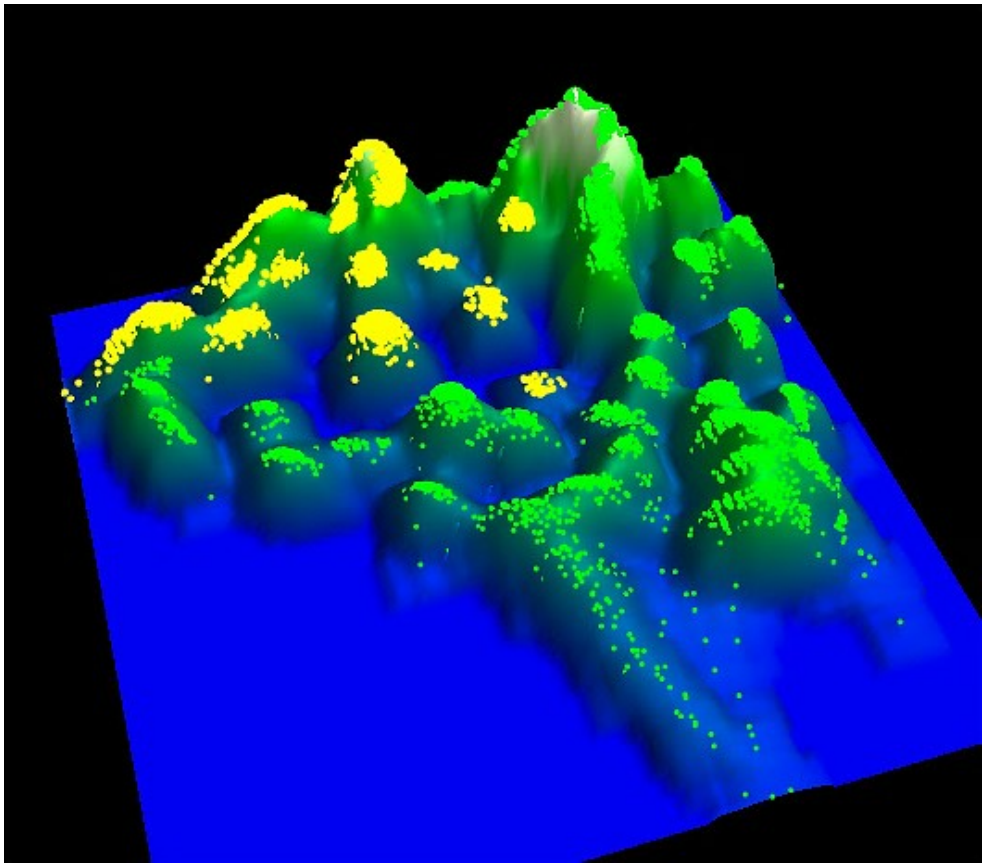


Figure 54 Cognitive radio documents dealing with resource management in the 3D publication landscape

