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Telecommunications Patent Landscape

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IEEE commissioned 1790 Analytics LLC, an intellectual property consulting firm, to analyze the telecommunications patent landscape to gain an understanding of the major players, trends, and how IEEE-published information influences patents within this industry.

Inside this Report

Based on an analysis of patents granted by the USPTO, this report will outline:

- How Telecom patents are classified across technology areas
- How technology in the Telecom industry has changed over time
- The most innovative companies in Telecom and their patenting activity
- How Telecom patents score in terms of quality and strength
- How scientific publications have impacted these leading organizations and the industry at large

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Introduction

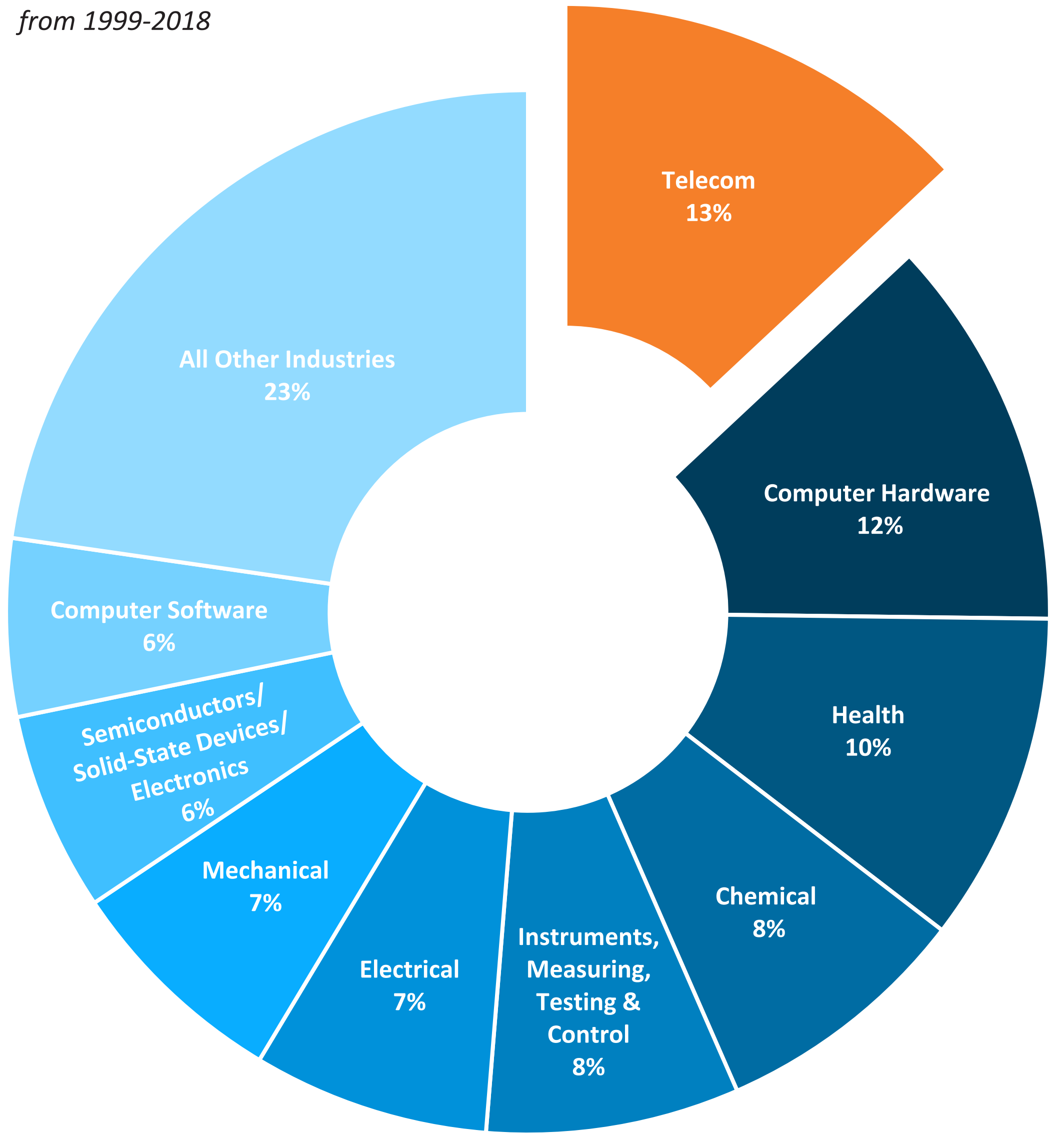
Patents and the Measure of Innovation

The Telecommunications (Telecom) industry is highly innovative and has continuously evolved from the invention of the telegraph in 1837, to the telephone in 1876, radio and television broadcasts in the early 1900's, and now the development of wireless networks and the Internet of Things. In the next few years, 5G networks will come online with download speeds that are expected to revolutionize the Telecom industry again.[1]

Global revenues in Telecom services are estimated at $1.3 trillion, with roughly $325 billion coming from the US, $307 billion from Europe, and almost $450 billion from Asia.[2]

Innovation in the Telecom industry can be analyzed in terms of patents granted in this area, which this report will explore.

Figure 1: *US Patents Issued from 1999-2018*



The Evolving Patent System

13% of US patents issued in the past 20 years are related to Telecom.

This is the largest percentage of patents from any industry, followed by Computer Hardware (12%) and Health (10%).

Industry Shift

This is a big change from a generation ago, when the patent system was dominated by Pharmaceuticals, Chemicals, and Mechanical patents. Those three sectors combined now make up just 25% of the current patent system.

Because Telecom is such an immense and innovative portion of this system, looking at patent activity can show us how the industry has changed and where it might be headed.

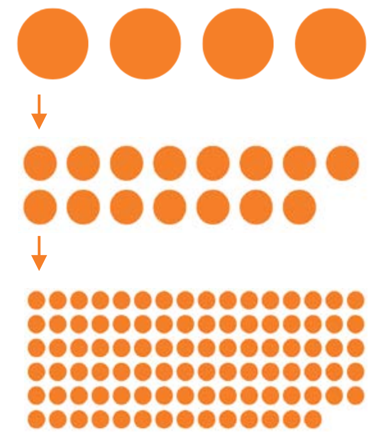
Patent Taxonomy and Overall Patent Activity

This analysis divides Telecom patents into a taxonomy of technology categories. In this taxonomy, patents are classified into 4 broad categories, made up of 15 subcategories, further broken down into 94 fine categories[3].

4 Broad Categories
Ex. Telecom Networks

15 Subcategories
Ex. Coding/Decoding

94 Fine Categories
Ex. Analog/digital conversion



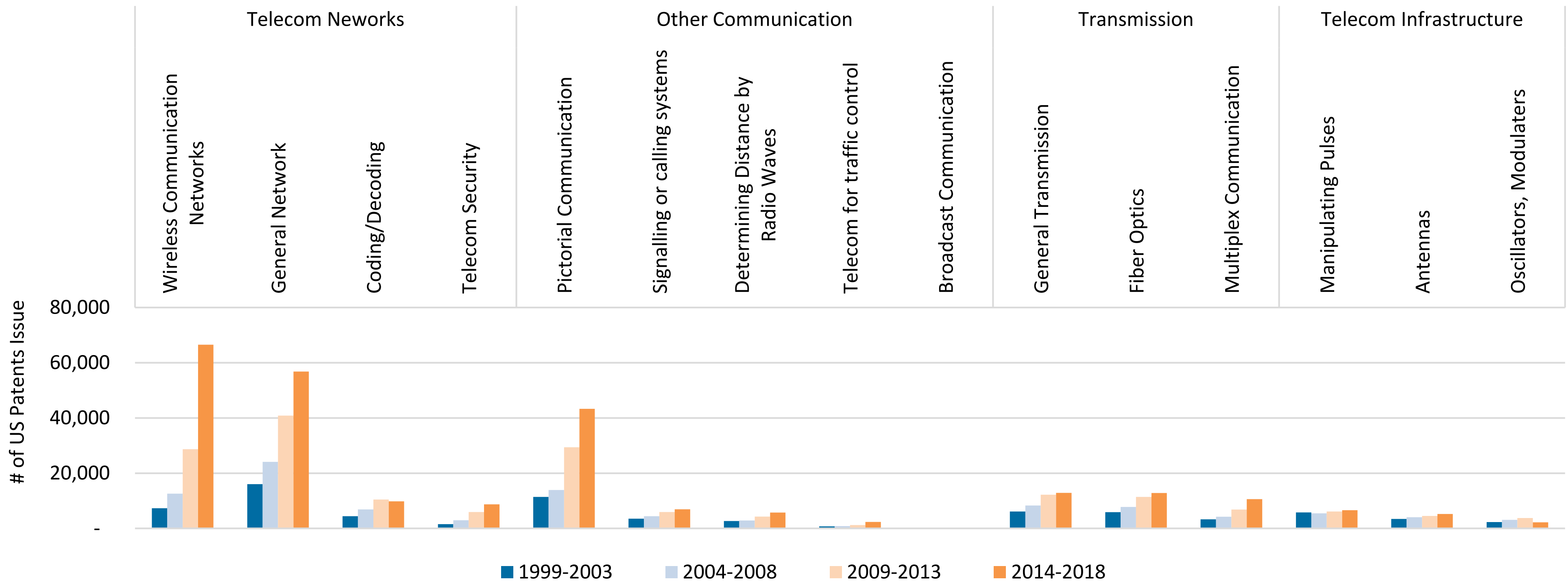
Greater details of the taxonomy can be found in Appendix A.

Wireless Networking leads in both patent volume and growth

Figure 2 shows patent activity over time at the 15-subcategory level of the taxonomy. This graphic reveals that General Networking and Wireless Networking consistently lead in patent volume. Wireless Networking has seen rapid growth over the past 20 years (average of 111% per five-year period) and surpassed General Networking in patent volume for the first time in 2014-2018.

Telecom Security is a relatively small area, but is also growing rapidly (average of 80% per period). Meanwhile, older areas of infrastructure such as modulators (some of which are still analog) are shrinking.

Figure 2: *US Patent Activity by Subcategory and Time Period*



The Impact of Referencing Science

In addition to patent counts, prior art references on patents were also analyzed. When inventors file a patent, they must reference what came earlier in order to show the new invention is novel, useful, and non-obvious.

References to earlier documents show how the new invention either builds upon, or improves upon, what came earlier.

Breakthroughs and future innovation

Many of these prior art references are to earlier patents and may represent only incremental improvements on what came before. In other cases, scientific breakthroughs documented in published research lead to new and unique innovations.

