# Radio "Fences" and Inventor Attention to Property Rights: Evidence from Wireless Patents

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# Radio “Fences” and Inventor Attention to Property Rights: Evidence from Wireless Patents

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**Abstract:** Do the inventors of radio “fences” (which restrict transmissions externalities) care about property rights? I hypothesize that inventors do pay attention to policy regimes such as licensed and unlicensed spectrum when building technologies to handle interference. To answer this question, I conduct textual analysis of 500,000 wireless patents to estimate inventor attention to property rights. I find that inventors are more likely to mention interference and sensor technology if they mention property rights, than if they do not discuss property rights. While further research is needed to determine causality, textual analysis provides evidence of inventor attention to property rights regimes.

*Keywords: property rights, spectrum policy, textual analysis*

*JEL: K11, K23, L51, L96, O31, P14, P48*

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## 1 Introduction

Do spectrum property rights help or hurt innovation? Scholars debate whether open commons or flexible licenses better serve ecosystem growth. In developing a theory of innovation, empirical evidence can help explain how inventors respond to property rights. The 90th anniversary of the Radio Act of 1927 seems an appropriate time to consider this interaction of innovation and policy on the radio waves.

## 2 Background

Ninety years after the Radio Act of 1927, we can study how property rights have influenced innovation with respect to the airwaves.[1] The Radio Act of 1927 started an era of agency regulation of spectrum licensing. Scholars have described the Act as a "calculated rent-sharing arrangement serving the interests of regulators and industry" (Hazlett, 1998, p. 543).

After the Radio Act, use permits and broadcast station authorizations were distributed by regulators at the Federal Radio Commission (1927-1934), which was later renamed the Federal Communications Commission in 1934. Zero-priced awards ("comparative hearings") have been used to allocate commercial spectrum since 1927, and are still used today for license renewals (Hazlett, 1998, p. 531). Lotteries were authorized by Congress in 1981 as an alternative method to distribute licenses, and were used for many cellular telephone license allocations between 1984 and 1989 (*Id.*). In 1993, Congress authorized yet another method of spectrum allocation: by competitive auction (*Id.*). Competitive auctions have led to efficient exchange of spectrum licenses since 1994 through bid and offer prices for licenses by city according to market demand.

Coase (1959) made a case for future market mechanisms that would better serve economic growth and innovation with respect to radio spectrum, by arguing for the efficacy

[1] The Radio Act of 1927, Public Law No. 632, February 23, 1927, 69th Congress.

of property rights in spectrum licenses. Coase argued that a government regulator could not possibly know as much as industry in predicting future use cases for spectrum. Allocations through agency rulemaking would be inferior to price mechanisms that responded to distributed market knowledge.

Coase did not observe platforms as we know them today, but he consistently emphasized the incentives of property owners. In other articles, he described organizational structures that align incentives for productive activity. By including externalities in the calculus of social cost, he described how agents make decisions that reflect transaction costs and respond to the incentives of alternative governance regimes.

## 3 Interference and Property Rights

Coase understood that increased activity on the radio waves could increase conflicts. But rules to limit interference also conflict with certain productive pursuits. Coase reasoned that increasing consumer welfare should be the primary economic policy goal, rather than minimizing interference. In fact, optimal congestion may be far from zero, but much closer to "chaos in broadcasting" (Coase, 1959, p. 5).

In this paper, I gather empirical evidence of inventor attention to interference and property rights. I assume that inventors seek to increase spectrum efficiency through new inventions. Inventions may avoid "interference" by reducing emission levels (for radiated power) or improving receivers. The latter may include "filter" or "sensor" technologies. These wireless technologies may be considered radio "fences" that can better define and/or respect noise boundaries across spectrum frequencies.

Inventors of new digital communications may show concern for property rights by discussing "licensed" or "unlicensed" policy regimes in their patent applications. Licensed regimes generally refer to the use of frequencies on an exclusive basis; unlicensed is where wireless access is non-exclusive. But property rights may not be a primary driver of inventive activity. Network effects may instead be a main motivator of research and development. For example, the number of global users of unlicensed technology may spur ecosystem growth due to the scale of the potential market. Some policymakers have credited the absence of property rights as a driver of rapid uptake of cordless phones and other Part 15 devices (Carter et al., 2003).

However, property rights in spectrum have generated enormous network effects as well. Patents in licensed spectrum bands have outpaced those of unlicensed spectrum. In the cellular bands, tens of thousands of patents have been filed for the CDMA, GSM, and LTE technologies that have become global standards. Handset manufacturers develop new devices annually. Mobile carriers reinvest profits to deploy more wireless infrastructure. This virtuous cycle of reinvestment creates incentives for more discovery and development.

This article presents an introductory treatment of inventor attention to property rights in radio spectrum with the use of methods of textual analysis. Spectrum value caused by property rights has been studied empirically (Hazlett and Honig, 2016). Other studies in law and economics research discuss creative activity that is generated by property rights and other appropriation mechanisms (O'Connor, 2015). With big data tools, we can now apply textual analysis to inventor activity to advance the literature on causal effects of property rights on innovation.

## 4 Textual Analysis of Radio Patents

Textual analysis is now used in empirical studies of wide-ranging subject matter.[2] Text mining techniques have been applied to patent databases for many years (Bergeaud et al., 2017; Tseng

[2] For a brief summary of textual analysis, *see generally,* Merrick, Amy, "Why Words are the New Numbers," Chicago Booth Review. Mar. 17, 2015, http://review.chicagobooth.edu/magazine/spring-2015/why-words-are-the-new-numbers.

et al., 2007). Recently, scholars reported success in semantically classifying 4 million patents from the United States Patent & Trademark Office database from 1976 onward with the use of "big data" tools (Bergeaud et al., 2017). Patent text can be analyzed to forecast technology diffusion, with methods such as "text segmentation, summary extraction, feature selection, term association, cluster generation, topic identification, and information mapping" (*Id.*). Specific inventions can be studied through key-word extraction (*Id.*).

Text miners prefer to search for multi-word phrases in patents, rather than single word phrases, to add more specificity in analysis. Key-term-extraction algorithms weigh terms with 1 or 0 values, thereby "denoting the presence or absence of the terms in documents" (*Id.*, p. 1224). Thus, the mean value of terms "becomes a value exactly proportional to the number of documents" in which terms occur (*Id.*). Textual analysis methods include heuristic rules for measuring term co-occurrence and term association (*Id.*).

Finance researchers study patents to predict technology trends (Lerner and Seru, 2015). Forecasting techniques that measure S-shaped growth have been applied to patent text (Daim et al., 2006). While forecasting and diffusion are not relevant to this study, this dataset on radio patents can be used to investigate further questions of innovation in the wireless sector.

### 4.1 Hypothesis

I investigate inventive activity that is associated with property rights by extracting and counting key terms from radio patents. Inventors who seek to lessen "interference" or build "filters" would cite those terms in their patent filings. Inventors may build "sensors" in response to favorable policy regimes. I estimate inventor attention to property rights by extracting key terms such as "licensed" and "unlicensed" spectrum.

I assume that inventors who discuss terms in their patent filings are concerned about those terms. If a term appears in more patent filings, I assume that the presence of the term indicates more attention to the issue. Patents do not mean inventions are necessarily valuable, however. Patent filings do not have equal importance or weight in innovative activity. Certain patents may have disproportionate importance, and hundreds of patents may have little or no relevance. There are no straightforward measurement devices, however, to differentiate among these inventions. Hence, we are left with a first approximation. This study treats radio patents as independent and equal in weight.

### 4.2 Empirical Strategy

I measure inventor attention to interference and property rights through a binary choice logit model. Key term data are extracted in binary format -- 0 or 1 -- which indicates if a term is absent or present in the full text of a patent. In addition to the main terms of interest, I measure the presence of 130 additional terms that are relevant to spectrum policy research.[3]

Binary choice logit regressions are better suited to analyzing binary data than is ordinary least squares regression.[4] A binary choice logit model gives probabilities such that $Prob(y > 0) = \Lambda(x\beta) = exp(x\beta)/(1 + exp(x\beta))$. Errors are assumed to be distributed with mean 0 and variance of $\pi^2 / 3$, or $\lambda(\epsilon) = e^{\epsilon} /(1 + e^{\epsilon})^2$.

Equation (1) shows the model for $y = 1(InventionTerm > 0)$, where the dependent variable is an invention term, and independent variables include property rights terms such as "licensed" and "unlicensed." I test three invention terms: "interference," "filter," and "sensor." Vectors of other terms are included as well: Γ for policy terms; **Ω** for technology

[3]I counted key terms taking into account the presence of a plural "s" or not. Several terms were counted with different spellings: Cancellation includes "cancellation" or "cancelation"; CFR includes "CFR," "C.F.R.," or "Code of Federal" Regulations; FCC includes "Federal Communications Commission" or "FCC"; TV includes "television" or "TV"; white space includes "white spaces" or "white space"; WiFi includes "Wi-Fi" or "WiFi"; and 3G includes "3G" or "3GPP." The number of times that a term appeared in the full text of a patent was not measured, which is consistent with key term extraction methods in the literature.
[4]Greene (2008).

terms; and Φ for general terms.

$$Prob(InventionTerm_{it}) > 0) = \Lambda(\beta_1 + \beta_2 licensed_{it} + \beta_3 unlicensed_{it} + \Gamma_{it} + \Omega_{it} + \Phi_{it}) \quad (1)$$

The radio patent dataset includes $i = 0$ to 500,000 observations and patents from years $t = 1976$ to 2016. Table 1 includes a list of key terms that are extracted for this study. Invention terms include “interference,” “filter,” and “sensor.” Property rights terms include “licensed” and “unlicensed.” Policy keywords include, for example, “property,” “rights,” and “Federal Communications Commission.” Technology terms include, for example, “3G,” “4G,” “LTE,” “5G,” “CDMA,” “Wi-Fi,” and “white space.” General terms include, for example, “hertz,” “MHz,” “GHz,” “colocation,” “receiver,” and “transmitter.”