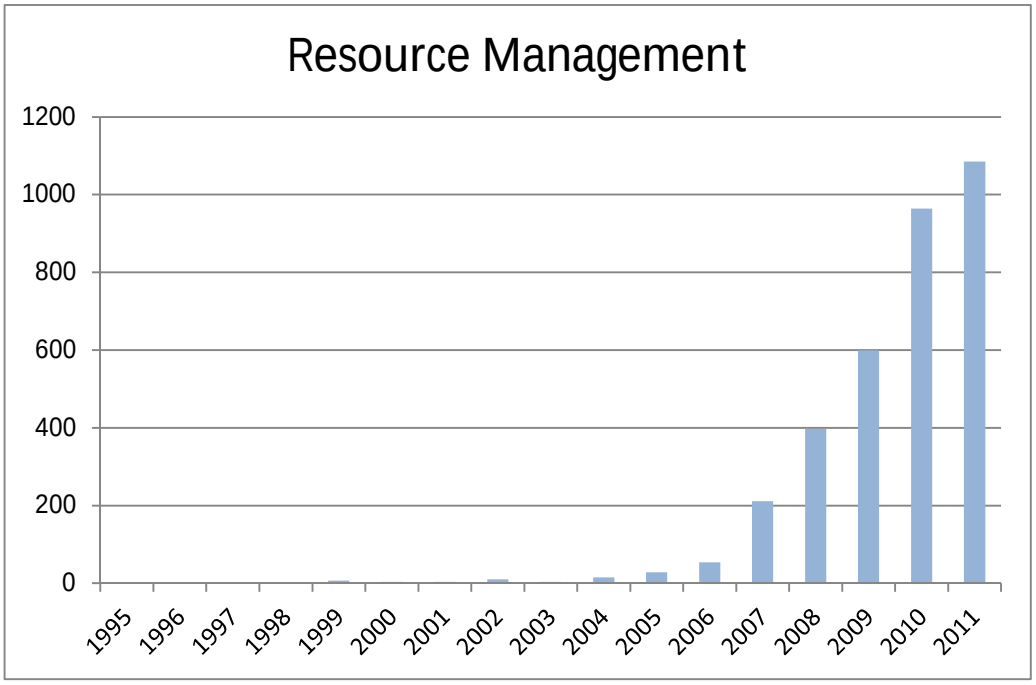


Figure 55 Cognitive radio documents dealing with resource management in 1995-2011

3.2 Key Organizations

The most active organizations (top 6 before IEEE) are from China, the USA and Singapore (Figure 56). The most active one is Beijing University of Posts and Telecommunication (China). The University of California (USA) is 2nd, if we count the publications from all its campus areas together. Otherwise, the Los Angeles campus is its best with a 10th ranking. The 3rd is Nanjing University of Post and Telecommunication (China). The 4th is Virginia Polytechnic Institute and State University (USA). The 5th is Nanyang Technological University (Singapore) and the 6th is the Institute for Infocomm Research, A-Star (Singapore).

The top European organizations are the Polytechnic University of Catalonia (Spain) and RWTH Aachen University (Germany), ranked 20th and 21st respectively. The top Finnish organization is Aalto University in 33rd place.

The top company is Nippon Telegraph and Telephone (NTT) in 42nd place. Nokia (45th) and Motorola (47th) also have more than 55 documents and are listed in Figure 58.

The most active organizations are presented in figures by the organizations' publication numbers. The most active organizations in Figure 56 have 140-455 publications, followed by organizations with 100-135 publications in Figure 57. Figure 58 shows other organizations with at least 55 publications in order to also show some companies.