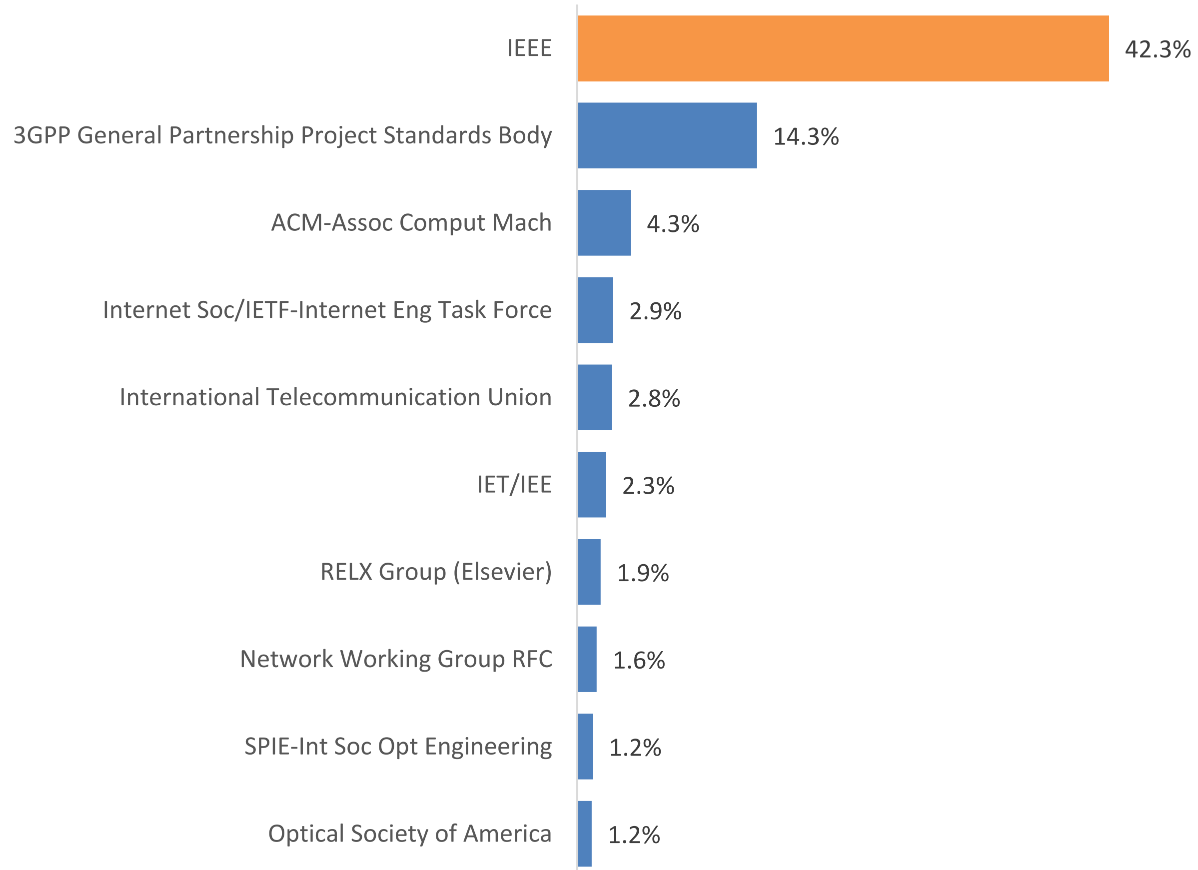
Prior art references from patents to scientific documents (articles, conference proceedings, standards, etc.) reflect the influence of these breakthroughs on subsequent innovations. References from Telecom patents to scientific publications can be examined, starting with those publications associated with IEEE.

Evidence supports...

Patents with links to scientific articles are likely to contain new leading-edge ideas.

Patents that only reference earlier patents are likely to be incremental improvements on earlier patented technologies.[4]

Figure 3: Top Publishers Supplying Science Base of US Telecom Patents (1999-2018)



IEEE is cited more often than any other publisher

42% of references from Telecom patents were to scientific documents from IEEE.

This is more than the next 22 publishers combined, and three times as many as the next publisher in the list (3GPP).

IEEE science base across Telecom patents continues to increase

IEEE References

These charts reveal that the IEEE science base for all Telecom patents has increased over the last 20 years, with some subcategories being particularly dependent on IEEE scientific papers.

IEEE References Per Patent

Multiplex Communication and Coding/Decoding patents reference over two IEEE publications on average in recent years. In Telecom overall, there is approximately one reference per patent to IEEE.

Appendix A provides a more granular view of the data in **Figure 4**, this time at the level of the 94 fine technology categories. This reveals some of the specific areas that are particularly dependent on IEEE science.
For example, in the Fiber Optic Waveguide area, patents reference over five IEEE papers each on average. These patents are using new scientific breakthroughs to expand the capacity and effectiveness of existing telecommunication networks, which is more economical than adding hubs to these networks.

Figure 4: References to IEEE Journals, Conferences, and Standards by Time Period

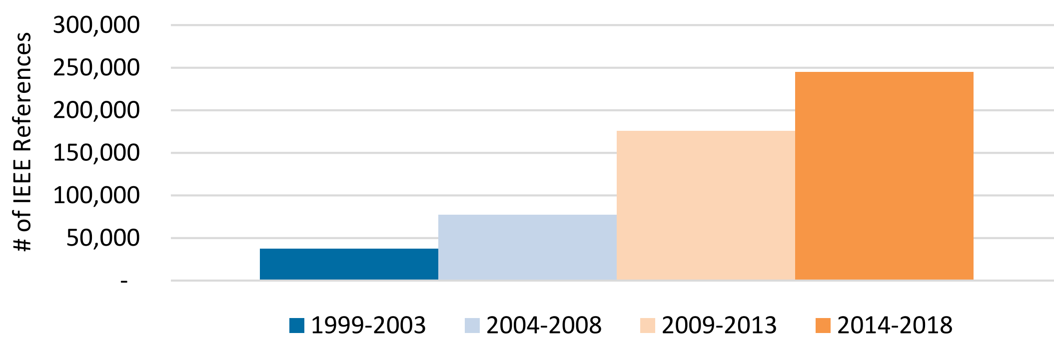
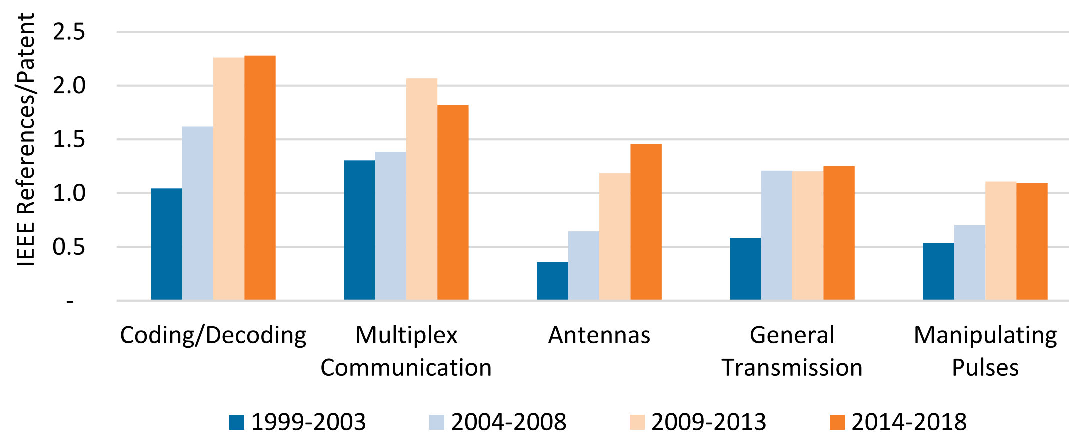
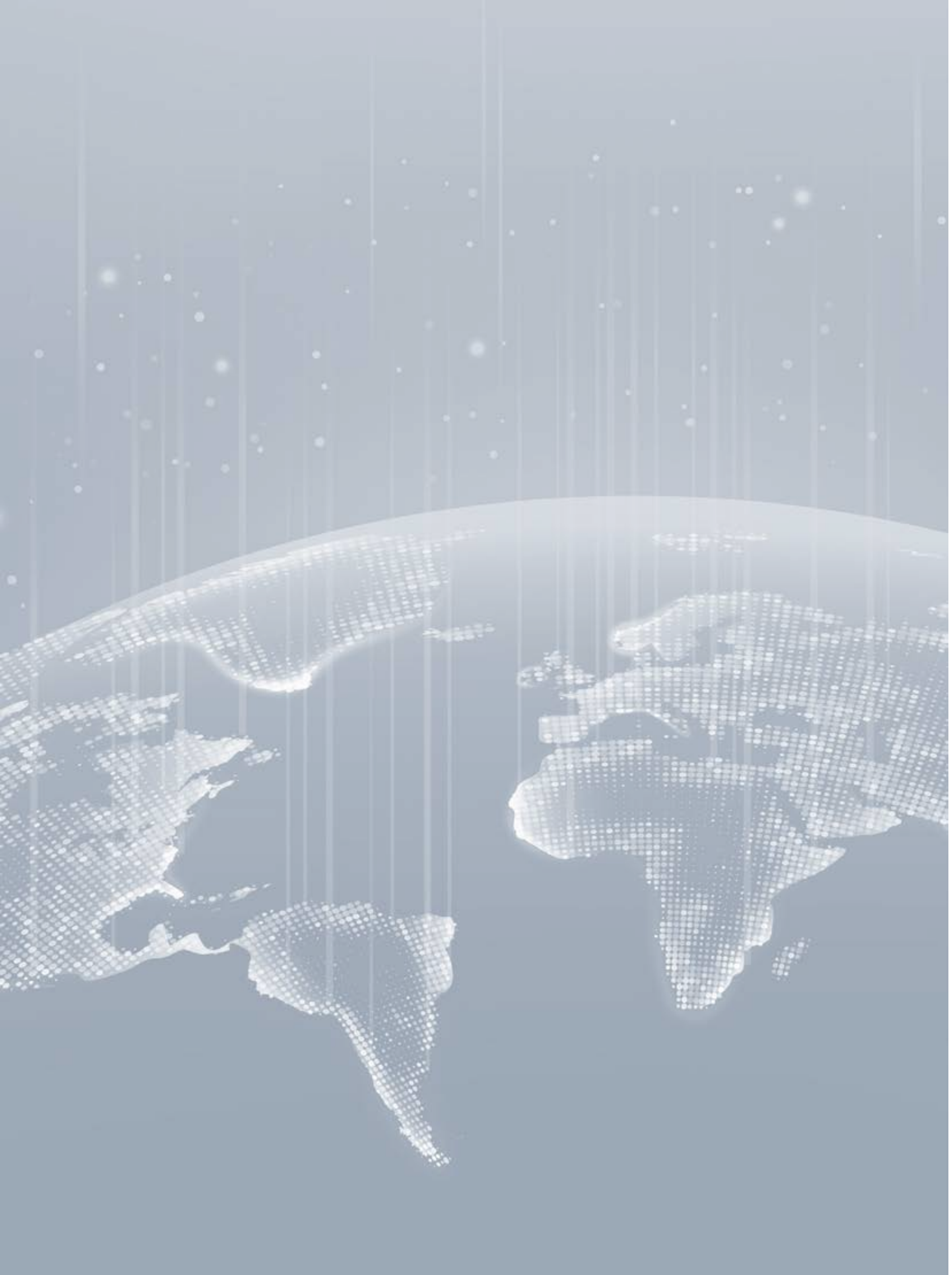