**Table 1** Key term extraction

| | |
|---|---|
| Invention Terms | *interference, filter, sensor* |
| Property Rights Terms | *licensed, unlicensed* |
| Policy Terms, Γ | *spectrum, allocation, band, cancellation, CFR, FCC, adjacent, collocation, harmful, monitoring, enforcement, property, rights* |
| Technology Terms, Ω | *3G, 4G, 5G, LTE, WiMax, WiFi, GPS, CDMA, MIMO* |
| General Terms, Φ | *1927, 1996, AC, AM, analog, antenna, auction, band, base, bluetooth, broadcast, carrier, cell, cellular, channel, CINR, coaxial, code, computer, consumer, current, database, DC, digital, downlink, edge, electromagnetic, error, FDMA, federal, fiber, fixed, FM, frequency, GHz, gigahertz, ground, GSM, handover, HD, hertz, high, Hz, IEEE, industrial, infrared, internet, kHz, kilohertz, Kv, laser, legal, load, low, market, medical, megahertz, MHz, microphone, microwave, millisecond, mobile, multiplex, OFDMA, ohms, PCS, positioning, power, processor, radar, receiver, regulatory, relay, resistor, retail, RF, RSSI, satellite, shared, signal, station, TDMA, telephone, terrestrial, threshold, tower, transceiver, transmitter, TV, UMTS, uplink, v, volts, wave, WCDMA, white space, wireless, xray* |

### 4.3 Data

The data come from the United States Patent & Trademark Office Patent Full-Text and Image Database (USPTO Full-Text Database, 2017).[5] A term search for "radio" resulted in search results for over 500,000 radio patents.[6] The full-text of these patents was scraped and stored for textual analysis.

Figure 1 shows radio patents compared to all U.S. patents. Patents with the term "radio" appear to decrease in number in 2014, while the total volume of U.S. patents rises rapidly after 2010. An explanation may be that the term "wireless" has grown in popularity for describing technology that utilizes the radio waves, with a decline in the use of the word "radio." Logit regressions rely on pooled data.

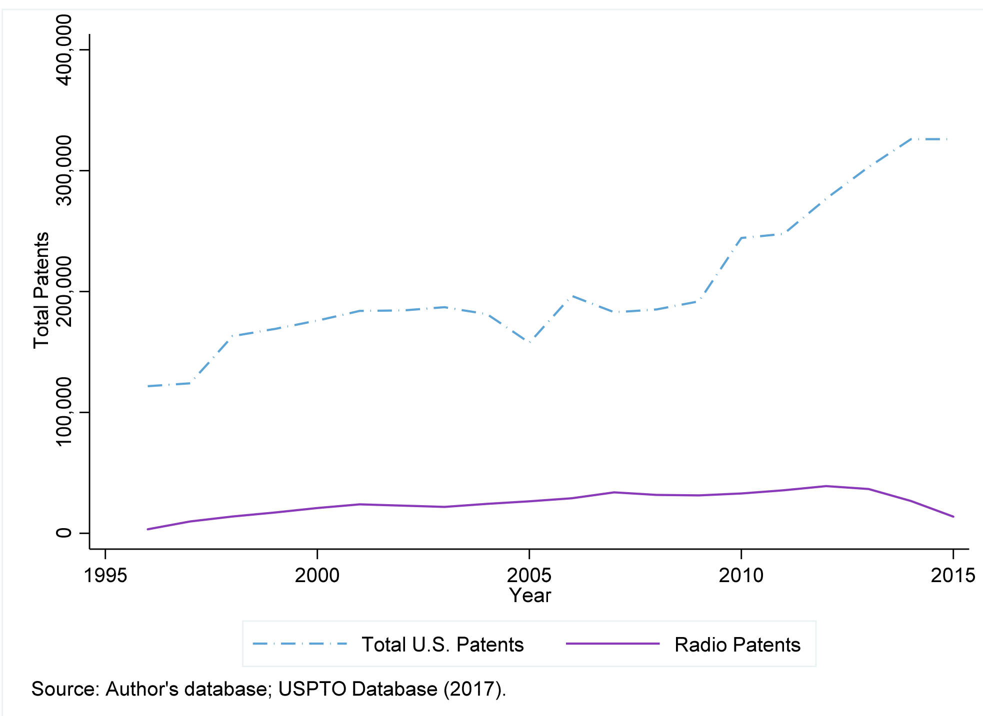


**Fig. 1** "Radio" patents

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[5] *See also* USPTO Statistics (2017).
[6] Query results contained over 600,000 patents for the term "radio." Data for this paper contains a sample of 500,000 of these listings from the search query.

**Table 2** Selected descriptive statistics

| Variable | Mean | Min | Max |
|---|---|---|---|
| *interference* | 0.23 | 0 | 1 |
| *filter* | 0.36 | 0 | 1 |
| *sensor* | 0.31 | 0 | 1 |
| *licensed* | 0.03 | 0 | 1 |
| *unlicensed* | 0.02 | 0 | 1 |
| *property* | 0.13 | 0 | 1 |
| *rights* | 0.07 | 0 | 1 |
| *harmful* | 0.02 | 0 | 1 |
| *spectrum* | 0.19 | 0 | 1 |
| *FCC* | 0.03 | 0 | 1 |
| *3G* | 0.16 | 0 | 1 |
| *4G* | 0.05 | 0 | 1 |
| *5G* | 0.03 | 0 | 1 |
| *CDMA* | 0.18 | 0 | 1 |
| *LTE* | 0.10 | 0 | 1 |
| *Wi-Fi* | 0.12 | 0 | 1 |
| *GPS* | 0.16 | 0 | 1 |

Descriptive Statistics are available in the Data Appendix. Terms have 500,000 observations each.

Table 2 displays selected descriptive statistics for terms in the radio patent dataset. Invention terms are listed at the top. “Interference” appears in an average of 23% of the 500,000 radio patents, while “filter” and “sensor” appear in more patents: 36% and 31%, respectively, of observations in the dataset. Property rights terms -- “licensed” and “unlicensed” -- appear in fewer patents: only 3% and 2%, respectively, of radio patents. This means that of 500,000 radio patents, 15,000 and 10,000 patents include these property-rights terms.

Common policy terms -- such as “property” and “spectrum” -- are used frequently by patent writers: 13% and 19%, respectively, of radio patents include these terms. Other policy terms -- such as “harmful” or “FCC” or “rights” -- appear less frequently: 2%, 3%, and 7%, respectively, of radio patents. Technology terms appear frequently in the dataset, with “GPS” and “3G” appearing in 16% of radio patents. The wireless standard “CDMA” appears in 18% of the patents in this dataset. Other standards -- such as “Wi-Fi” and “LTE” -- appear in 12%

and 10%, respectively, of the radio patents in the dataset.

Firms are identified in the dataset as well. The names of firms were cleaned and simplified to remove miscellaneous spellings. In some instances, firms filed patents with or without abbreviations in their names, using words such as “Corporation” as “Corp.” or “Incorporated” as “Inc.” or “Limited” as “Ltd.” Some discrepancies remain in the dataset, so the number of firms may be overstated. The largest corporate filers, however, were checked for spelling discrepancies.

Figures 2 and 3 provide graphical depictions of changes in key term citations over time. Figure 2 shows one dependent variable -- “interference” -- compared to the property rights terms “licensed” and “unlicensed.” Over 20% of radio patents each year included the term “interference,” with a decline in later years. The term “licensed” appears more frequently each year in radio patents than does “unlicensed.” These terms increase in citation around the year 2004, but do not exceed 2% or 3% each year.

Figure 3 shows the mean value over the years of three dependent variables -- “interference,” “filter,” and “sensor” -- along with a few technology terms. Diffusion of technologies -- such as “GPS,” “LTE,” “3G,” and “Wi-Fi” -- are apparent in an S-curve shape after the year 2005. The term “sensor” increases steadily across the years, while “interference” and “filter” are less present in the text of radio patents. For comparison, the term “MIMO” shows a slight uptick in 2010, but is not cited as frequently as the other technologies.