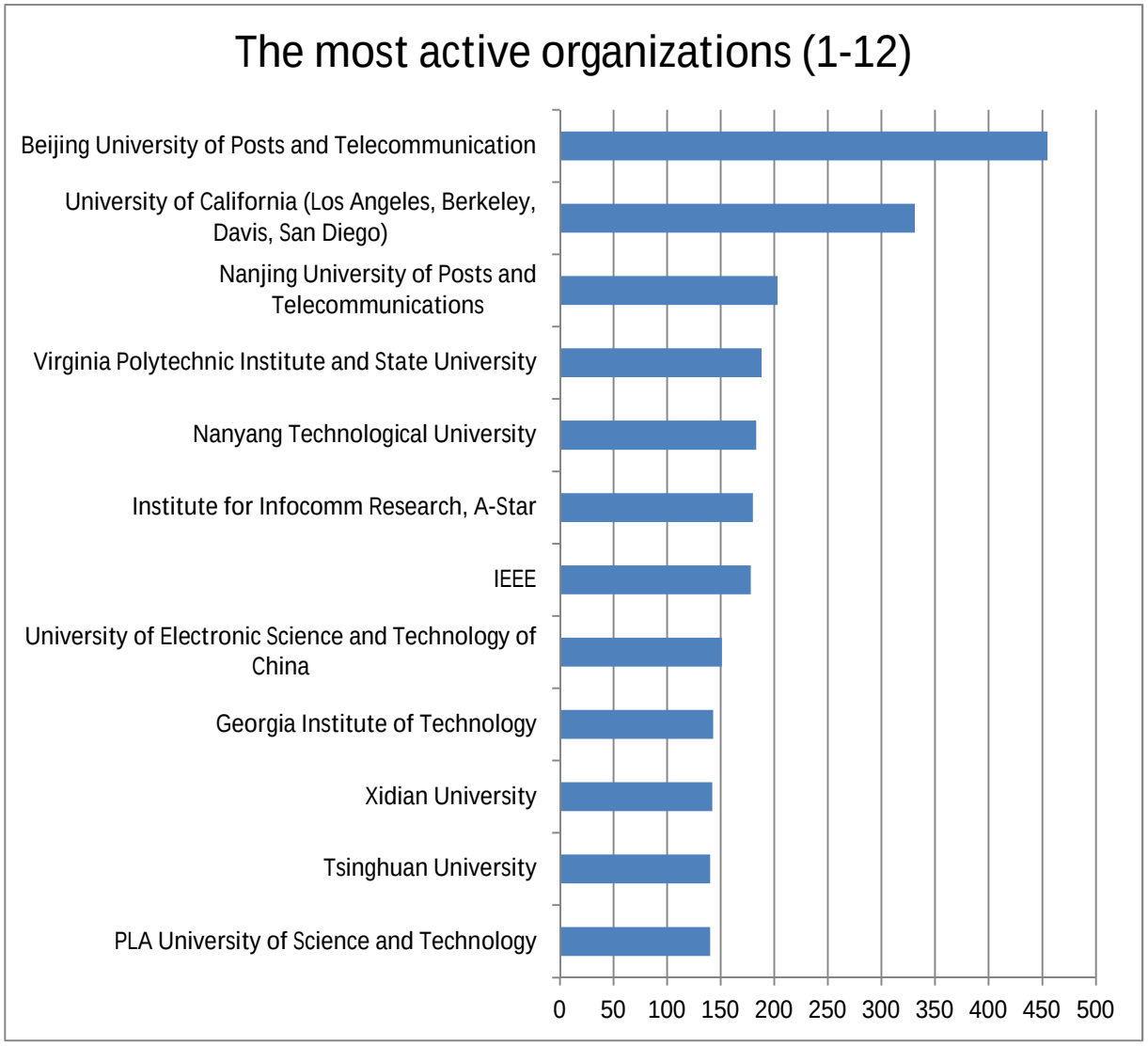


Figure 56 Most active organizations (top 12) with 140-455 published documents (1970-8/2012)