Figure 5: Subcategories with >1 Average IEEE References Per Patent in 2014-2018





Organizations Creating the Most Patented Innovations in Telecom

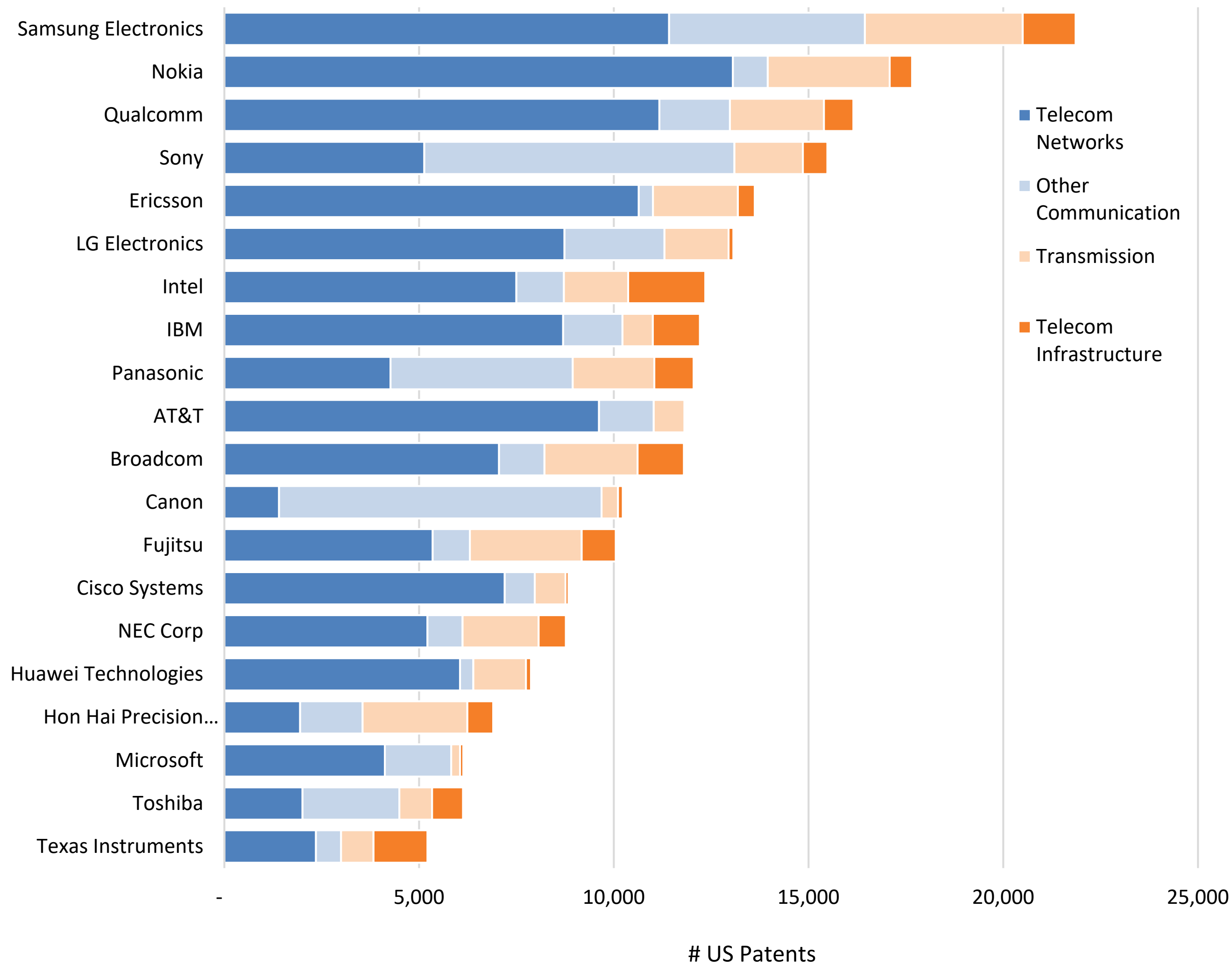
This section looks at the organizations with the most patented innovations in the Telecom industry and identifies trends among the top patent assignees.

A top-down look at the companies leading the way

Figure 6 shows Samsung has the most patents overall, followed by Nokia and Qualcomm.

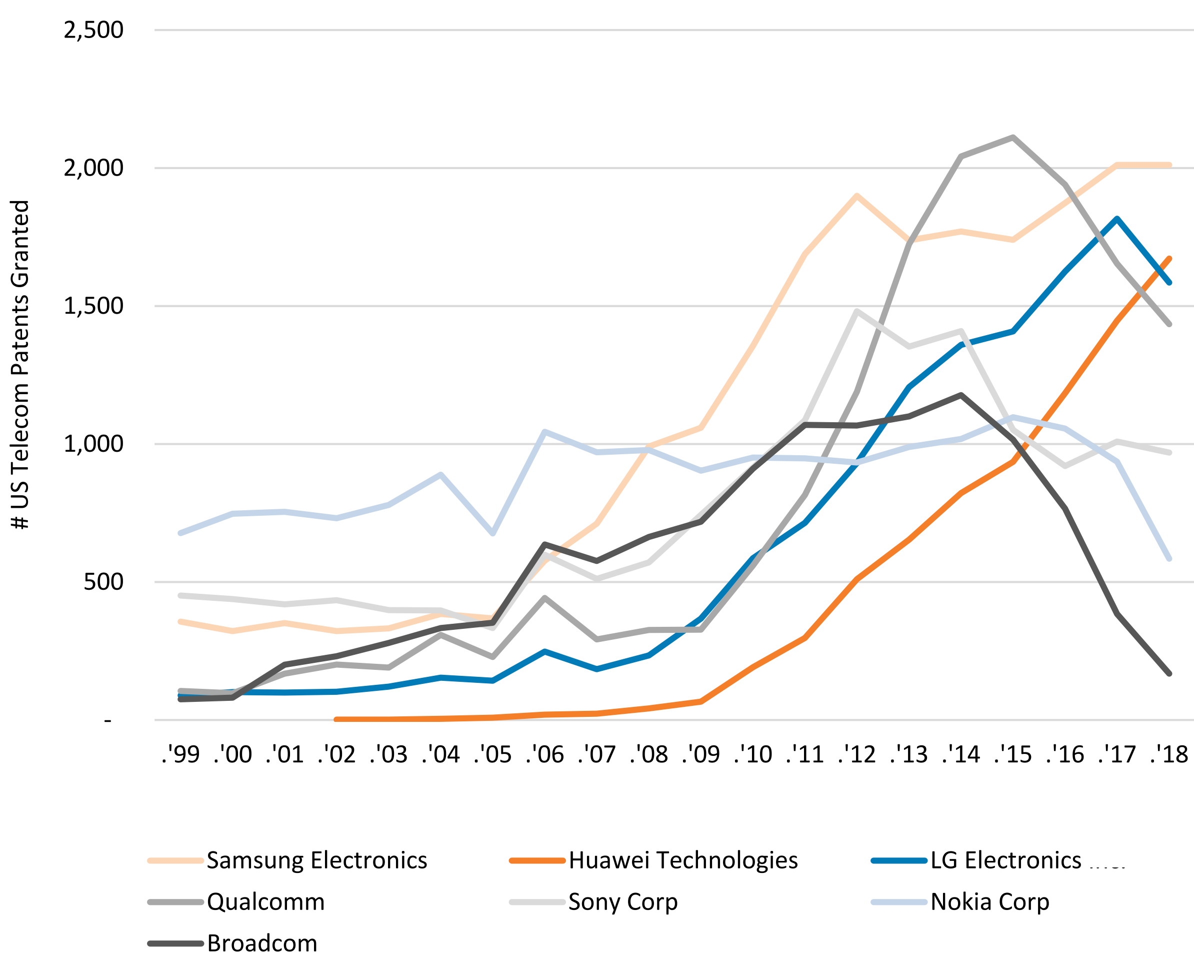
For most of the companies, the bulk of their Telecom patenting is related to Telecom Networks.

Figure 6: *Organizations Creating the Most Patented Innovations in Telecom (1999-2018)*



Huawei climbs into second place while LG Electronics' growth trend continues

Figure 7: *Telecom Patenting Activity Among Top Assignees By Year (1999-2018)*



Company Highlights:

Huawei Technologies

Huawei had very few patents prior to 2009 but has been trending up sharply since then. In 2018, Huawei had the second most Telecom patents behind only Samsung.

Most firms had fewer Telecom patents issued in 2018 than in 2017, but Huawei patents increased.

If current trends continue, Huawei will be the top patenting Telecom firm in 2020.

LG Electronics

LG Electronics has a steady rise in patenting mirroring Huawei, but with even more patent activity. In 2018, however, it had a large drop from 2017, opening the question as to whether this drop is temporary or the start of a broader downward trend for LG.

Nokia

While Nokia is one of the leading patent assignees in Telecom (as seen in Figure 6) and was the top Telecom patent assignee in 1999, its patenting activity has flattened, and has been trending down since 2015.