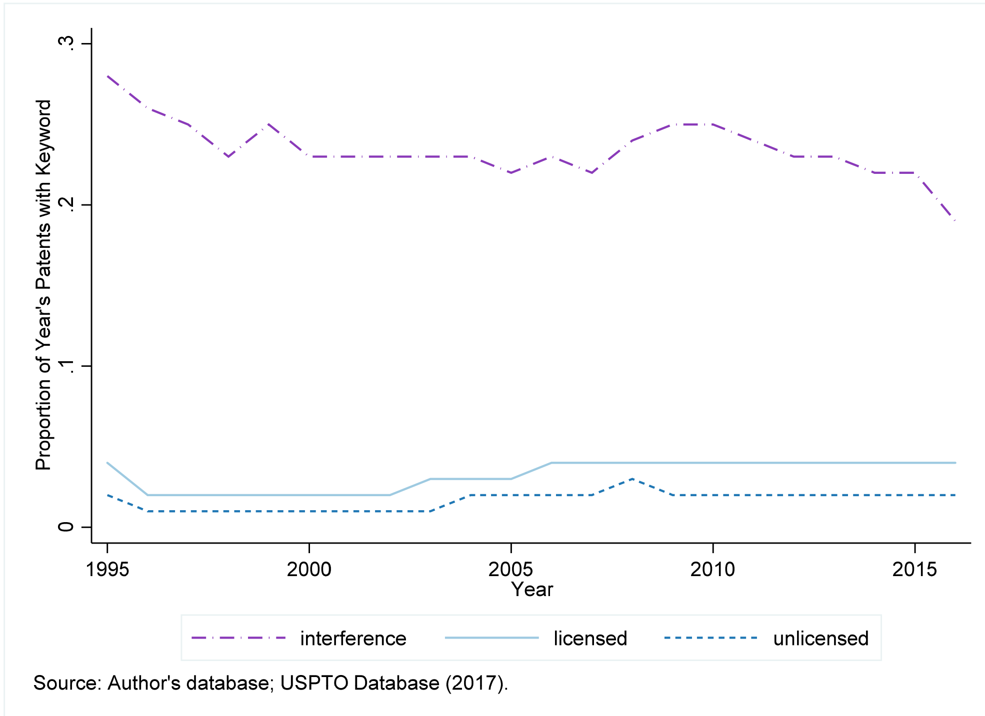


**Fig. 2** Property rights terms

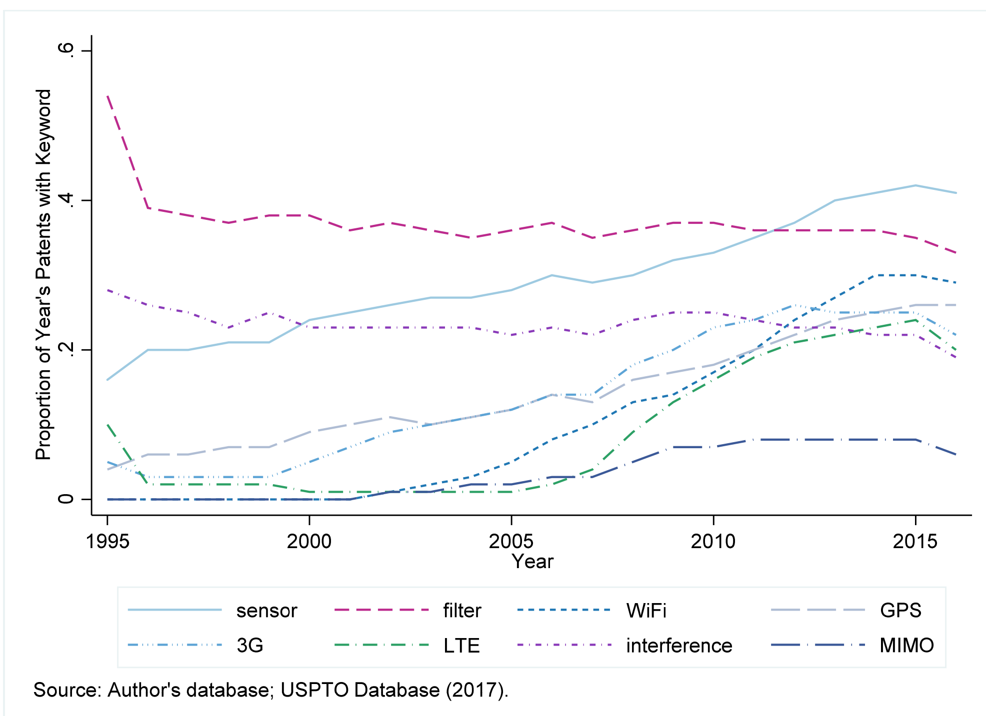


**Fig. 3** Technology terms

### 4.4 Model Assumptions

Binary choice logit models assume that there are no interaction effects between independent variables. Before running logit regressions, I tested correlation coefficients and other diagnostics on the independent variables. The correlation coefficient between the property rights terms, “licensed” and “unlicensed,” is 0.73. These two words are highly correlated in the radio patent dataset. This result can also be seen graphically in Figure 2, where “licensed” and “unlicensed” move together over time. Knowing that there may be a multicollinearity issue with these property rights terms, I also estimate the logit model including only one these terms at a time.

Table 3 shows correlation coefficients for “interference,” “filter,” and “sensor” with “licensed” and “unlicensed.” This table shows, for instance, that patents with “interference” and “licensed” terms are positively correlated with a coefficient of 0.10, while patents with “interference” and “unlicensed” terms are similar with a positive correlation of 0.11. The terms, “filter” and “sensor,” appear to be less correlated with the property rights terms than other terms. Other terms such as “GHz” or “FCC” are positively correlated with “licensed” or “unlicensed” with a correlation coefficient of 0.18.

Further investigation of these other terms may yield interesting results in future studies. The citation of “auction” appears to be more correlated with the term “licensed,” than “unlicensed,” while the term “white space” appears to be more correlated with the term “unlicensed,” than with “licensed.” Notably, the terms “allocation,” “cellular,” and “shared” appear to be more correlated with the term “licensed” than with the term “unlicensed.”

**Table 3** Correlation with "licensed" and "unlicensed" terms

| Term | *licensed* | *unlicensed* |
|---|---|---|
| *licensed* | 1.00 | 0.73 |
| *interference* | 0.10 | 0.11 |
| *filter* | 0.05 | 0.04 |
| *sensor* | 0.01 | 0.01 |
| *GHz* | 0.18 | 0.22 |
| *FCC* | 0.18 | 0.18 |
| *spectrum* | 0.18 | 0.18 |
| *WiFi* | 0.15 | 0.15 |
| *consumer* | 0.12 | 0.10 |
| *IEEE* | 0.12 | 0.13 |
| *wireless* | 0.12 | 0.11 |
| *auction* | 0.12 | 0.09 |
| *Hz* | 0.12 | 0.14 |
| *band* | 0.11 | 0.11 |
| *shared* | 0.11 | 0.09 |
| *transceiver* | 0.11 | 0.11 |
| *white space* | 0.11 | 0.12 |
| *allocation* | 0.11 | 0.09 |
| *cellular* | 0.11 | 0.09 |
| *satellite* | 0.10 | 0.09 |
| *database* | 0.10 | 0.06 |

Correlation coefficients between the invention terms are 0.17 for "interference" and "filter," -0.01 for "interference" and "sensor," and 0.07 for "filter" and "sensor." These results are not included in Table 3, but provide information on the similarity of these three invention terms in radio patents.

## 5 Results

I tested three invention terms, "interference," "filter," and "sensor," in a binary choice logit model. Odds ratios are presented along with regression results.[7] For each term of interest, I include figures that show the top firms that filed patents with these terms.

Since $log(p/(1 - p)) = \beta_1 + \beta_2 licensed_{it} + \beta_3 unlicensed_{it} + \Gamma_{it} + \Omega_{it} + \Phi_{it}$, we know that

[7] Fewer than 500,000 observations appear in regression results due to some missing values in the textual analysis.

the odds ratio, *OR*, for *licensed* is $e^{\beta_2}$. The odds ratio, *OR*, for *unlicensed* is $e^{\beta_3}$. The odds ratio is the relative increase in the odds of the dependent variable -- e.g., *interference* -- going from 0 to 1 when the independent binary variable goes from 0 to 1, holding all other variables fixed.

From this dataset, I can compare inventor attention to certain invention terms in the presence or absence of discussion of property rights. Inventor attention to "licensed" and "unlicensed" rights is studied independently in this binary logit model. Further investigation can explore the interaction effects between the two property rights terms.

**Table 4** Results summary

| | Odds Ratios | | |
|---|---|---|---|
| | *Interference* | *filter* | *sensor* |
| Odds with *licensed* term ("licensed" = 1) than without *licensed* term ("licensed" = 0) | 1.27 | 0.97 | 0.78 |
| Odds with *unlicensed* term ("unlicensed" = 1) than without *unlicensed* term ("unlicensed" = 0) | 1.55 | 0.76 | 1.40 |

Table 4 summarizes the odds ratios of the property rights terms that are regressed onto invention terms. I find that inventors who discuss "licensed" rights are 1.27 times as likely to discuss "interference," than inventors who do not discuss "licensed" rights. Inventors who discuss "unlicensed" rights are 1.55 times as likely to discuss "interference," than are inventors who do not discuss "unlicensed" rights. This result is similar for the "sensor" term, where inventors who discuss "unlicensed" rights are 1.40 times as likely to discuss "sensors" than are inventors who do not discuss "unlicensed" rights.

Inventor attention to "filter" technology shows the opposite result, however. Inventors who discuss "licensed" rights are 0.97 times as likely to discuss "filter" technology than are inventors who do not discuss "licensed" rights. Inventors who discuss "unlicensed" rights are 0.76 times as likely to discuss "filter" technology than are those who do not discuss "unlicensed" rights. Inventors who invent filters appear relatively less concerned with property rights. Possible reasons are discussed further below.

### 5.1 "Interference" Results

Equation (2) presents model estimates for the odds that an inventor who discusses "licensed" or "unlicensed" terms will discuss "interference" more than does an inventor who does not discuss "licensed" or "unlicensed" rights. Table 5 shows results that include policy, technology, or general terms. Column (4) includes results that are displayed in Eq. (2).