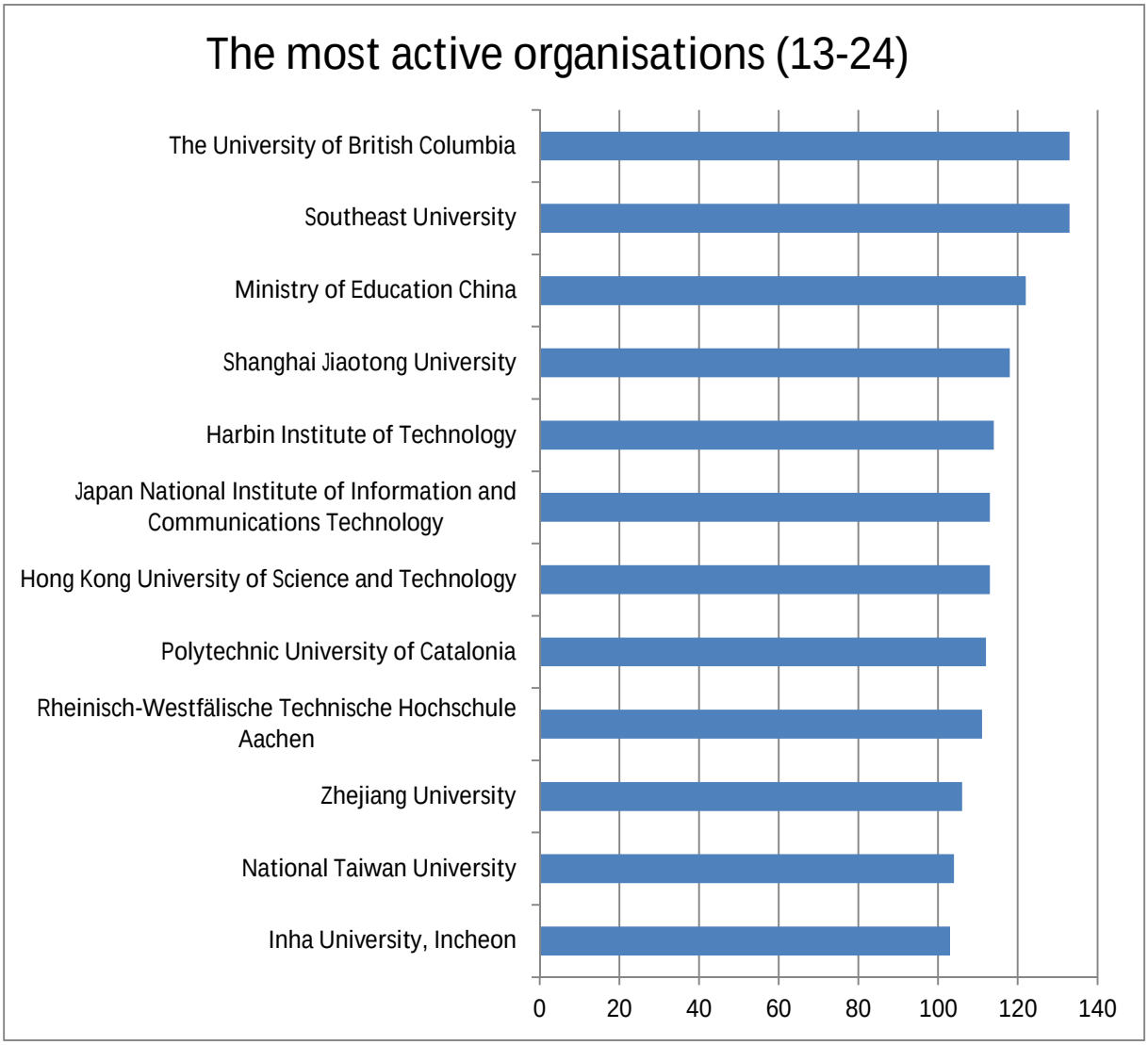


Figure 57 Active organizations with 100-135 published documents (1970-8/2012)