Heat Map of Telecom Patents by Country/Region

Figure 8: *US Telecommunication Patents.*
# of US Patents by Country/Region of First Inventor and Issue Year (2009-2018)

Country/Region	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
United States	12,333	13,860	15,612	17,713	19,601	22,128	22,530	22,552	23,946	23,128	193,403
Japan	5,712	6,485	7,434	8,489	8,479	8,353	7,710	7,177	7,354	6,793	73,986
South Korea	2,259	2,728	3,352	3,807	4,243	4,439	4,476	4,996	5,435	5,017	40,752
China	288	492	724	1,193	1,510	2,257	2,380	3,017	3,763	3,972	19,596
Taiwan	1,105	1,243	1,468	1,857	1,662	1,677	1,547	1,572	1,564	1,401	15,096
Canada	705	839	1,018	1,277	1,564	1,628	1,514	1,383	1,386	1,267	12,581
Germany	793	904	954	1,068	1,189	1,400	1,305	1,364	1,407	1,433	11,817
United Kingdom	507	572	662	823	917	1,101	1,076	1,043	1,055	1,008	8,764
France	439	559	618	779	831	890	831	840	907	815	7,509
Sweden	212	284	446	575	661	929	917	1,021	1,078	988	7,111
Israel	341	406	424	560	653	733	789	794	944	984	6,628
India	132	204	233	305	474	641	772	942	1,050	1,120	5,873
Finland	361	399	411	413	500	543	495	562	523	469	4,676
Netherlands	157	174	226	236	306	312	267	317	279	293	2,567
Italy	120	134	178	209	244	264	227	217	244	209	2,046
Australia	134	181	181	141	149	190	178	155	192	180	1,681
Switzerland	91	130	122	121	141	167	175	200	249	224	1,620
Austria	76	92	77	90	76	132	117	119	143	132	1,054
Singapore	81	85	80	109	92	119	122	117	133	108	1,046
111 Other Countries	361	463	554	737	828	999	1,014	1,188	1,339	1,305	8,788

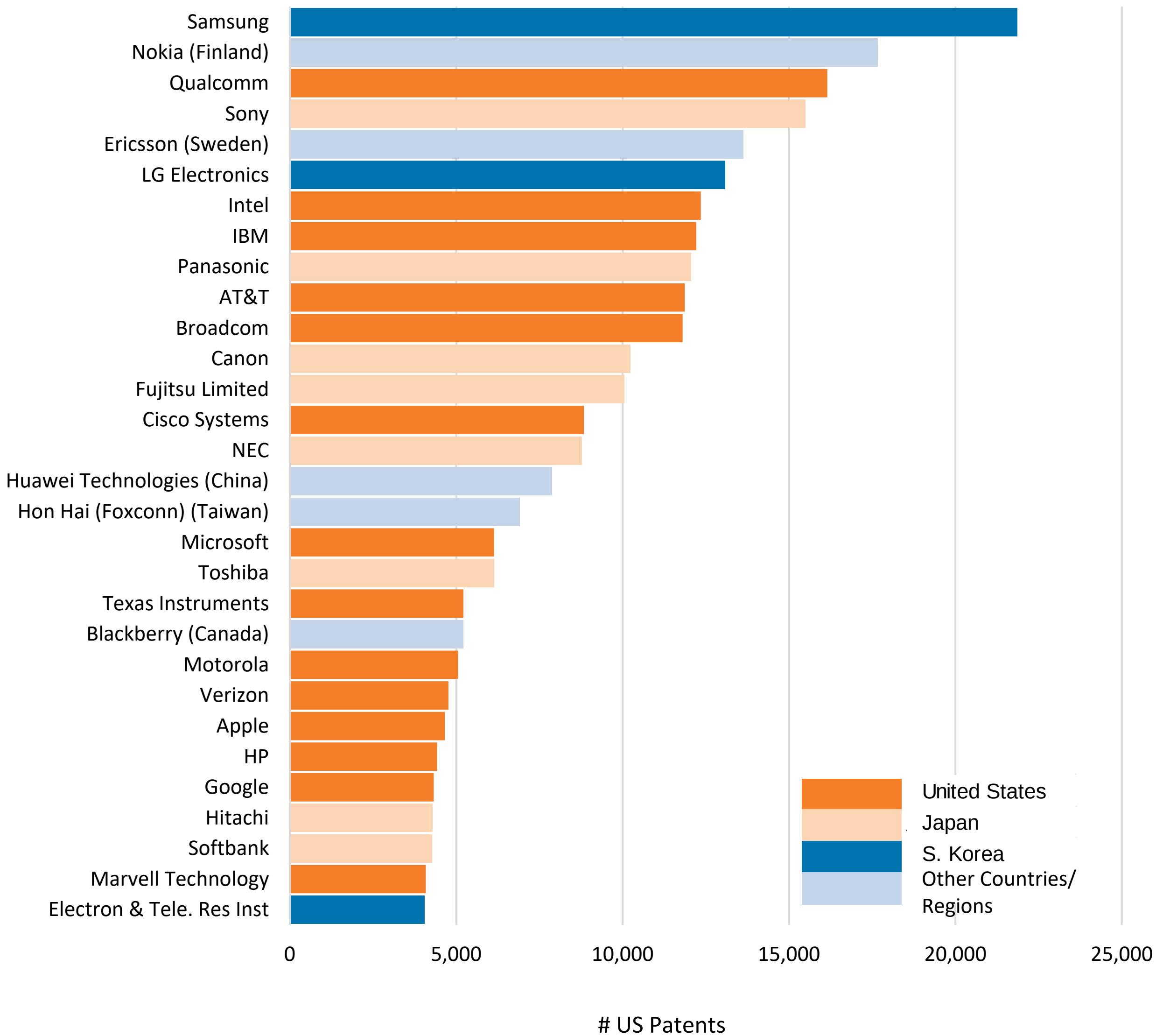
Heatmap Key: Hot Cold

Over the past 10 years the US has invented 45% of all Telecom patents, followed by Japan (17%) and South Korea (10%).

Again, 2018 was a down year for Telecom patenting, with only five countries showing an increase in patenting over 2017: China, Germany, Israel, India, and Netherlands.

Compared to 10 years ago, China has moved up 8 places in the top country rankings (from 12th to 4th), growing by over 13 times.

Figure 9: *Top 30 Assignees by Home Country/Region*



How can the US can have such a dominant lead when four of the top five Telecom firms are based outside of the US?

Figure 9 reveals:

The US has 14 of the top 30 Telecom firms in terms of patent counts—more firms in the top 30 than any other country/region.

South Korea has the top firm (Samsung) and the sixth ranked firm (LG), but only has 3 of the top 30 firms overall.

Huawei is the only top patenting firm based in **China**, which shows it was a major contributor to China's rapid patent growth shown in **Figure 8.**

Conversely, Nokia is the only Finnish firm in the top 30, but because its patenting activity has been trending down in recent years, **Finland** is ranked fairly low in the **Figure 8** heat map.

Patent Quality Scoring

When assessing technologies and companies within an industry, it is necessary to go beyond just counting patents, as only a small percentage of patents are tremendously valuable and many have little to no value.

This section discusses four quality metrics used to weight patents across Telecom subcategories and companies to demonstrate quality.

The Pipeline Strength Formula

The Pipeline Strength metric of quality is derived by combining three different metrics that reflect the growth, impact, and generality of the patent portfolio. When evaluating the growth, impact, and generality metrics, scores over 1.0 indicate a more than expected increase.

Pipeline Strength = **Pipeline Growth (normalized)*** + **Pipeline Generality (normalized)*** + **Pipeline Impact (normalized)***

*Normalizing each metric prior to summing allows each to play an equal part in the overall Pipeline Strength metric. The raw and normalized data can be found in Appendix B.

Pipeline Growth increased in the past five years, but at a slower rate

Patent quality was scored in two five-year periods. Telecom patenting has grown rapidly in the last five years (1.46 growth index in 2014-2018). However, it has slowed compared to the previous five-year period (2009-2013) by -14%.

Highs

Wireless Communication Networks continues to see the highest growth (2.3 growth index).

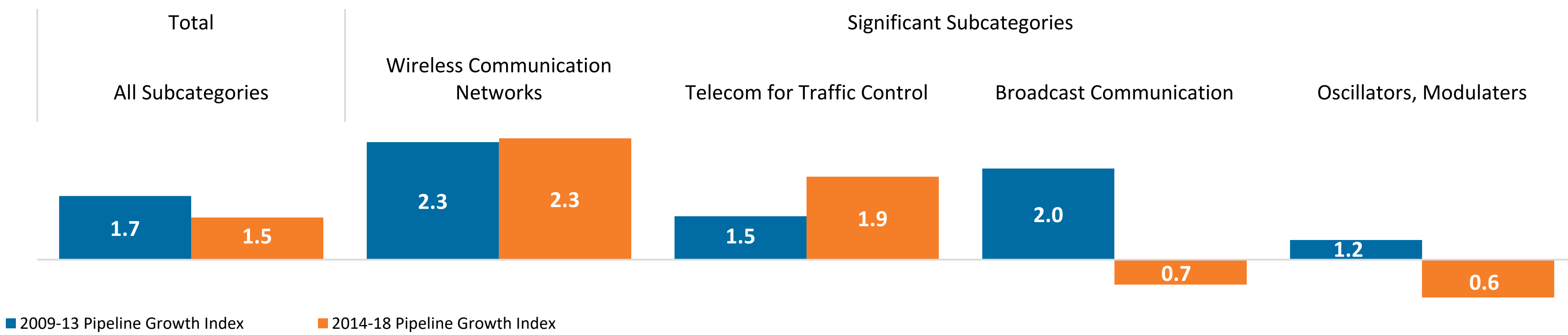
Telecom for Traffic Control saw the largest growth improvement over the previous five-year period (29%).

Lows

Broadcast Communication saw the largest growth decrease over the previous five-year period (-63% decrease), going from the third highest growth to 1 of only 3 negative growth subcategories.

Oscillators, Modulators saw the worst negative growth in the last five years (0.6 growth index).

Figure 10: *US Patent Pipeline Growth Index for Telecom Subcategories*



Increase in Pipeline Generality shows applicability of Telecom patents across industries

Pipeline Generality measures the breadth of applicability of patents. It is measured based on the distribution of forward citations across patent classifications and has an expected value of 1.0. Values above this are associated with greater than expected generality.

Pipeline Generality has grown in the last five years (1.1 growth index); however, it has only increased compared to the previous five-year period by 1%.

Multiple versus single classifications

Patents that are cited as prior art by other patents from multiple classifications have higher generality.

Highs

Fiber Optics and Telecom Security saw the highest generalities (1.4), with Telecom Security also having the largest increase over the previous five-year period (20%).

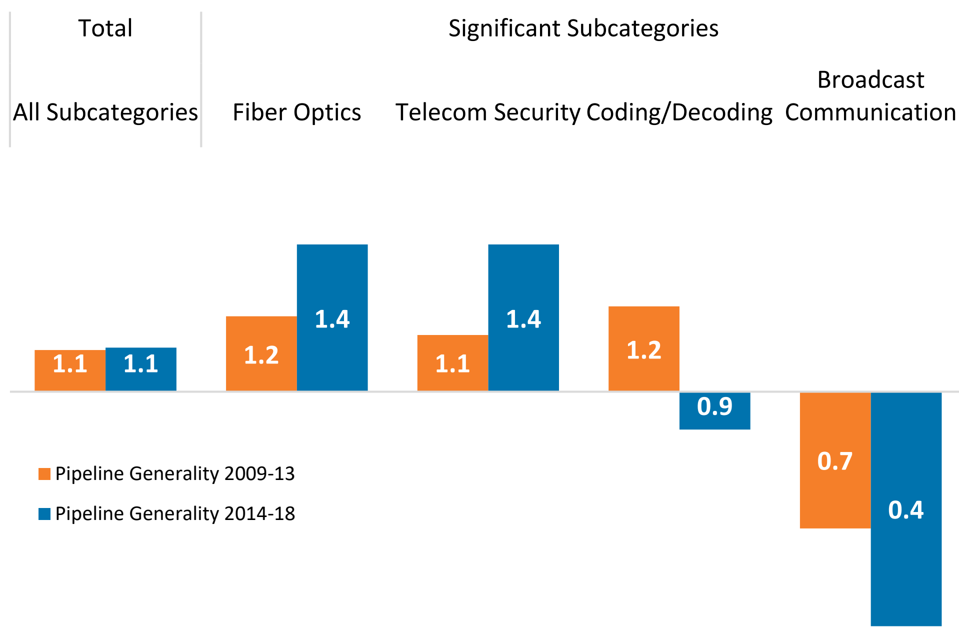
- Fiber Optics scores well because this technology is used in the aerospace and automotive industries.
- Telecom Security scores well because methods to secure telephone networks can be applied to computer networks, airplane avionics, and power grids.