In Table 5, the odds ratio of inventors who have a concern about "interference" is 1.27 = $e^{0.24}$ for a unit increase in the "licensed" term. Inventors who discuss "licensed" rights are 1.27 times as likely to discuss "interference" rights than are inventors who do not discuss "licensed" rights. The odds ratio of inventors who have a concern about "interference" is 1.55 = $e^{0.44}$ for a unit increase in the "unlicensed" term. Inventors who discuss "unlicensed" rights are 1.55 times as likely to discuss "interference" than are inventors who do not discuss "unlicensed" rights.

This result that inventors who discuss property rights are more concerned with "interference" than are those who do not discuss property rights holds true after including policy, technology, and general terms as control variables. Inventors in "unlicensed" bands may indeed be more concerned with "interference" issues because unlicensed (FCC Part 15) rules do not protect users from "interference." Inventors may be solving the problem of "interference" through invention in "licensed" bands as well.

$$Prob(interference) > 0) = \Lambda(-4.47 + 0.24 licensed + 0.44 unlicensed + \Gamma_{it} + \Omega_{it} + \Phi_{it}) \qquad (2)$$

**Table 5** Logit regression: "Interference" results

| | *interference* | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *OR* with *licensed* term than without *licensed* term | 1.65 | 1.11 | 1.63 | 1.27 | 1.62 | |
| | 0.50*** | 0.10*** | 0.49*** | 0.24*** | 0.48*** | |
| | *(0.02)* | *(0.03)* | *(0.03)* | *(0.03)* | *(0.02)* | |
| *OR* with *unlicensed* term than without *unlicensed* term | 2.92 | 1.70 | 2.66 | 1.55 | | 1.93 |
| | 1.07*** | 0.53*** | 0.98*** | 0.44*** | | 0.66*** |
| | *(0.03)* | *(0.04)* | *(0.03)* | *(0.04)* | | *(0.03)* |
| Policy Terms | No | Yes | No | Yes | Yes | Yes |
| Technology Terms | No | No | Yes | Yes | Yes | Yes |
| General Terms | No | No | No | Yes | Yes | Yes |
| Constant | -1.24*** | -2.34*** | -1.30*** | -4.47*** | -4.47*** | -4.47*** |
| | *(0.01)* | *(0.01)* | *(0.01)* | *(0.11)* | *(0.11)* | *(0.11)* |
| Observations | 499,816 | 499,816 | 499,816 | 499,813 | 499,813 | 499,813 |

Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

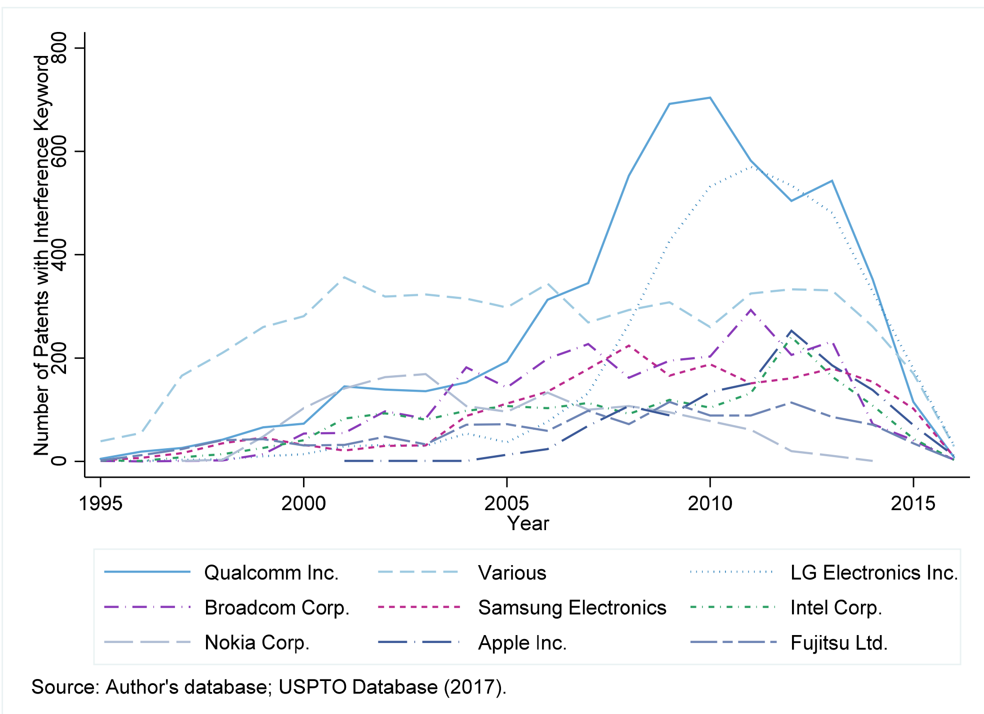


**Fig. 4** "Interference" citations by firm

Figure 4 shows graphical results for inventor attention to “interference” as separated by firm and year. The firm with the most radio patents that are concerned with “interference” is Qualcomm, Inc., followed by a large category of various unaffiliated inventors, then LG Electronics, Inc., Broadcom Corp., Samsung Electronics, Intel Corp., Nokia Corp., Apple Inc., and Fujitsu Ltd. For a list of all firms with more than 500 radio patents that cite the term “interference,” see the Data Appendix.

### 5.2 “Filter” Results

The model shows opposite results for the “filter” term. Equation (3) shows that the odds ratio of an inventor who cites “filter” is $0.97 = e^{-0.03}$ for a unit increase in the “licensed” term. The odds ratio for an inventor who discusses “filter” technology is $0.76 = e^{-0.27}$ for a unit increase in the “unlicensed” term. Table 6 shows results that include policy, technology, and general terms. Column (4) includes results that are displayed in Eq. (3).

Inventors who discuss “licensed” rights were 0.97 times as likely to discuss “filter” technology, than were those who did not discuss “licensed” rights. This result that inventors did not seem to discuss “filters” and property rights together holds true after including policy, technology, and general terms as control variables.

Inventors of “filters” may not be concerned with property rights issues because they already have certainty in emission boundaries. Inventors who build “filters” may rely on predetermined boundaries through spectrum allocations, without the need to discuss “licensed” or “unlicensed” alternatives. Further investigation is needed to consider inventors of “filter” technologies and their comparative lack of attention to property rights.

$$Prob(filter) > 0) = \Lambda(-4.48 - 0.03 licensed - 0.27 unlicensed + \Gamma_{it} + \Omega_{it} + \Phi_{it}) \quad (3)$$

**Table 6** Logit regression: "Filter" results

| | *filter* | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *OR* with *licensed* term than without *licensed* term | 1.62 | 1.04 | 1.52 | 0.97 | 0.84 | |
| | 0.48*** | 0.04 | 0.42*** | -0.03 | -0.18*** | |
| | *(0.02)* | *(0.02)* | *(0.02)* | *(0.03)* | *(0.02)* | |
| *OR* with *unlicensed* term than without *unlicensed* term | 1.14 | 0.75 | 1.08 | 0.76 | | 0.73 |
| | 0.13*** | -0.29*** | 0.08** | -0.27*** | | -0.31*** |
| | *(0.03)* | *(0.03)* | *(0.03)* | *(0.04)* | | *(0.03)* |
| Policy Terms | No | Yes | No | Yes | Yes | Yes |
| Technology Terms | No | No | Yes | Yes | Yes | Yes |
| General Terms | No | No | No | Yes | Yes | Yes |
| Constant | -0.57*** | -1.48*** | -0.63*** | -4.48*** | -4.48*** | -4.48*** |
| | *(0.01)* | *(0.01)* | *(0.01)* | *(0.10)* | *(0.10)* | *(0.10)* |
| Observations | 499,816 | 499,816 | 499,816 | 499,813 | 499,813 | 499,813 |

Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

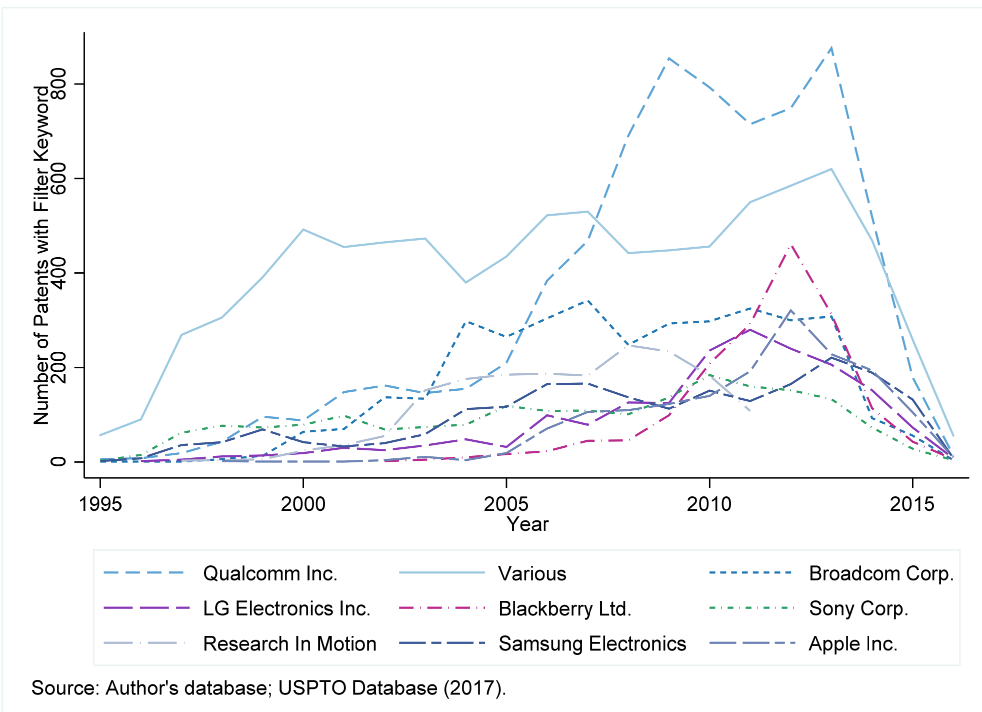


**Fig. 5** "Filter" citations by firm

Figure 5 shows graphical results for inventor attention to "filter" technologies as separated by firm and year. The firm with the most radio patents concerned with "filters" is Qualcomm, Inc., followed by various unaffiliated inventors, Broadcom Corp., LG Electronics Inc., Blackberry Ltd., Sony Corp., Research In Motion, Samsung Electronics, and Apple Inc. For a list of all firms with more than 500 radio patents that cite the term "filter," see the Data Appendix.