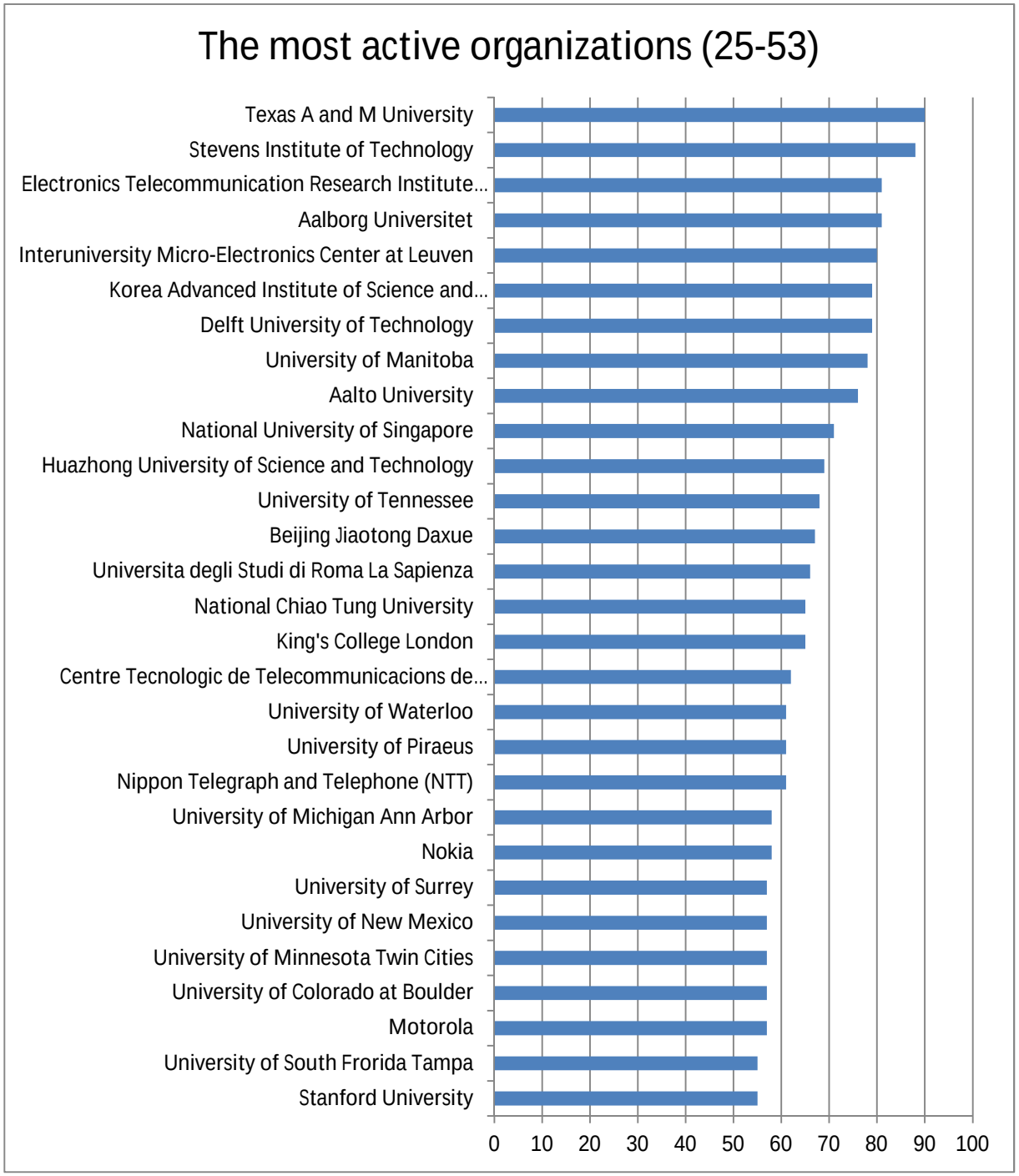


Figure 58 Active organizations with 55-90 published documents (1970-8/2012)

3.3 Year Trends

The number of publications starts to increase at the end of the 1990s (Figure 59). Before that there were only a few publications (fewer than 20 documents). In previous years, from 2005, the number of documents dealing with spectrum and resource management increased strongly (Figure 60).