Lows

Coding/Decoding and Broadcast Communication were the only subcategories with generalities less than 1, with Broadcast Communication also having the largest generality decrease over the previous five-year period (-36%).

- Broadcast Communication not scoring well does not mean that the patents have no value, it only suggests that these patents do not have many applications outside of Broadcasting.

Figure 11: *US Patent Pipeline Generality for Telecom Subcategories*

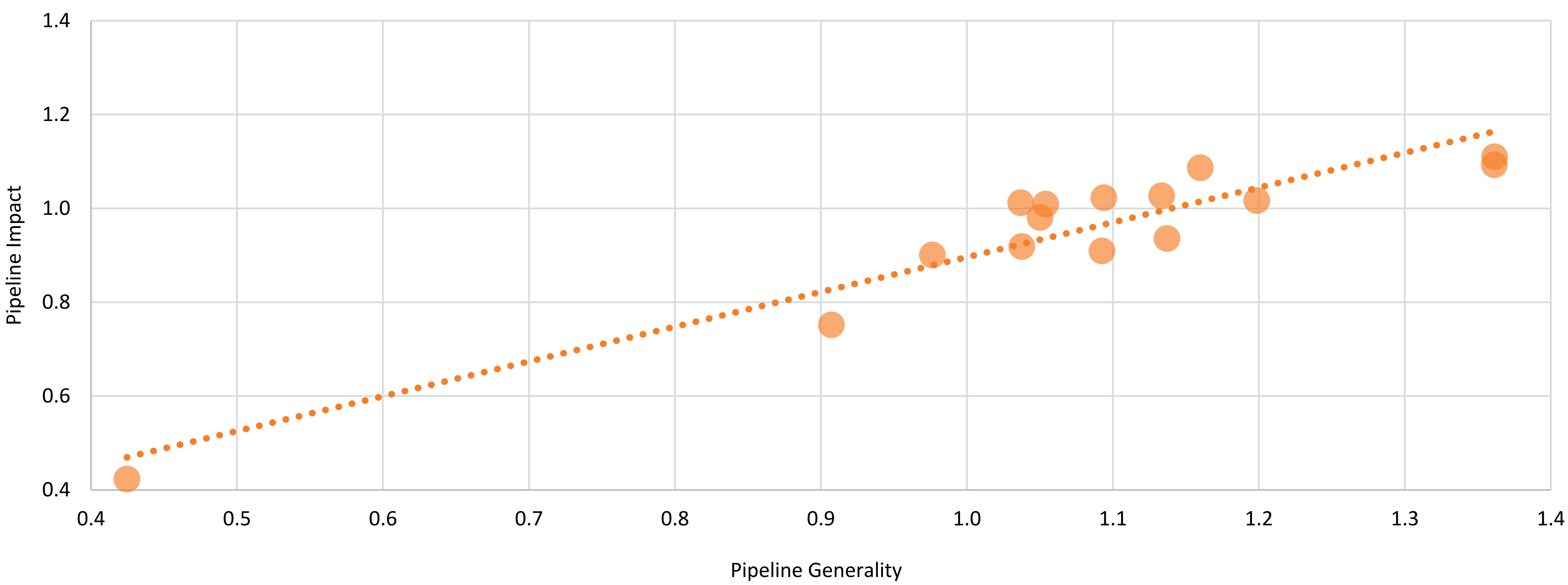


Pipeline Impact is strongly related to Pipeline Generality

Pipeline Impact is a forward citation measure that measures the impact of patents on subsequent innovations. It again has an expected value of 1.0, with values above this showing a greater impact than expected. Most of the values are close to 1.0, but 47% of subcategories (7 out of 15) saw scores below 1.0.

A clear trend emerges when we compare Impact to Generality in the below scatterplot. The dots show all Telecom subcategories grouped tightly to the trendline, visualizing that subcategories with high Generality scores also have high Impact scores. This means the varied applicability of a patent is a strong indicator of having a higher impact.

Figure 12: *All Telecom Subcategories showing relationship between Pipeline Impact vs. Pipeline Generality*



Wireless Communication and General Networks lead in Number of US Patents and Pipeline Strength

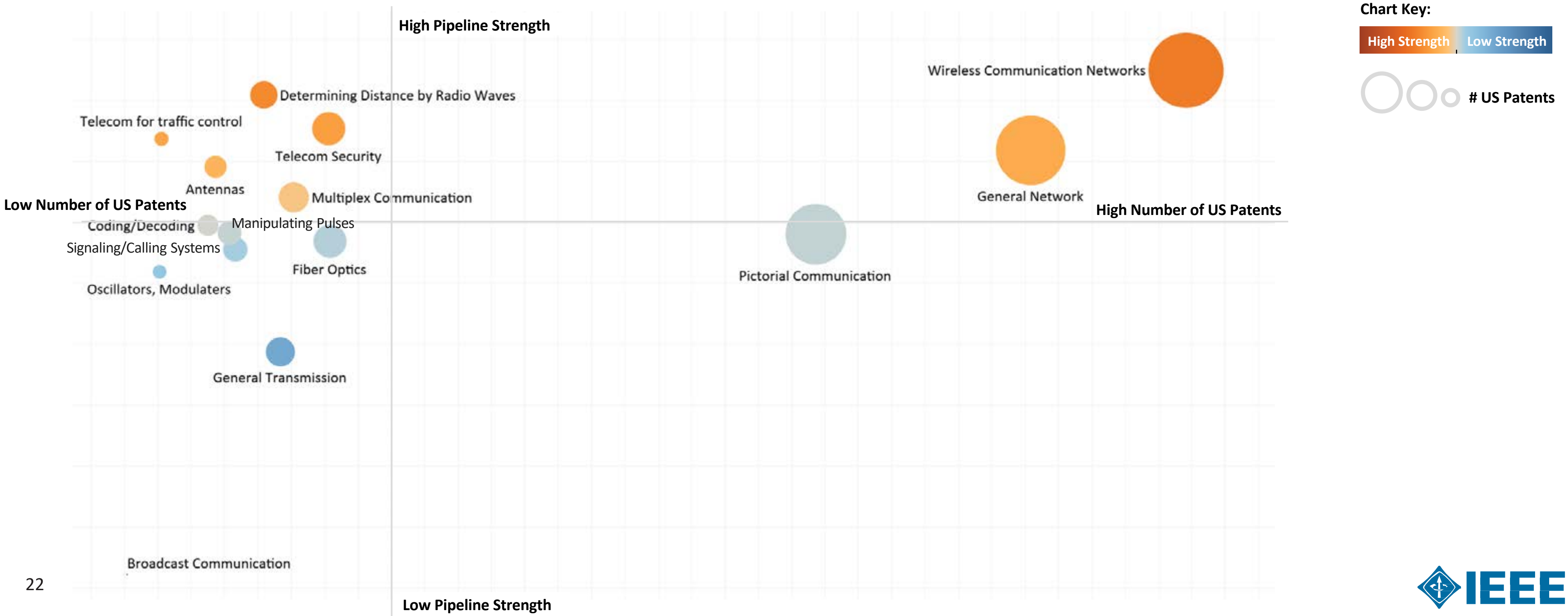
Pipeline Strength combines the quality metrics of Growth, Generality, and Impact.

Comparing Pipeline Strength to the Number of US Patents shows the standout performance of Wireless Communication Networks and General Networks as very numerous and high strength. Pictorial Communication has a lot of patents, but subpar strength.

Of the subcategories with a lower volume of US Patents, Determining Distance by Radio Waves and Telecom Security stand out because they still rank highly in terms of pipeline strength. While they may not be producing the same quantity of patents as others in this industry, their high strength scores suggest that patents in these subcategories have great value.

Broadcast Communication saw a decrease in both patent quantity and strength in the last 5 year period and relatively low scores overall, which suggests that the opportunity in this area of Telecom is declining.

Figure 13: *2014-18 US Patent Pipeline Strength vs. US Number of Patents for Telecom Subcategories*



Significant Increases in Scientific References to IEEE

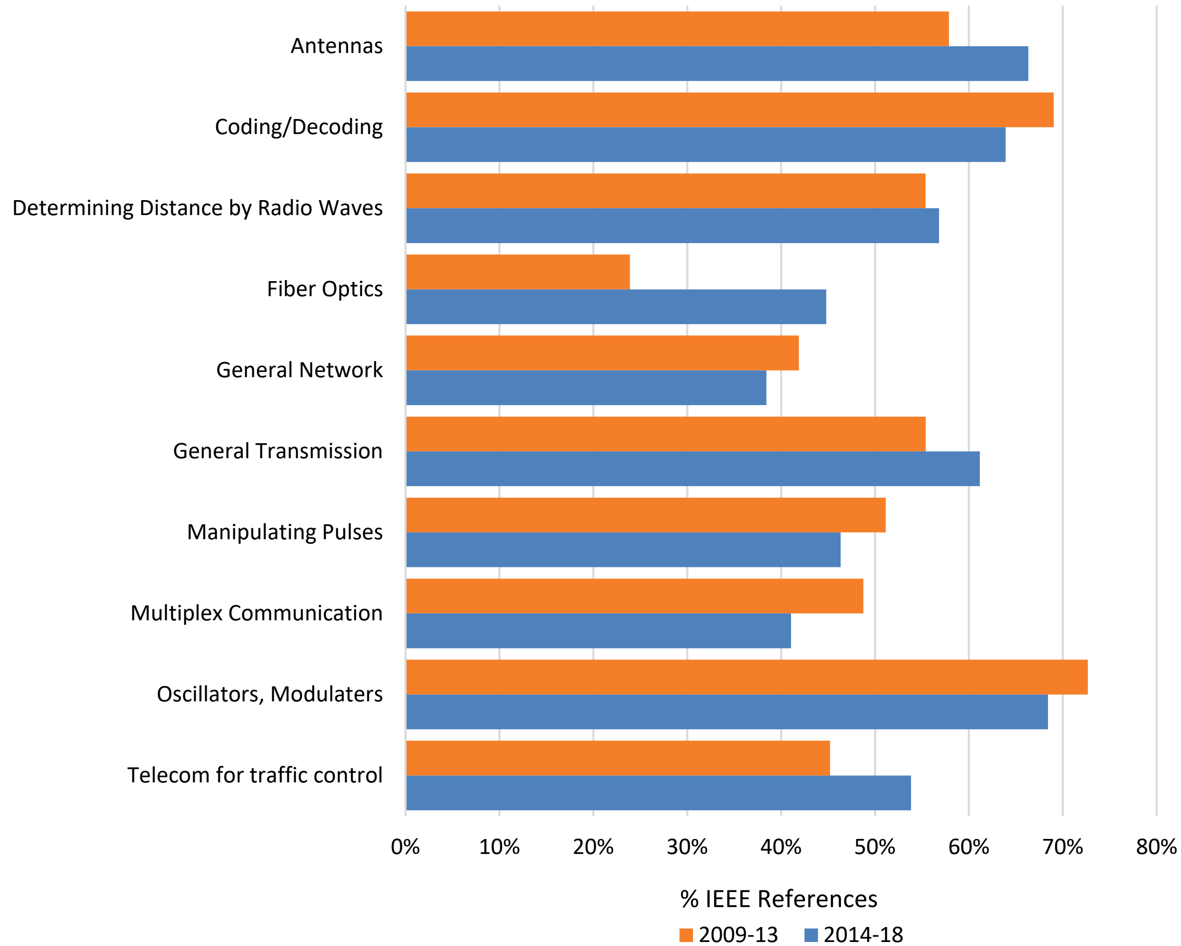
Earlier, this study showed that 42% of all scientific references in Telecom patents are to IEEE journals, conferences, or standards. **Figure 14** reveals that the percentage is even higher in several subcategories such as General Transmission, Coding/Decoding, and Antennas where more than 60% of the science base comes from IEEE.