### 5.3 "Sensor" Results

The model shows that results for the "sensor" term are similar to those of the "interference" term. Equation (4) shows that inventors who discuss "unlicensed" rights are as likely to discuss "sensor" technology than are inventors who do not discuss "unlicensed" rights, with an odds ratio of $1.40 = e^{0.34}$. Compared to inventors who do not discuss "licensed" rights, inventors who discuss "licensed" rights discuss "sensor" technology with an odds ratio of $0.78 = e^{-0.25}$. Table 7 shows results that include policy, technology, and general terms. Column (4) includes results that are displayed in Eq. (4).

Inventors who discuss "unlicensed" rights are 1.40 times as likely to discuss "sensor" technology than are those who do not discuss "unlicensed" rights. This result holds true after including policy, technology, and general terms as control variables. Inventors in "unlicensed" bands may be relying on "unlicensed" policies to build low-power devices. An increase in radio patents that cite the term "sensor" has been increasing over the years, but the number of patents that cite "unlicensed" rights has not increased much over the years and remains smaller than "licensed" rights. Further investigation of patents for "sensors" may be able to explain these wireless technology trends.

$$Prob(sensor) > 0) = \Lambda(-4.67 - 0.25 licensed + 0.34 unlicensed + \Gamma_{it} + \Omega_{it} + \Phi_{it}) \quad (4)$$

**Table 7** Logit regression: "Sensor" results

| | *sensor* | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *OR* with *licensed* term than without *licensed* term | 1.06 | 0.88 | 0.90 | 0.78 | 0.92 | |
| | 0.06** | -0.13*** | -0.11*** | -0.25*** | -0.08*** | |
| | *(0.02)* | *(0.03)* | *(0.03)* | *(0.03)* | *(0.02)* | |
| *OR* with *unlicensed* term than without *unlicensed* term | 1.11 | 1.32 | 1.21 | 1.40 | | 1.11 |
| | 0.10*** | 0.28*** | 0.19*** | 0.34*** | | 0.10*** |
| | *(0.03)* | *(0.03)* | *(0.03)* | *(0.04)* | | *(0.03)* |
| Policy Terms | No | Yes | No | Yes | Yes | Yes |
| Technology Terms | No | No | Yes | Yes | Yes | Yes |
| General Terms | No | No | No | Yes | Yes | Yes |
| Constant | -1.12*** | -1.63*** | -1.17*** | -4.67*** | -4.67*** | -4.67*** |
| | *(0.01)* | *(0.01)* | *(0.01)* | *(0.10)* | *(0.10)* | *(0.10)* |
| Observations | 499,816 | 499,816 | 499,816 | 499,813 | 499,813 | 499,813 |

Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

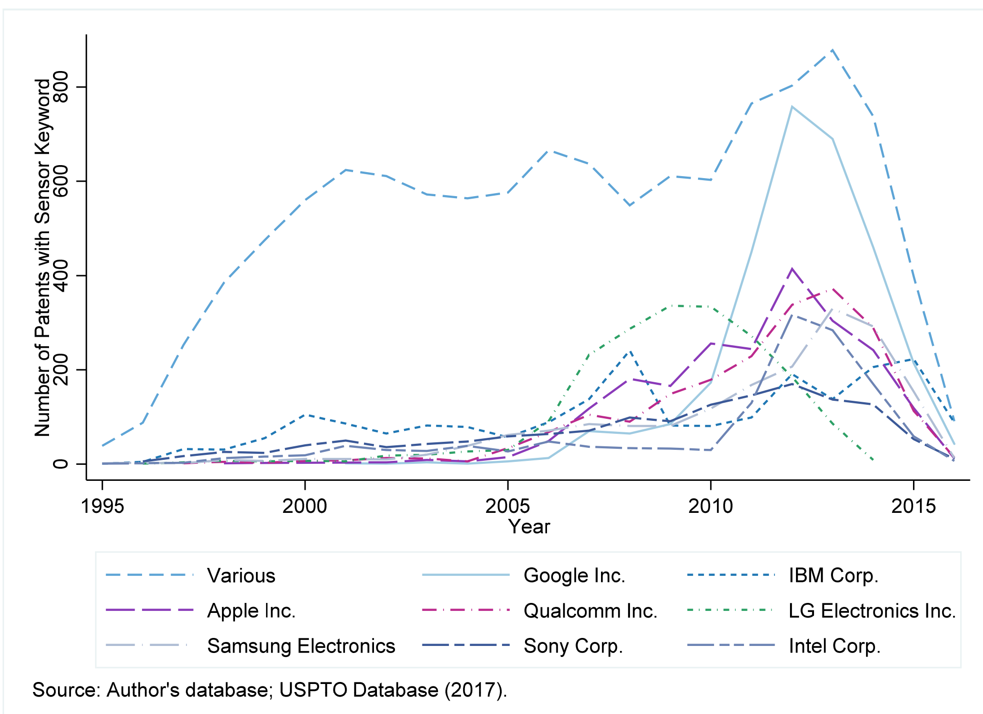


**Fig. 6** "Sensor" citations by firm

Figure 6 shows graphical results for inventor attention to “sensor” technologies as separated by firm and year. The most radio patents concerned with “sensors” were filed by various inventors, then Google Inc., IBM Corp., Apple Inc., Qualcomm Inc., LG Electronics Inc., Samsung Electronics, Sony Corp., and Intel Corp. For a list of all firms with more than 500 radio patents that cite the term “sensor,” see the Data Appendix.

### 5.4 Policy Terms

Table 8 shows model estimates for a vector of other policy terms as independent variables. Estimates for property rights terms “licensed” and “unlicensed” appear as they have been reported earlier in Tables 5, 6, and 7.

**Table 8** Logit regression: Policy terms

| | (1)<br>*interference* | (2)<br>*filter* | (3)<br>*sensor* |
|---|---|---|---|
| *licensed* | 0.10*** | 0.04 | -0.13*** |
| | *(0.03)* | *(0.02)* | *(0.03)* |
| *unlicensed* | 0.53*** | -0.29*** | 0.28*** |
| | *(0.04)* | *(0.03)* | *(0.03)* |
| *harmful* | 0.19*** | 0.50*** | 0.45*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *property* | 0.02** | 0.40*** | 0.28*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *rights* | -0.45*** | 0.17*** | 0.12*** |
| | *(0.02)* | *(0.01)* | *(0.01)* |
| *band* | 0.90*** | 0.89*** | -0.25*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *allocation* | 0.65*** | -0.30*** | -0.67*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *adjacent* | 0.64*** | 0.26*** | 0.56*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *cancellation* | 0.97*** | 0.83*** | -0.14*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *collocation* | 0.39*** | 0.31*** | 0.06 |
| | *(0.11)* | *(0.10)* | *(0.10)* |
| *monitoring* | 0.09*** | 0.29*** | 1.23*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *enforcement* | -0.49*** | 0.28*** | 0.24*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *CFR* | -0.11*** | 0.15*** | 0.09*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *FCC* | 0.49*** | 0.02 | -0.07*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *spectrum* | 0.90*** | 0.89*** | 0.08*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| Constant | -2.34*** | -1.48*** | -1.63*** |

| | | | |
|---|---|---|---|
| | *(0.01)* | *(0.01)* | *(0.01)* |
| Observations | 499,816 | 499,816 | 499,816 |

Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

These results show that terms such as "band," "cancellation," "collocation," "allocation," and "spectrum," are more likely to be cited in patents that also discuss property rights such as "licensed" or "unlicensed" rights than in patents that do not discuss property rights. Further investigation of phrases, such as "harmful interference," rather than the singular term "harmful" could reveal additional insights into inventor attention to interference.

Policy terms -- such as "CFR" for the Code of Federal Regulations, and "FCC" for the Federal Communications Commission -- were extracted as well. The Data Appendix includes model estimates for general terms such as "1927" and "1996," which may point to inventor attention to legislation such as the Radio Act of 1927 or the Communications Act of 1996. This novel dataset allows for further study of inventor attention to other matters of spectrum policy.

## 6 Conclusion

This article presents a novel dataset for textual analysis of radio patents. With a binary choice logit model, I generate odds ratios that provide estimates of inventor attention to property rights and policy terms. Such empirical findings can reveal the effects of property rights on innovation. If inventors respond to policy conditions with more productive output, evidence of inventor activity may be seen in patent claims.

I find that certain invention terms -- such as "interference" and "sensor" -- appear more frequently in patents that also contained the terms "licensed" and "unlicensed" than in patents that did not mention those property rights terms. These empirical findings suggest that inventors of radio "fences" pay attention to property rights.

In future studies, the causal effect of property rights on invention can be further confirmed using this dataset after applying more sophisticated classification methods that extract natural language meaning from patent text.