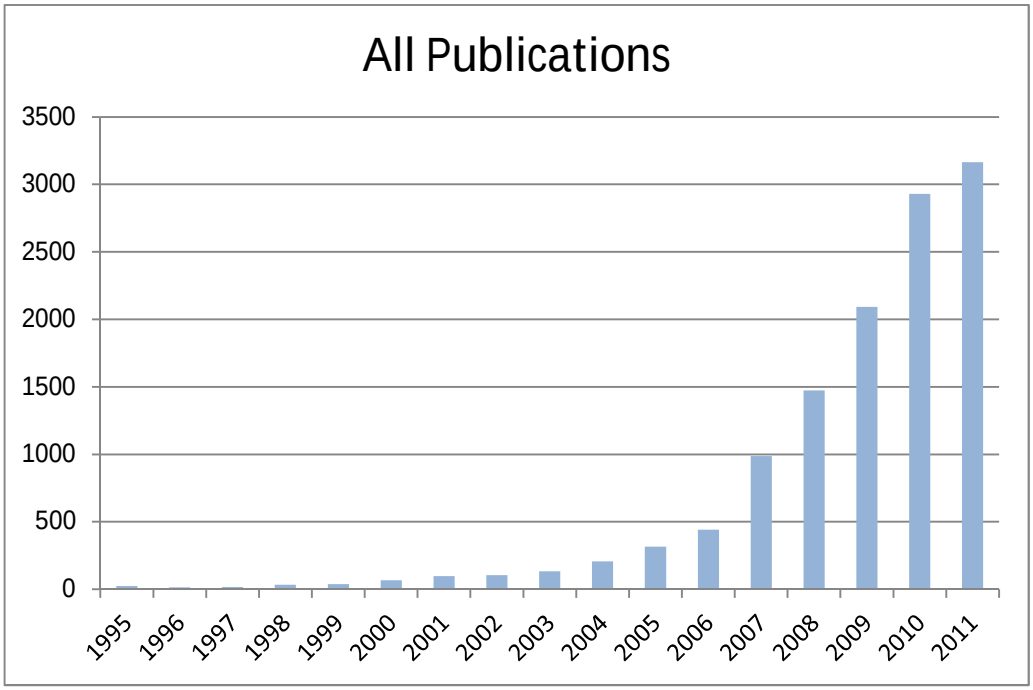


Figure 59 Cognitive radio publications in 1995-2011

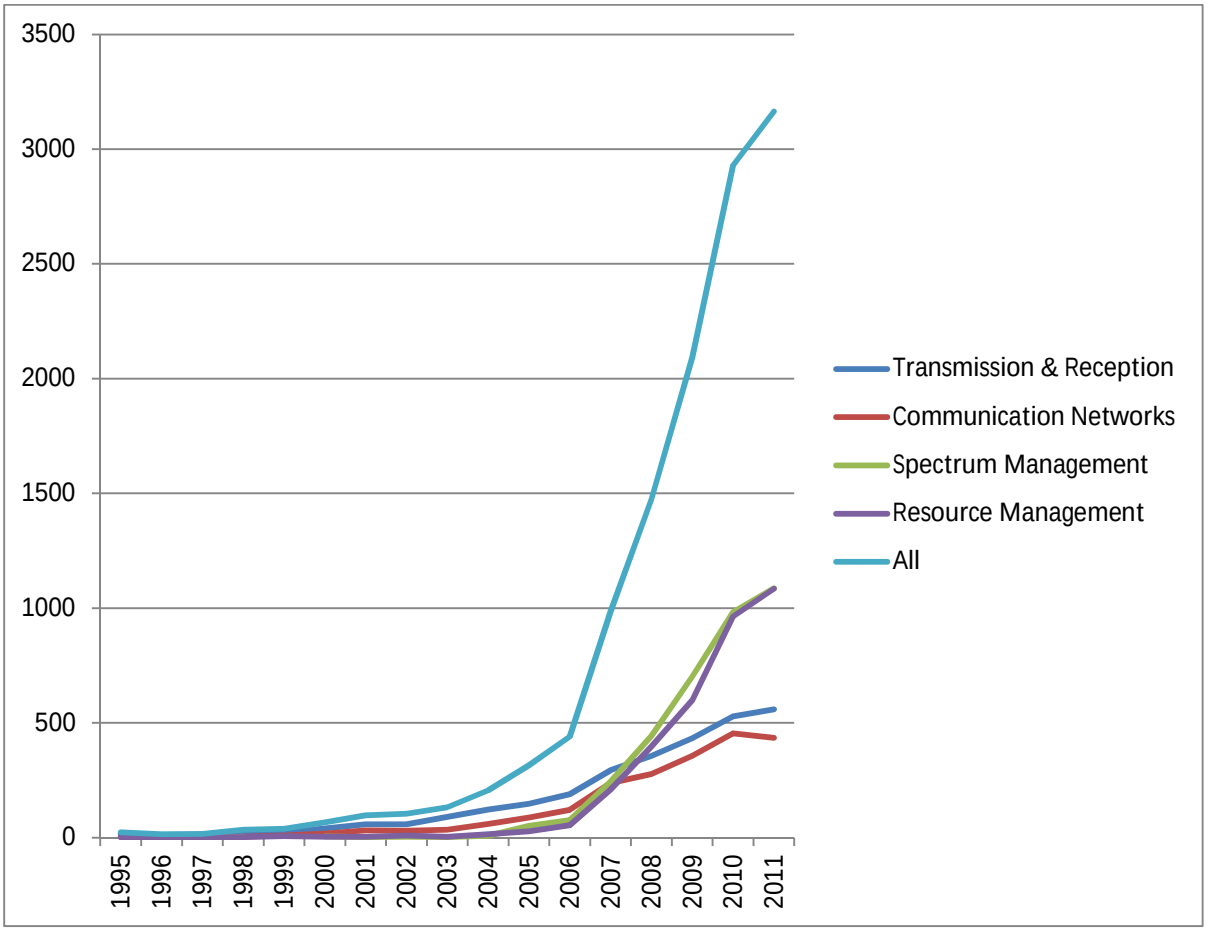


Figure 60 Year trends of Cognitive radio application areas in 1995-2011

4 Analysing Method

4.1 Search Terms

4.1.1 World Patent Index (WPINDEX) Patent Database

The patent search looked for completely new innovations without earlier priority patent publications. This means that enhancement patent applications of earlier patents are not included in the final result set (**3221 documents**).

- Cognitive radio (708 documents)
- Software defined radio (448 documents)
- Smart / Intelligent / Ubiquitous radio (199 documents)
- Adaptive radio (203 documents)
- Spectrum sensing (265 documents)
- Cognitive network & Spectrum / Frequency / Radio / WiFi / Wireless (259 documents)
- Cognitive & Database (7 documents)
- Cognitive & Energy / Spectrum / Frequency efficiency (18 documents)
- Cognitive & Implementation technology (0 documents)
- Cognitive & Spectrum sensing (94 documents)
- Cognitive & LTE (26 documents)
- Cognitive & WiFi / Femtocell / WLAN (94 documents)
- Cognitive & Receiver & Transmitter (54 documents)
- Cognitive & Antenna (6 documents)
- Cognitive & Smart antenna (2 documents)
- Cognitive & Multicast / Multihop / Channel-hop / Cocast & Spectrum / Frequency / Radio / WiFi / Wireless (11 documents)
- White space & Spectrum / Frequency (137 documents)
- White space & LTE (17 documents)
- White space & WiFi / Femtocell / WLAN (74 documents)
- White space & Spectrum sensing (9 documents)
- Dynamic spectrum sharing / management (60 documents)
- Shared access license & Cognitive / Spectrum / Frequency / Radio (0 documents)