IEEE publications have had a significant impact across all areas of Telecom, with all sub-categories referencing IEEE in 29% or more of their citations.

In recent years the Fiber Optics category has become more science-linked, and the percentage of references to IEEE has increased to 44% in the last five years. At the same time, the impact and generality of these patents has increased, (generality is shown in **Figure 11**.)

This supports previous findings that patents with links to scientific articles are likely to contain new leading-edge ideas.

Figure 14: Telecom Subcategories with High % IEEE References (2009-13 and 2014-2018)

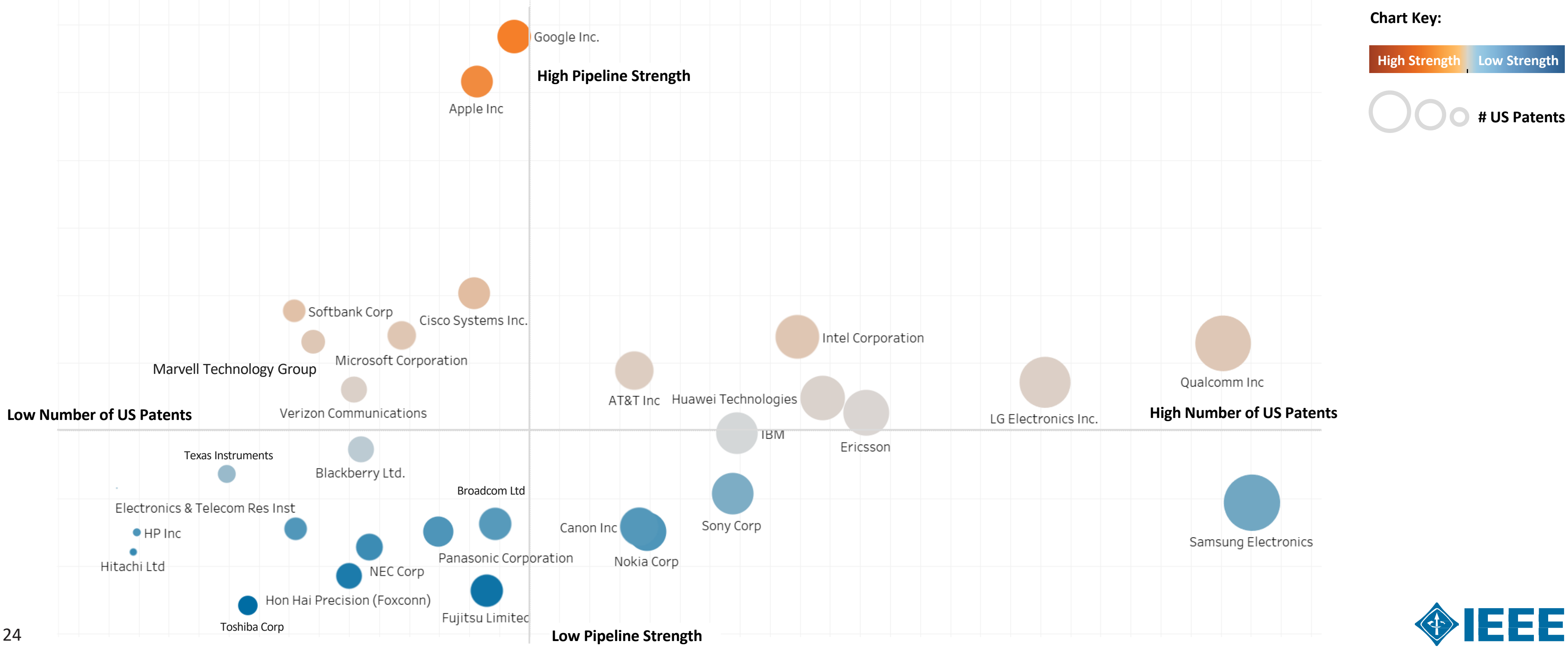


Patent Quality Scoring: Companies

Figure 15 plots Pipeline Strength with Number of Patents for the top 30 Telecom assignees. There are two main points to note in this figure:

1. **Apple and Google** have strong indicators across all metrics – i.e. above average growth, generality, and impact. As a result, their Pipeline Strength is almost 10 times as large as their patent portfolio size. This is very unusual and hard to achieve.
2. **Huawei** is growing very fast, but so far its patents have a low generality and impact, suggesting that the rest of the industry is not building upon its patents. As a result, its Pipeline Strength is smaller than its portfolio size.
3. **Samsung** has the most patents overall, but it ranks below average for Pipeline Strength (19th out of 30).

Figure 15: *US Patent Pipeline Strength vs. Us. Number of Patents for Telecom Assignees*



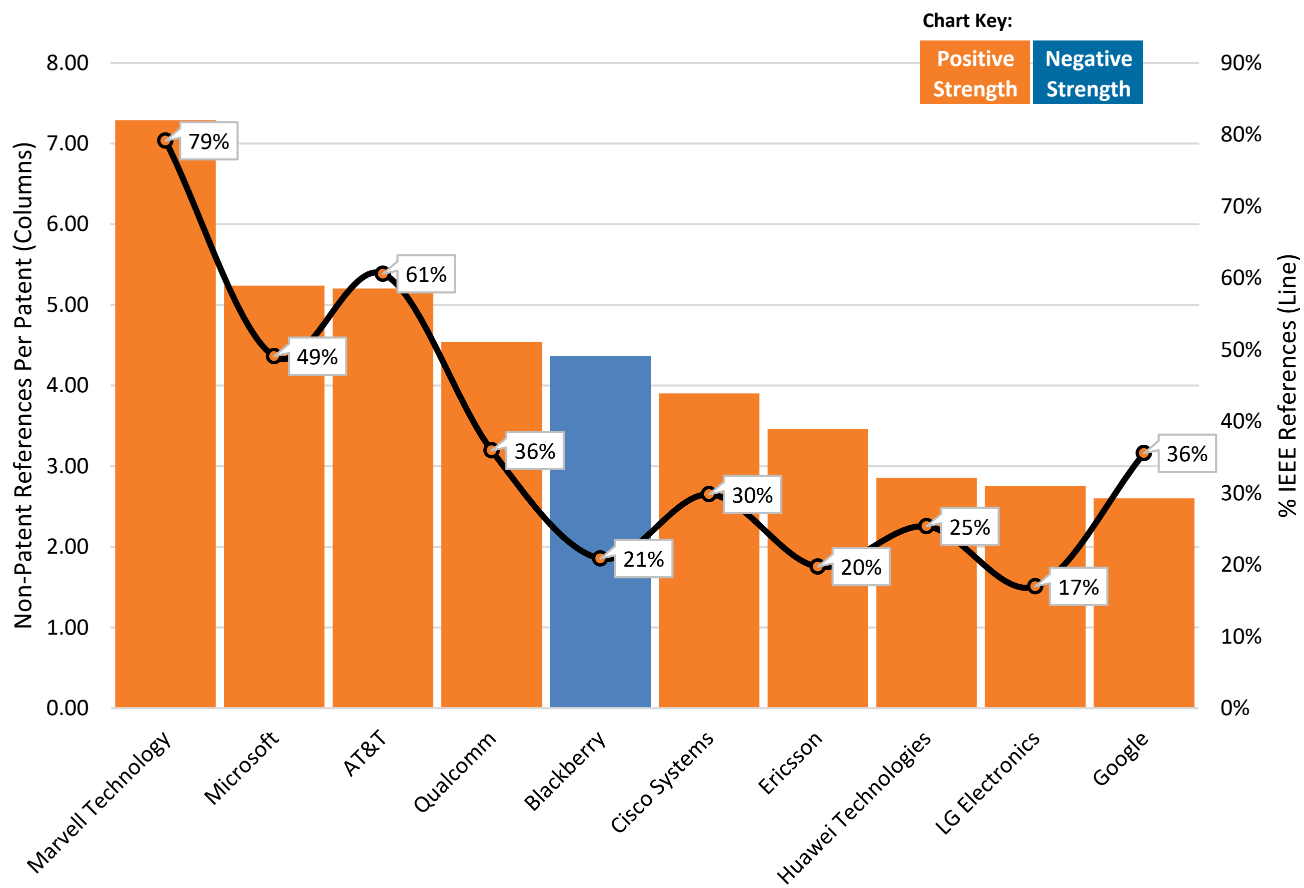
Assignee Non-Patent References

Figure 16 reveals that 9 of the top 10 assignees with the most non-patent references per patent have positive pipeline strength scores vs. the average.

This provides further evidence that patents with links to scientific articles are likely to be more valuable.

The figure also shows the influence of IEEE on non-patent referencing since all companies cite IEEE in at least 16% of their references, with Marvell Technology citing up to 79%.