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## Data Appendix

**Table A1** Descriptive statistics

| *Variable* | Obs. | Mean | S.D. | Min | Max |
|---|---|---|---|---|---|
| *Firm*[8] | 499,964 | 23,126 | 11,978 | 1 | 45,606 |
| *Year*[9] | 499,852 | 267 | 168 | 1 | 451 |
| *1927* | 500,000 | 0.02 | 0.14 | 0 | 1 |
| *1996* | 500,000 | 0.39 | 0.49 | 0 | 1 |
| *AC* | 500,000 | 0.96 | 0.20 | 0 | 1 |
| *adjacent* | 500,000 | 0.31 | 0.46 | 0 | 1 |
| *allocation* | 500,000 | 0.13 | 0.33 | 0 | 1 |
| *AM* | 500,000 | 0.54 | 0.50 | 0 | 1 |
| *analog* | 500,000 | 0.37 | 0.48 | 0 | 1 |
| *antenna* | 500,000 | 0.39 | 0.49 | 0 | 1 |
| *auction* | 500,000 | 0.01 | 0.10 | 0 | 1 |
| *band* | 500,000 | 0.54 | 0.50 | 0 | 1 |
| *base* | 499,997 | 0.90 | 0.29 | 0 | 1 |
| *bluetooth* | 500,000 | 0.01 | 0.09 | 0 | 1 |
| *broadcast* | 499,997 | 0.22 | 0.42 | 0 | 1 |
| *cancellation* | 500,000 | 0.04 | 0.20 | 0 | 1 |
| *carrier* | 500,000 | 0.36 | 0.48 | 0 | 1 |
| *CDMA* | 500,000 | 0.18 | 0.38 | 0 | 1 |
| *cell* | 500,000 | 0.58 | 0.49 | 0 | 1 |
| *cellular* | 500,000 | 0.35 | 0.48 | 0 | 1 |
| *CFR* | 500,000 | 0.02 | 0.13 | 0 | 1 |
| *channel* | 500,000 | 0.49 | 0.50 | 0 | 1 |
| *CINR* | 500,000 | 0.00 | 0.05 | 0 | 1 |
| *coaxial* | 500,000 | 0.11 | 0.32 | 0 | 1 |
| *code* | 500,000 | 0.62 | 0.48 | 0 | 1 |
| *collocation* | 500,000 | 0.00 | 0.03 | 0 | 1 |
| *computer* | 500,000 | 0.65 | 0.48 | 0 | 1 |
| *consumer* | 500,000 | 0.13 | 0.33 | 0 | 1 |
| *current* | 500,000 | 0.73 | 0.45 | 0 | 1 |
| *database* | 500,000 | 0.27 | 0.45 | 0 | 1 |
| *DC* | 500,000 | 0.28 | 0.45 | 0 | 1 |
| *digital* | 500,000 | 0.60 | 0.49 | 0 | 1 |
| *downlink* | 500,000 | 0.09 | 0.29 | 0 | 1 |
| *edge* | 499,997 | 0.42 | 0.49 | 0 | 1 |
| *electromagnetic* | 500,000 | 0.22 | 0.42 | 0 | 1 |
| *enforcement* | 500,000 | 0.03 | 0.16 | 0 | 1 |
| *error* | 500,000 | 0.36 | 0.48 | 0 | 1 |

[8] Firms are identified with numbers between 1 and 45,606.

[9] Years are coded in Stata 12.0, ranging from 1976 to 2016. Note: Key term extraction counted terms in the presence of a plural "s" or not. Several terms were counted with different spellings. Cancellation includes "cancellation" or "cancelation," CFR includes "CFR," "C.F.R.," or "Code of Federal," FCC includes "Federal Communications Commission" or "FCC," TV includes "television" or "TV," white space includes "white spaces" or "white space," WiFi includes "Wi-Fi" or "WiFi," and 3G includes "3G" or "3GPP."

| | | | | | |
|---|---|---|---|---|---|
| *FCC* | 500,000 | 0.03 | 0.16 | 0 | 1 |
| *FDMA* | 500,000 | 0.06 | 0.23 | 0 | 1 |
| *federal* | 500,000 | 0.01 | 0.09 | 0 | 1 |
| *fiber* | 500,000 | 0.22 | 0.41 | 0 | 1 |
| *filter* | 500,000 | 0.36 | 0.48 | 0 | 1 |
| *5G* | 500,000 | 0.03 | 0.18 | 0 | 1 |
| *fixed* | 500,000 | 0.47 | 0.50 | 0 | 1 |
| *FM* | 500,000 | 0.07 | 0.26 | 0 | 1 |
| *4G* | 500,000 | 0.05 | 0.23 | 0 | 1 |
| *frequency* | 500,000 | 0.72 | 0.45 | 0 | 1 |
| *GHz* | 500,000 | 0.11 | 0.31 | 0 | 1 |
| *gigahertz* | 500,000 | 0.01 | 0.10 | 0 | 1 |
| *GPS* | 500,000 | 0.16 | 0.36 | 0 | 1 |
| *ground* | 500,000 | 0.37 | 0.48 | 0 | 1 |
| *GSM* | 500,000 | 0.16 | 0.36 | 0 | 1 |
| *handover* | 499,997 | 0.04 | 0.20 | 0 | 1 |
| *harmful* | 500,000 | 0.02 | 0.15 | 0 | 1 |
| *HD* | 500,000 | 0.10 | 0.30 | 0 | 1 |
| *hertz* | 500,000 | 0.04 | 0.20 | 0 | 1 |
| *high* | 500,000 | 0.83 | 0.38 | 0 | 1 |
| *Hz* | 500,000 | 0.28 | 0.45 | 0 | 1 |
| *IEEE* | 500,000 | 0.32 | 0.46 | 0 | 1 |
| *industrial* | 500,000 | 0.06 | 0.24 | 0 | 1 |
| *infrared* | 500,000 | 0.23 | 0.42 | 0 | 1 |
| *interference* | 500,000 | 0.23 | 0.42 | 0 | 1 |
| *internet* | 500,000 | 0.13 | 0.34 | 0 | 1 |
| *kHz* | 500,000 | 0.07 | 0.26 | 0 | 1 |
| *kilohertz* | 500,000 | 0.01 | 0.10 | 0 | 1 |
| *Kv* | 500,000 | 0.01 | 0.09 | 0 | 1 |
| *laser* | 500,000 | 0.14 | 0.35 | 0 | 1 |
| *legal* | 500,000 | 0.06 | 0.23 | 0 | 1 |
| *licensed* | 500,000 | 0.03 | 0.18 | 0 | 1 |
| *load* | 499,997 | 0.55 | 0.5 | 0 | 1 |
| *low* | 500,000 | 0.99 | 0.11 | 0 | 1 |
| *LTE* | 500,000 | 0.10 | 0.30 | 0 | 1 |
| *market* | 500,000 | 0.13 | 0.34 | 0 | 1 |
| *medical* | 500,000 | 0.13 | 0.34 | 0 | 1 |
| *megahertz* | 500,000 | 0.02 | 0.13 | 0 | 1 |
| *MHz* | 500,000 | 0.17 | 0.38 | 0 | 1 |
| *microphone* | 499,997 | 0.18 | 0.38 | 0 | 1 |
| *microwave* | 500,000 | 0.12 | 0.32 | 0 | 1 |
| *millisecond* | 500,000 | 0.06 | 0.25 | 0 | 1 |
| *MIMO* | 500,000 | 0.04 | 0.20 | 0 | 1 |
| *mobile* | 500,000 | 0.48 | 0.50 | 0 | 1 |
| *monitoring* | 500,000 | 0.27 | 0.44 | 0 | 1 |
| *multiplex* | 499,997 | 0.17 | 0.38 | 0 | 1 |
| *OFDMA* | 500,000 | 0.03 | 0.18 | 0 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| *ohms* | 500,000 | 0.02 | 0.15 | 0 | 1 |
| *PCS* | 500,000 | 0.04 | 0.21 | 0 | 1 |
| *positioning* | 500,000 | 0.21 | 0.41 | 0 | 1 |
| *power* | 500,000 | 0.65 | 0.48 | 0 | 1 |
| *processor* | 500,000 | 0.60 | 0.49 | 0 | 1 |
| *property* | 500,000 | 0.13 | 0.34 | 0 | 1 |
| *radar* | 500,000 | 0.04 | 0.19 | 0 | 1 |
| *receiver* | 500,000 | 0.44 | 0.50 | 0 | 1 |
| *regulatory* | 500,000 | 0.04 | 0.20 | 0 | 1 |
| *relay* | 500,000 | 0.13 | 0.34 | 0 | 1 |
| *resistor* | 500,000 | 0.09 | 0.28 | 0 | 1 |
| *retail* | 500,000 | 0.05 | 0.21 | 0 | 1 |
| *RF* | 500,000 | 0.50 | 0.50 | 0 | 1 |
| *rights* | 500,000 | 0.07 | 0.26 | 0 | 1 |
| *RSSI* | 500,000 | 0.02 | 0.15 | 0 | 1 |
| *satellite* | 500,000 | 0.20 | 0.40 | 0 | 1 |
| *sensor* | 500,000 | 0.31 | 0.46 | 0 | 1 |
| *shared* | 500,000 | 0.20 | 0.40 | 0 | 1 |
| *signal* | 500,000 | 0.84 | 0.36 | 0 | 1 |
| *spectrum* | 500,000 | 0.19 | 0.39 | 0 | 1 |
| *station* | 499,997 | 0.49 | 0.5 | 0 | 1 |
| *TDMA* | 500,000 | 0.09 | 0.29 | 0 | 1 |
| *telephone* | 500,000 | 0.34 | 0.47 | 0 | 1 |
| *terrestrial* | 500,000 | 0.05 | 0.22 | 0 | 1 |
| *3G* | 500,000 | 0.16 | 0.37 | 0 | 1 |
| *threshold* | 500,000 | 0.29 | 0.46 | 0 | 1 |
| *tower* | 500,000 | 0.05 | 0.21 | 0 | 1 |
| *transceiver* | 500,000 | 0.24 | 0.43 | 0 | 1 |
| *transmitter* | 500,000 | 0.35 | 0.48 | 0 | 1 |
| *TV* | 500,000 | 0.21 | 0.41 | 0 | 1 |
| *UMTS* | 500,000 | 0.09 | 0.29 | 0 | 1 |
| *unlicensed* | 500,000 | 0.02 | 0.13 | 0 | 1 |
| *uplink* | 500,000 | 0.09 | 0.29 | 0 | 1 |
| *v* | 500,000 | 0.97 | 0.17 | 0 | 1 |
| *volts* | 500,000 | 0.05 | 0.22 | 0 | 1 |
| *wave* | 500,000 | 0.50 | 0.50 | 0 | 1 |
| *WCDMA* | 500,000 | 0.05 | 0.22 | 0 | 1 |
| *white space* | 500,000 | 0.00 | 0.06 | 0 | 1 |
| *WiFi* | 500,000 | 0.12 | 0.33 | 0 | 1 |
| *WiMax* | 500,000 | 0.03 | 0.16 | 0 | 1 |
| *wireless* | 500,000 | 0.57 | 0.49 | 0 | 1 |
| *xray* | 500,000 | 0.00 | 0.02 | 0 | 1 |