- Geo-location database (25 documents)
- Terminal & Base station & Database (1185 documents)

4.1.2 Scopus Scientific Publications Database

The result set to visualization was **13,966 documents**.

- Cognitive radio (9123 documents)
- Software defined radio (2722 documents)
- Smart radio (52 documents)
- Adaptive radio (748 documents)
- Cognitive network) & spectrum / frequency / radio / white space / wireless (5864 documents)
- Cognitive database (289 documents)
- Cognitive & energy / frequency / spectrum efficiency (283 documents)

- Cognitive implementation technology (8 documents)
- Cognitive spectrum sensing (2268 documents)
- Cognitive & LTE (124 documents)
- Cognitive & WiFi / Femtocell / WLAN (523 documents)
- Cognitive & Receiver & Transmitter (521 documents)
- Cognitive antenna (386 documents)
- Cognitive & Smart antenna (38 documents)
- White space & Spectrum / Frequency (351 documents)
- White space & LTE (15 documents)
- White space & WiFi / Femtocell / WLAN (36 documents)
- White space & Spectrum sensing (29 documents)
- Dynamic spectrum sharing / management (543 documents)
- Shared access license & spectrum / frequency / cognitive / radio (12 documents)
- Geo-location database (35 documents)
- Terminal & Base station & Database (26 documents)
- Cognitive & Multicast / Multihop / Channel hop / Cocast & Spectrum / Frequency / Radio / White space / Wireless (248 documents)

4.2 Visualization

The used visualization tools gather similar publications into clusters. The similarity is decided by how many similar terms are used in the documents. The closer two clusters or documents are the more similar their contents.