Figure 16: *Top Telecom Assignees with Highest Non-Patent References Per Patent*



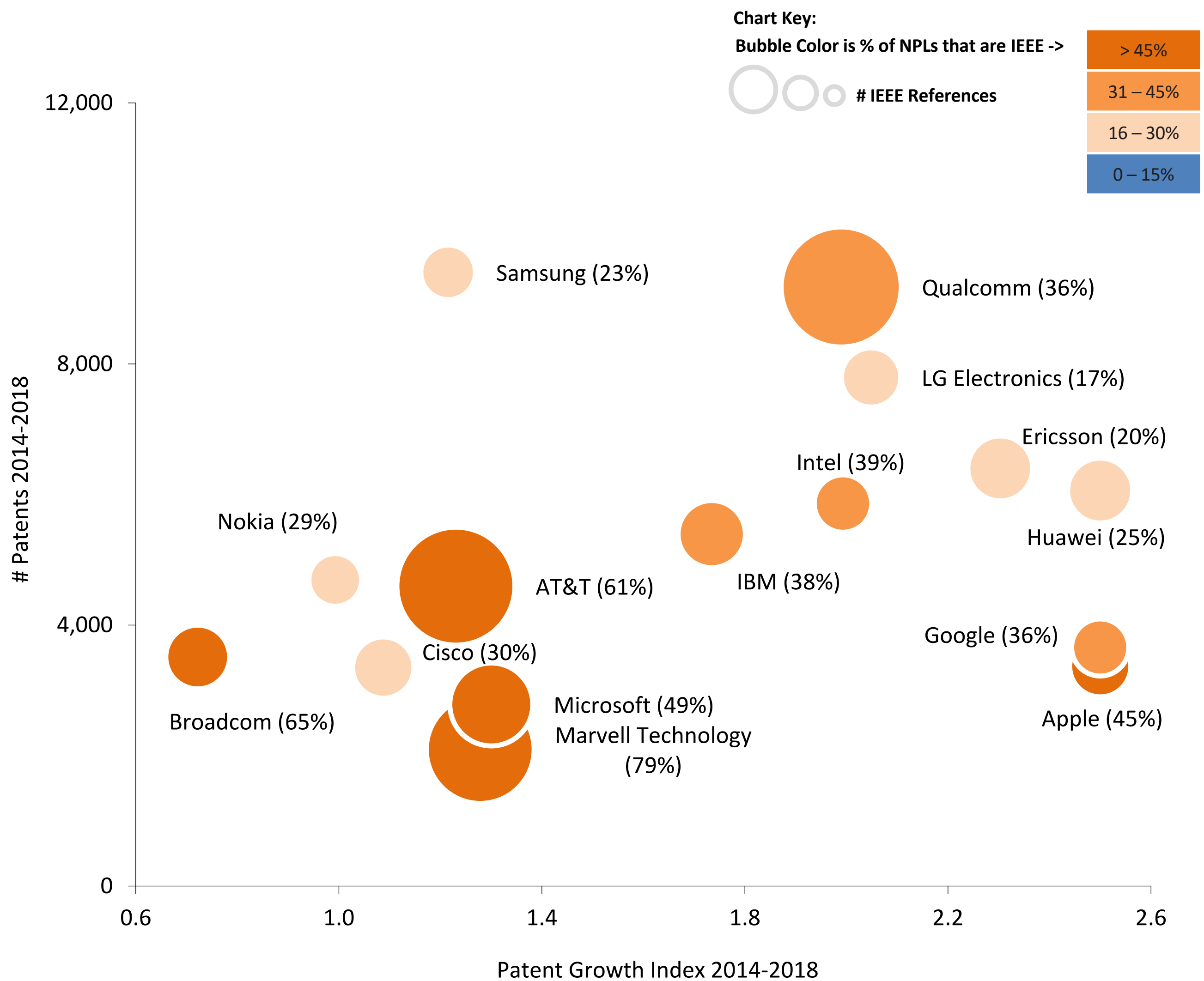
Assignee IEEE References

Figure 17 plots patent activity with patent growth for Telecom firms with the highest amount of IEEE references in 2014-2018. The bubble shading indicates the percentage of the science base that is provided by IEEE. **13 of the top 15 companies show above average growth, and all cite IEEE in over 16% of their patent references.**

There are a number of companies with large Telecom portfolios that show strong growth and depend on IEEE for their science base. For example, Qualcomm, which ranks high for both patent activity and patent growth, cites IEEE in 36% of its Telecom patent references.

Other notable companies that rely heavily on IEEE for their science base include Marvell Technology (79% of science references to IEEE) and AT&T (61% of science references to IEEE). Though these companies have smaller patent portfolios, they still show above average patent growth with indexes over 1.0.

Figure 17: Top 15 Firms with Highest IEEE References 2014-2018 (Telecom Patent Activity versus Patent Growth)



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Conclusion

IEEE: Fueling Innovation in Telecommunications

- **The Telecommunications industry is worth $1.3 trillion dollar worldwide** that relies on continuous innovation. That commitment to innovation is reflected in the US patent system. In the last 20 years, of the nearly five million US patents that have been issued, approximately 1 out of every 8 is related to the Telecom industry.

- **Technology in Telecom is changing rapidly**, particularly in Wireless Networking. This area of Telecom has seen consistent patent growth period over period for the past 20 years (average of 111% per five-year period).

- **Scientific literature is an important resource to the Telecom community** for keeping up with fast-paced innovation and supporting technological breakthroughs. IEEE publications, in particular, have been especially influential to patents across all Telecom categories.

- **42% of references from Telecom patents to all publishers were to scientific documents from IEEE**. This is more than the next 22 publishers combined, and three times as many as the second-ranked publisher (3GPP).

- **Quantity does not equal quality when it comes to Telecom patents.** While Samsung has the most patents overall and Huawei is growing the fastest, their portfolios have below average Pipeline Strength scores. Meanwhile, Google and Apple, companies with relatively small patent portfolios, are the highest ranked for strength.

- **Evidence suggests that patents with references to scientific literature are likely to contain new leading edge ideas**, while those that only reference other patents are likely incremental improvements on earlier innovations. This study supports these previous findings and shows that companies with more references to non-patent literature tend to have stronger, higher quality patent portfolios.

- **The most innovative companies in Telecom rely on IEEE for their science base**. Those that score well in Pipeline Growth and Pipeline Strength cite IEEE in 16% or more of their patent references.

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Appendix A: Telecommunications Taxonomy

Broad Category	Sub-Category	Fine Category	# Patents	#IEEE Refs	IEEE Refs/Patent
Telecom Neworks	Coding/Decoding	Analog/digital conversion	7859	9144	1.16
		Coding/Decoding not covered elsewhere	1081	514	0.48
		Conversion from a numeric value to another numeric value	2718	3827	1.41
		Error Detection/Correction	19887	48246	2.43
	General Network	Application independent communication protocol aspects or techniques in packet data networks	1304	625	0.48
		Arrangements for monitoring or testing packet switching networks	1159	534	0.46
		Arrangements for synchronising receiver with transmitter	3153	2810	0.89
		Automatically connecting calls	15174	6438	0.42
		Baseband systems	7512	13061	1.74
		Data switching networks	17550	13559	0.77
		Maintenance or administration or management of packet switching networks	2679	1332	0.50
		Metering, charging or billing arrangements	2107	410	0.19
		Modulated-carrier systems	10380	18958	1.83
		Network architectures or network communication protocols for network security	19702	13744	0.70
		Network arrangements or protocols for real-time communications	2947	2028	0.69
		Network Path Selection	4546	2330	0.51
		Network-specific arrangements or communication protocols	8791	5686	0.65
		Other Network Aspects not specified elsewhere	6109	4671	0.76
		Packet switching elements	2105	1499	0.71
		Routing or path finding of packets in data switching networks	6505	4956	0.76
		Substation equipment	18726	5114	0.27
		Telephonic communication systems adapted for combination with other electrical systems	1785	1931	1.08
		Text Messaging/Instant Messaging	1075	272	0.25
		Traffic regulation in packet switching networks	4482	3754	0.84
	Telecom Security	Cryptographic methods for secret communication	9523	7361	0.77
		Jamming of communication; Counter-measures	463	403	0.87
		Secret Communication	680	5152	7.58
		Wireless security arrangements/authentication	8554	5291	0.62
	Wireless Communication Networks	Communication routing or communication path finding	1170	1589	1.36
		Connection management	7397	3531	0.48
		Devices specially adapted for wireless communication networks	18737	16584	0.89
		Hand-off or reselection arrangements	4613	2227	0.48
		Locating users or terminals for network management purposes	2565	3185	1.24
		Network data management	7138	3419	0.48
		Network planning, deployment	1757	2895	1.65
		Network topologies	12410	15409	1.24
		Network traffic or resource management	3517	3756	1.07
		Power management	11399	10815	0.95
		Services specially adapted for wireless	2217	748	0.34
		Supervisory, monitoring or testing arrangements	5407	5397	1.00
		Synchronisation arrangements	1004	970	0.97
		Techniques for reducing energy consumption in wireless communication networks	3619	3716	1.03
		Wireless channel access	1105	1135	1.03
		Wireless not covered elsewhere	3501	1521	0.43
		Wireless traffic resource management	27542	36421	1.32