**Table A2** Mean value of key terms in year's patents (sorted by 2016)

| Terms | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *low* | 0.99 | 0.93 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 0.98 | 0.97 | 0.97 |
| *AC* | 0.96 | 0.90 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.96 | 0.95 | 0.96 |
| *v* | 0.98 | 0.91 | 0.98 | 0.97 | 0.97 | 0.97 | 0.97 | 0.96 | 0.96 | 0.95 | 0.95 |
| *base* | 0.91 | 0.86 | 0.93 | 0.93 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.93 | 0.94 |
| *signal* | 0.84 | 0.79 | 0.85 | 0.86 | 0.86 | 0.87 | 0.88 | 0.88 | 0.88 | 0.87 | 0.89 |
| *current* | 0.73 | 0.69 | 0.74 | 0.74 | 0.75 | 0.75 | 0.76 | 0.77 | 0.77 | 0.77 | 0.82 |
| *high* | 0.83 | 0.78 | 0.83 | 0.83 | 0.84 | 0.84 | 0.84 | 0.84 | 0.84 | 0.83 | 0.81 |
| *computer* | 0.64 | 0.62 | 0.68 | 0.68 | 0.69 | 0.71 | 0.74 | 0.76 | 0.77 | 0.76 | 0.81 |
| *processor* | 0.58 | 0.57 | 0.64 | 0.64 | 0.67 | 0.69 | 0.73 | 0.74 | 0.75 | 0.75 | 0.81 |
| *wireless* | 0.58 | 0.56 | 0.64 | 0.64 | 0.66 | 0.68 | 0.72 | 0.73 | 0.74 | 0.74 | 0.78 |
| *code* | 0.62 | 0.60 | 0.65 | 0.64 | 0.66 | 0.67 | 0.69 | 0.69 | 0.71 | 0.71 | 0.76 |
| *digital* | 0.59 | 0.57 | 0.61 | 0.61 | 0.62 | 0.64 | 0.66 | 0.67 | 0.69 | 0.70 | 0.75 |
| *AM* | 0.52 | 0.51 | 0.55 | 0.56 | 0.59 | 0.60 | 0.62 | 0.64 | 0.66 | 0.66 | 0.72 |
| *load* | 0.55 | 0.53 | 0.56 | 0.57 | 0.59 | 0.60 | 0.62 | 0.61 | 0.62 | 0.62 | 0.70 |
| *wave* | 0.49 | 0.47 | 0.51 | 0.51 | 0.50 | 0.51 | 0.51 | 0.52 | 0.54 | 0.56 | 0.64 |
| *frequency* | 0.71 | 0.68 | 0.73 | 0.74 | 0.74 | 0.74 | 0.74 | 0.75 | 0.73 | 0.71 | 0.63 |
| *cell* | 0.57 | 0.55 | 0.59 | 0.61 | 0.62 | 0.64 | 0.66 | 0.65 | 0.65 | 0.65 | 0.63 |
| *power* | 0.65 | 0.61 | 0.65 | 0.67 | 0.67 | 0.67 | 0.68 | 0.69 | 0.68 | 0.68 | 0.62 |
| *mobile* | 0.45 | 0.44 | 0.50 | 0.51 | 0.53 | 0.56 | 0.59 | 0.59 | 0.60 | 0.60 | 0.57 |
| *edge* | 0.42 | 0.40 | 0.42 | 0.43 | 0.44 | 0.45 | 0.44 | 0.44 | 0.47 | 0.48 | 0.57 |
| *band* | 0.54 | 0.51 | 0.56 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.56 | 0.52 |
| *RF* | 0.52 | 0.49 | 0.52 | 0.53 | 0.54 | 0.54 | 0.55 | 0.56 | 0.55 | 0.54 | 0.46 |
| *station* | 0.47 | 0.46 | 0.50 | 0.51 | 0.52 | 0.52 | 0.53 | 0.52 | 0.50 | 0.49 | 0.46 |
| *fixed* | 0.47 | 0.44 | 0.47 | 0.48 | 0.48 | 0.47 | 0.47 | 0.46 | 0.46 | 0.47 | 0.45 |
| *channel* | 0.48 | 0.46 | 0.50 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.50 | 0.49 | 0.44 |
| *fiber* | 0.20 | 0.20 | 0.22 | 0.23 | 0.23 | 0.23 | 0.26 | 0.27 | 0.29 | 0.30 | 0.43 |
| *database* | 0.28 | 0.28 | 0.29 | 0.28 | 0.28 | 0.31 | 0.33 | 0.33 | 0.34 | 0.35 | 0.42 |
| *cellular* | 0.32 | 0.32 | 0.35 | 0.35 | 0.37 | 0.40 | 0.43 | 0.43 | 0.43 | 0.43 | 0.42 |
| *electromagnetic* | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.24 | 0.24 | 0.25 | 0.28 | 0.30 | 0.41 |
| *sensor* | 0.30 | 0.29 | 0.30 | 0.32 | 0.33 | 0.35 | 0.37 | 0.40 | 0.41 | 0.42 | 0.41 |
| *receiver* | 0.44 | 0.41 | 0.46 | 0.46 | 0.45 | 0.45 | 0.46 | 0.46 | 0.45 | 0.45 | 0.41 |
| *threshold* | 0.28 | 0.27 | 0.30 | 0.31 | 0.32 | 0.33 | 0.35 | 0.37 | 0.37 | 0.38 | 0.39 |
| *IEEE* | 0.33 | 0.32 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 | 0.38 | 0.37 | 0.37 | 0.36 |
| *ground* | 0.38 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 | 0.37 | 0.37 | 0.35 |
| *error* | 0.36 | 0.35 | 0.37 | 0.36 | 0.36 | 0.34 | 0.35 | 0.35 | 0.35 | 0.34 | 0.34 |
| *analog* | 0.37 | 0.36 | 0.37 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.36 | 0.36 | 0.34 |
| *antenna* | 0.39 | 0.37 | 0.40 | 0.42 | 0.41 | 0.41 | 0.42 | 0.41 | 0.40 | 0.40 | 0.34 |
| *telephone* | 0.34 | 0.33 | 0.34 | 0.33 | 0.33 | 0.34 | 0.36 | 0.35 | 0.35 | 0.34 | 0.34 |
| *filter* | 0.37 | 0.35 | 0.36 | 0.37 | 0.37 | 0.36 | 0.36 | 0.36 | 0.36 | 0.35 | 0.33 |
| *carrier* | 0.36 | 0.35 | 0.37 | 0.38 | 0.38 | 0.40 | 0.40 | 0.40 | 0.39 | 0.37 | 0.33 |
| *transmitter* | 0.35 | 0.33 | 0.36 | 0.36 | 0.35 | 0.35 | 0.34 | 0.35 | 0.34 | 0.33 | 0.29 |
| *Wi-Fi* | 0.08 | 0.10 | 0.13 | 0.14 | 0.17 | 0.20 | 0.24 | 0.27 | 0.30 | 0.30 | 0.29 |
| *monitoring* | 0.27 | 0.26 | 0.27 | 0.26 | 0.28 | 0.27 | 0.28 | 0.29 | 0.29 | 0.29 | 0.29 |
| *adjacent* | 0.31 | 0.29 | 0.30 | 0.30 | 0.30 | 0.31 | 0.30 | 0.31 | 0.30 | 0.31 | 0.29 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *shared* | 0.18 | 0.19 | 0.21 | 0.20 | 0.22 | 0.24 | 0.26 | 0.27 | 0.27 | 0.28 | 0.27 |
| *DC* | 0.28 | 0.26 | 0.27 | 0.28 | 0.30 | 0.30 | 0.30 | 0.31 | 0.30 | 0.30 | 0.27 |
| *transceiver* | 0.22 | 0.22 | 0.26 | 0.26 | 0.26 | 0.27 | 0.30 | 0.32 | 0.31 | 0.31 | 0.27 |
| *infrared* | 0.22 | 0.22 | 0.25 | 0.26 | 0.27 | 0.27 | 0.28 | 0.30 | 0.29 | 0.28 | 0.26 |
| *GPS* | 0.14 | 0.13 | 0.16 | 0.17 | 0.18 | 0.20 | 0.22 | 0.24 | 0.25 | 0.26 | 0.26 |
| *microphone* | 0.17 | 0.17 | 0.18 | 0.18 | 0.20 | 0.21 | 0.24 | 0.25 | 0.26 | 0.26 | 0.26 |
| *market* | 0.14 | 0.14 | 0.13 | 0.12 | 0.13 | 0.13 | 0.13 | 0.13 | 0.15 | 0.16 | 0.26 |
| *Hz* | 0.29 | 0.26 | 0.27 | 0.28 | 0.28 | 0.28 | 0.27 | 0.27 | 0.27 | 0.26 | 0.24 |
| *TV* | 0.21 | 0.21 | 0.21 | 0.21 | 0.22 | 0.23 | 0.25 | 0.25 | 0.25 | 0.25 | 0.24 |
| *positioning* | 0.20 | 0.19 | 0.21 | 0.23 | 0.22 | 0.23 | 0.24 | 0.26 | 0.26 | 0.26 | 0.24 |
| *1996* | 0.41 | 0.35 | 0.32 | 0.31 | 0.30 | 0.27 | 0.25 | 0.24 | 0.23 | 0.22 | 0.22 |
| *3G* | 0.14 | 0.14 | 0.18 | 0.20 | 0.23 | 0.24 | 0.26 | 0.25 | 0.25 | 0.25 | 0.22 |
| *satellite* | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.22 | 0.23 | 0.23 | 0.24 | 0.21 |
| *broadcast* | 0.22 | 0.22 | 0.24 | 0.24 | 0.25 | 0.25 | 0.24 | 0.24 | 0.25 | 0.23 | 0.21 |
| *LTE* | 0.02 | 0.04 | 0.09 | 0.13 | 0.16 | 0.19 | 0.21 | 0.22 | 0.23 | 0.24 | 0.20 |
| *interference* | 0.23 | 0.22 | 0.24 | 0.25 | 0.25 | 0.24 | 0.23 | 0.23 | 0.22 | 0.22 | 0.19 |
| *internet* | 0.13 | 0.13 | 0.15 | 0.15 | 0.16 | 0.17 | 0.18 | 0.18 | 0.18 | 0.18 | 0.19 |
| *CDMA* | 0.17 | 0.17 | 0.19 | 0.20 | 0.20 | 0.22 | 0.23 | 0.22 | 0.22 | 0.22 | 0.18 |
| *GSM* | 0.14 | 0.14 | 0.17 | 0.18 | 0.19 | 0.21 | 0.22 | 0.21 | 0.21 | 0.21 | 0.18 |
| *consumer* | 0.12 | 0.14 | 0.14 | 0.13 | 0.14 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 0.18 |
| *allocation* | 0.10 | 0.12 | 0.14 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.15 | 0.16 | 0.17 |
| *spectrum* | 0.19 | 0.17 | 0.18 | 0.19 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.17 |
| *laser* | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 |
| *property* | 0.14 | 0.14 | 0.14 | 0.13 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.14 | 0.16 |
| *4G* | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.08 | 0.10 | 0.10 | 0.12 | 0.12 | 0.15 |
| *multiplex* | 0.16 | 0.16 | 0.19 | 0.19 | 0.19 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.15 |
| *medical* | 0.14 | 0.13 | 0.13 | 0.14 | 0.14 | 0.13 | 0.13 | 0.14 | 0.14 | 0.14 | 0.14 |
| *MHz* | 0.18 | 0.16 | 0.16 | 0.17 | 0.18 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 | 0.14 |
| *HD* | 0.09 | 0.10 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.14 | 0.15 | 0.15 | 0.14 |
| *relay* | 0.13 | 0.12 | 0.13 | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.15 | 0.14 |
| *UMTS* | 0.08 | 0.08 | 0.11 | 0.12 | 0.13 | 0.13 | 0.14 | 0.13 | 0.13 | 0.12 | 0.11 |
| *coaxial* | 0.10 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.14 | 0.13 | 0.12 | 0.11 |
| *microwave* | 0.10 | 0.10 | 0.12 | 0.13 | 0.13 | 0.13 | 0.13 | 0.14 | 0.13 | 0.12 | 0.11 |
| *downlink* | 0.07 | 0.08 | 0.11 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.12 | 0.12 | 0.10 |
| *rights* | 0.07 | 0.08 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 |
| *GHz* | 0.12 | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 | 0.11 | 0.09 |
| *TDMA* | 0.08 | 0.08 | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.09 |
| *uplink* | 0.07 | 0.08 | 0.11 | 0.12 | 0.13 | 0.13 | 0.13 | 0.13 | 0.12 | 0.11 | 0.09 |
| *resistor* | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 |
| *legal* | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.08 |
| *FDMA* | 0.04 | 0.05 | 0.07 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 |
| *tower* | 0.04 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| *industrial* | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| *WCDMA* | 0.06 | 0.05 | 0.06 | 0.06 | 0.07 | 0.08 | 0.07 | 0.07 | 0.08 | 0.08 | 0.06 |
| *FM* | 0.07 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 | 0.06 |
| *kHz* | 0.07 | 0.07 | 0.06 | 0.07 | 0.07 | 0.06 | 0.06 | 0.07 | 0.06 | 0.07 | 0.06 |
| *MIMO* | 0.03 | 0.03 | 0.05 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.06 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *retail* | 0.05 | 0.05 | 0.05 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 |
| *millisecond* | 0.06 | 0.06 | 0.06 | 0.07 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 |
| *5G* | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 |
| *OFDMA* | 0.02 | 0.03 | 0.05 | 0.07 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 |
| *WiMax* | 0.02 | 0.03 | 0.04 | 0.03 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| *terrestrial* | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 |
| *radar* | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 |
| *enforcement* | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 |
| *handover* | 0.04 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.07 | 0.06 | 0.06 | 0.06 | 0.04 |
| *cancellation* | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 |
| *licensed* | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| *regulatory* | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| *CFR* | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 |
| *volts* | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 |
| *hertz* | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 |
| *RSSI* | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.03 |
| *PCS* | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 |
| *FCC* | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 |
| *1927* | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 | 0.03 |
| *unlicensed* | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| *harmful* | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| *ohms* | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| *federal* | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *gigahertz* | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *bluetooth* | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *megahertz* | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| *auction* | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *Kv* | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *kilohertz* | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *white space* | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| *CINR* | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *collocation* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *xray* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Source: Author's calculations, sorted by year 2016. USPTO Full-Text Database (2017).