4.2.1 STN Anavist

Patent analyses are performed with an STN Anavist text mining and visualization tool. A patent landscape presents a general view of the main players and geographic locations, contents of publications, and trends. Similar patent publications are gathered into clusters. The similarity is decided by how many similar terms are used in the documents. The closer two clusters or documents are the more similar their contents. Colours indicate the size of the cluster, the redder the colour, the bigger the cluster (and the more documents are included in the cluster).

Patenting trends are analysed by the priority application years – not document years, as the priority year is closer to the time when the invention was made and the research was on the way.

The priority application year means the year when the first application from the invention was filed in any office. In novelty examinations, applications filed in other countries, within one year of the date of this first filing, are regarded as being made on this same day.

In the year trend figures, the columns for the last 1.5 years (in this report until the end of April 2011) are incomplete since patent applications filed during the previous 18 months are not public and therefore cannot be included in the report. There is also a few weeks' delay due to value-added indexing before the publications enter the database.

In the sections (Application Areas, Key Organizations, Year Trends, Patenting Countries) of the patent analyses chapters only the bars connected to the matter

concerned are shown. The coloured part of the bar denotes the proportion of the application area's documents in relation to all documents (the grey part of the bar). Bars are ordered by this highlighted document count.

The documents that were irrelevant to this study were removed, leaving 3046 documents for detailed analysis.

4.2.2 BioWisdom's Omniviz

The analyses of scientific publications were done with a BioWisdom's OmniViz text mining and visualization tool. The tool clusters publications with similar terms. The closer two clusters or documents are, the more similar their contents.

The documents that were irrelevant to this study were removed, leaving 13,400 documents for detailed analysis.

5 Patent Glossary

PCT:
WO (PCT, the Patent Cooperation Treaty) is an international patent filing system concluded in 1970. It provides a unified procedure for filing patent applications to protect inventions in each of its 146 contracting states. A patent application filed under the PCT is called an international application, or PCT application. It does not provide a 'World patent' but makes it easier and cheaper to file for protection for a wider geographical area.
A PCT application must be followed up with the step of entering national or regional phases in order to proceed towards the grant of one or more patents. The PCT procedure essentially leads to a standard national or regional patent application, which may be granted or rejected according to applicable law in each jurisdiction in which a patent is desired.

EP patent:
A granted patent by the European Patent Office. The patent protection may be obtained at the same time for several European countries (38 European countries are members of the European Patent Convention).
The European Patent Organisation is an intergovernmental organization that was set up on 7 October 1977 on the basis of the European Patent Convention (EPC) signed in Munich in 1973. It has two bodies, the European Patent Office and the Administrative Council, which supervises the Office's activities.

Key Organizations / Assignees:
Organization(s) that own(s) the protected invention (patent).

Priority Application Years / Dates:
Priority application year means the year when the first application from the invention was filed in any office. In novelty examinations, applications filed in other countries within one year of the date of the first filing are regarded as having been made on this same day.

Patent Countries:
Countries in which patent applications have been filed for the invention. Indicates where the company intends to profit from the invention by using it there in production, by importing goods prepared using the invention, or by wanting to harass the competitors that are active in this country.

Appendix 1: Information Sources

WPINDEX patent database

WPINDEX (Derwent World Patents Index) is Thomson Reuter's patent database, which covers all technology areas. It contains over 21.7 million records covering 47 patent offices from 1963 onwards. The whole patent family is in one record. Value added data – new titles and abstracts written by real people to describe the invention in detail with normal technological terms.

Scopus Scientific publications database

SciVerse Scopus is an abstract and citation database of peer-reviewed literature and quality web sources. It contains 47 million records (70 % with abstracts) and over 19,500 titles from 5,000 publishers worldwide. It also includes over 4.9 million conference papers. The database is published by Elsevier.