Appendix A (cont.): Telecommunications Taxonomy

Broad Category	Sub-Category	Fine Category	# Patents	#IEEE Refs	IEEE Refs/Patent
Telecom Infrastructure	Antennas	Antenna Arrangement (e.g. changing orientation)	3167	1288	0.41
		Antenna arrays or systems	3337	2874	0.86
		Combinations of Antennas with other devices (e.g. optical devices)	1294	1190	0.92
		Details of Antenna systems not covered elsewhere	2480	1263	0.51
		Optical Devices	3244	5365	1.65
		Resonant/Non-Resonant Antennas	3733	4879	1.31
	Manipulating Pulses	Circuits for generating electric pulses	3399	2408	0.71
		Electronic switching or gating	5229	3579	0.68
		Logic circuits and inverting circuits	9348	10633	1.14
		Manipulating pulses not covered elsewhere	6038	4372	0.72
	Oscillators, Modulaters	Automatic control of frequency or phase	5515	3578	0.65
		Generation of oscillations using amplifier with regenerative feedback from output to input	1953	3488	1.79
		Oscillators, Modulators not covered elsewhere	3956	3914	0.99
Transmission	Fiber Optics	Auxilary devices (bends, movable joints)	3893	7668	1.97
		Couplers	1071	2190	2.04
		Devices for controlling phase or intensity of light	30952	4329	0.14
		Fiber Optic related not covered elsewhere	1274	1483	1.16
		Transmission lines of the waveguide type	689	3804	5.52
	General Transmission	Details of transmission systems, not covered elsewhere	18973	22550	1.19
		Line transmission systems	2155	2688	1.25
		Monitoring; Testing of line transmission systems	1352	1257	0.93
		Near-field transmission systems	1257	569	0.45
		Radio Transmission	7304	10499	1.44
		Suppression or limitation of noise or interference	971	842	0.87
		Transmission systems employing electromagnetic waves other than radio-waves, e.g. infrared, visible or ultraviolet light, or quantum communication	7492	6014	0.80
	Multiplex Communication	Aspects of multiplex systems not covered elsewhere	6032	10490	1.74
		Code division multiplex systems	3190	7433	2.33
		Optical multiplex systems	6037	9885	1.64
		Orthogonal multiplex systems	2635	8388	3.18
		Time-division multiplex systems	7090	7388	1.04
Other Communication	Broadcast Communication	Broadcast Communication	618	296	0.48
	Determining Distance by Radio Waves	Details of systems not covered elsewhere	4177	3882	0.93
		Position-fixing by co-ordinating two or more direction or position line determinations	2938	2897	0.99
		Satellite radio beacon positioning systems	2922	1129	0.39
		Systems using the reflection or reradiation of radio waves	5507	5399	0.98
	Pictorial Communication	3D Video Signal transmission	3868	3602	0.93
		Diagnosis, testing or measuring for television systems	1175	922	0.78
		Methods or arrangements for coding, decoding, compressing or decompressing digital video signals	14998	24944	1.66
		Pictorial Communication not covered elsewhere	2746	1435	0.52
		Scanning, transmission or reproduction of documents (e.g. fax transmissions)	16773	4491	0.27
		Selective content distribution (e.g. Video on demand)	20392	11467	0.56
		Television	38091	15542	0.41
	Signalling or calling systems	Alarm systems in which the location of the alarm condition is signalled to a central station, e.g. fire or police telegraphic systems	1037	193	0.19
		Alarms not specified elsewhere	4809	857	0.18
		Alarms responsive to an undesired or abnormal operating condition	8073	1168	0.14
		Theft alarms	6941	1622	0.23
	Telecom for traffic control	Motor vehicle systems	4335	1612	0.37
		Telecom for traffic control not covered elsewhere	157	65	0.41
		Traffic control systems for aircraft	711	247	0.35

Appendix B: Raw and Normalized Data

Broad Category	Sub-Category	Raw Data			Normalized Data		
		Pipeline Growth Index	Pipeline Generality	Pipeline Impact	Pipeline Growth Index	Pipeline Generality	Pipeline Impact
Telecom Networks	Wireless Communication Networks	2.3	1.1	1.0	2.4	0.3	0.5
	General Network	1.4	1.2	1.1	0.2	0.4	0.8
	Coding/Decoding	0.9	0.9	0.8	(0.8)	(0.7)	(1.1)
	Telecom Security	1.5	1.4	1.1	0.4	1.4	0.9
Telecom Infrastructure	Manipulating Pulses	1.1	1.1	0.9	(0.5)	0.3	(0.1)
	Antennas	1.2	1.0	1.0	(0.3)	(0.1)	0.4
	Oscillators, Modulators	0.6	1.1	1.0	(1.6)	0.1	0.4
Transmission	General Transmission	1.1	1.1	1.0	(0.5)	(0.1)	0.2
	Fiber Optics	1.1	1.4	1.1	(0.4)	1.4	1.0
	Multiplex Communication	1.6	1.1	0.9	0.6	0.1	(0.2)
Other Communication	Pictorial Communication	1.5	1.0	0.9	0.4	(0.4)	(0.3)
	Signaling or calling systems	1.2	1.0	0.9	(0.3)	(0.1)	(0.2)
	Determining Distance by Radio Waves	1.3	1.2	1.0	0.1	0.6	0.4
	Telecom for traffic control	1.9	1.1	1.0	1.4	(0.1)	0.4
	Broadcast Communication	0.7	0.4	0.4	(1.3)	(3.0)	(3.1)

Appendix B (cont.): Raw and Normalized Data

Assignee	Raw Data			Normalized Data		
	Pipeline Growth Index	Pipeline Generality	Pipeline Impact	Pipeline Growth Index	Pipeline Generality	Pipeline Impact
Samsung Electronics	1.22	0.55	0.6	(0.2)	(0.6)	(0.5)
Qualcomm Inc	1.99	1.06	0.84	1.0	0.3	0.3
LG Electronics Inc.	2.05	0.75	0.76	1.1	(0.3)	0.0
Ericsson	2.3	0.48	0.61	1.5	(0.8)	(0.5)
Huawei Technologies	2.5	0.52	0.57	1.9	(0.7)	(0.6)
Intel Corporation	1.99	1.07	0.87	1.0	0.3	0.4
IBM	1.73	0.73	0.64	0.6	(0.3)	(0.4)
Sony Corp	0.96	0.63	0.74	(0.7)	(0.5)	(0.0)
Nokia Corp	0.99	0.57	0.54	(0.6)	(0.6)	(0.7)
Canon Inc	1.62	0.44	0.32	0.4	(0.8)	(1.4)
AT&T Inc	1.23	1.13	1.03	(0.2)	0.4	0.9
Google Inc.	2.5	2.39	1.6	1.9	2.7	2.7
Broadcom Ltd	0.72	0.75	0.62	(1.1)	(0.3)	(0.4)
Fujitsu Limited	1.01	0.32	0.33	(0.6)	(1.0)	(1.4)
Apple Inc	2.5	2.28	1.4	1.9	2.5	2.1
Cisco Systems Inc.	1.09	1.53	1.32	(0.4)	1.2	1.8
Panasonic Corporation	0.74	0.65	0.62	(1.0)	(0.4)	(0.4)
Microsoft Corporation	1.3	1.48	1	(0.1)	1.1	0.8
NEC Corp	1.28	0.29	0.46	(0.1)	(1.1)	(0.9)
Blackberry Ltd.	1.07	0.95	0.76	(0.5)	0.1	0.0
Verizon Communications	1.98	0.9	0.67	1.0	0.0	(0.3)
Hon Hai Precision (Foxconn)	0.86	0.53	0.37	(0.8)	(0.7)	(1.2)
Marvell Technology Group	1.28	1.64	0.88	(0.1)	1.4	0.4
Electronics & Telecom Res Inst	1.28	0.32	0.55	(0.1)	(1.0)	(0.6)
Softbank Corp	1.21	1.56	1.14	(0.3)	1.2	1.3
Toshiba Corp	0.71	0.4	0.35	(1.1)	(0.9)	(1.3)
Texas Instruments	1.09	0.61	0.8	(0.4)	(0.5)	0.2
HP Inc	0.56	0.84	0.6	(1.3)	(0.1)	(0.5)
Hitachi Ltd	0.51	0.44	0.74	(1.4)	(0.8)	(0.0)
Motorola Solutions Inc.	0.62	0.92	0.78	(1.2)	0.1	0.1

Pipeline Growth Index

This measures whether a portfolio is increasing (suggesting a strong ongoing commitment to innovation) or decreasing (suggesting a declining commitment to innovation). It is calculated by taking the number of U.S. patents granted in the most recent time period (2014-2018 in this case), and dividing it by the number of US patents for the previous five years (2009–2013). Pipeline Growth values greater than 1.0 reflect an increase in patent activity (for example, a value of 1.3 shows a 30 percent increase in patenting). Meanwhile, values less than 1.0 reflect a decrease in patent activity (for example, a value of 0.8 shows a decrease of 20 percent). The Pipeline Growth metric is capped at 2.5; otherwise organizations with few patents prior to the current period could have extremely high Pipeline Growth values which would distort the scorecard.

Pipeline Generality

Pipeline Generality is designed to identify patents that are useful in a variety of industries. Specifically, patents cited by subsequent patents from numerous technologies (as defined by U.S. patent office classifications) are regarded as more general than those cited only by patents from a single technology. For example, a component of a cell tower with a single application is less general than a weatherproof insulating material that can be used on fiber optics, electrical wires, and a variety of other applications in multiple industries. Pipeline Generality is again normalized by age and technology and has an expected value of 1.0. Values greater than 1.0 suggest that an organization's patents are more generally applicable than peer patents, while values less than 1.0 suggest that an organization's patents have relatively narrow applicability relative to their peers. Pipeline Generality is not capped because it is very rare and difficult to attain a generality above 3.

Pipeline Impact

This metric shows the impact of patent portfolio on subsequent technological developments. It is based on the idea that patents containing important technological information will form the basis for many new innovations, and so will tend to be cited as prior art by many later patents. This does not mean that every frequently cited patent is important, or that patents cited infrequently are necessarily trivial. However, numerous validation studies have revealed the existence of a strong positive relationship between citations and measures of technological importance.

The Pipeline Impact metric is calculated by taking all patents granted in the most recent year and counting how many times they cite as prior art the patent portfolio of an organization or technology category over the previous five years. For example, the 2018 Pipeline Impact for Qualcomm is derived by counting the number of times patents granted to Qualcomm in 2012–2017 are cited as prior art by all patents issued in 2018. This number is then normalized by dividing it by the mean number of citations received by all patents from the same period and technology (as defined by U.S. Patent and Trademark Office and CPC [Cooperative Patent Classification] classes) as the Qualcomm patents. This normalization results in an index (the Pipeline Impact) with an expected value of 1.0. Pipeline Impact values greater than 1.0 show that an organization's patents have been cited more frequently than expected (for example, a value of 1.5 shows 50 percent more citations than peer patents) and are thus high impact on average. Meanwhile, Pipeline Impact values less than 1.0 show that an organization's patents have been cited less frequently than expected (for example, a value of 0.7 shows 30 percent fewer citations than peer patents) and are thus low impact on average.

It is possible for the Pipeline Impact to be skewed by organizations citing their own earlier patents excessively as prior art. A certain number of self-citations are to be expected, as organizations build on their own earlier research. However, extreme self-citation, combined with few citations from the patents of other organizations, may be an artifact of an organization's patent filing process, rather than a reflection of technological impact. To account for this self-citation effect, we discount all self-citations that are more than 30 percent of the total. For example, if an organization has a Pipeline Impact of 1.2 and a self-citation rate of 45 percent (that is, 45 percent of the citations of the organization's patents are from the organization's own subsequent patents), we adjust its Pipeline Impact by 15 percent to 1.02. This modified figure is the Pipeline Impact for the organization (capped at 5) that is included in the formula used to derive the Pipeline Power for an organization.

End Notes

1. (p4) Initially speeds are expected to be 5 times current 4G LTE networks with eventual speeds reaching 20 times faster. *Philadelphia Inquirer* September 1, 2019, p. E4.

2. (p4) Estimate is from Statista.com a leading provider of consumer data covering 170 industries for more than 1.5 million registered users. The estimate of $1.3 trillion dollars is based on a modest extrapolation from $1.2 trillion in 2015.

3. (p6) The taxonomy is based on the Cooperative Patent Classification (CPC) system and contains key parts of the G and H classes. See https://www.uspto.gov/web/patents/classification/cpc.html and Appendix A.

4. (p9) For a comprehensive study on various hypotheses surrounding the motivations of inventors in listing non-patent references, see [1].

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