**Table A3** Logit regression: Technology terms

| | (1)<br>*interference* | (2)<br>*filter* | (3)<br>*sensor* |
|---|---|---|---|
| *licensed* | 0.49*** | 0.42*** | -0.11*** |
| | *(0.03)* | *(0.02)* | *(0.03)* |
| *unlicensed* | 0.98*** | 0.08** | 0.19*** |
| | *(0.03)* | *(0.03)* | *(0.03)* |
| *3G* | 0.13*** | -0.09*** | -0.68*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *4G* | -0.08*** | 0.30*** | 0.40*** |
| | *(0.02)* | *(0.01)* | *(0.02)* |
| *5G* | 0.11*** | 0.61*** | 0.48*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *LTE* | 0.29*** | -0.13*** | -0.29*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *WiMax* | -0.23*** | 0.05*** | -0.05** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *WiFi* | -0.26*** | -0.01 | 0.52*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *GPS* | -0.04*** | 0.07*** | 1.21*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *CDMA* | 0.66*** | 0.34*** | -0.57*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *MIMO* | 1.61*** | 0.47*** | -0.75*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| Constant | -1.30*** | -0.63*** | -1.17*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| Observations | 499,816 | 499,816 | 499,816 |

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

**Table A4** Logit regression: All terms

| | (1)<br>*interference* | (2)<br>*filter* | (3)<br>*sensor* |
|---|---|---|---|
| *licensed* | 0.24*** | -0.03 | -0.25*** |
| | *(0.03)* | *(0.03)* | *(0.03)* |
| *unlicensed* | 0.44*** | -0.27*** | 0.34*** |
| | *(0.04)* | *(0.04)* | *(0.04)* |
| *3G* | -0.01 | 0.01 | -0.41*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *4G* | -0.07*** | 0.05*** | 0.19*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *5G* | 0.01 | 0.12*** | 0.20*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *LTE* | 0.07*** | -0.01 | -0.03 |
| | *(0.02)* | *(0.01)* | *(0.02)* |
| *WiMax* | -0.03 | 0.04* | -0.05** |
| | *(0.03)* | *(0.02)* | *(0.02)* |
| *WiFi* | -0.05*** | -0.08*** | 0.44*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *GPS* | -0.09*** | -0.11*** | 0.93*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *CDMA* | 0.23*** | 0.03** | -0.30*** |
| | *(0.01)* | *(0.01)* | *(0.02)* |
| *MIMO* | 0.47*** | 0.05*** | -0.17*** |
| | *(0.02)* | *(0.02)* | *(0.03)* |
| *spectrum* | 0.51*** | 0.52*** | -0.10*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *allocation* | 0.17*** | -0.27*** | -0.30*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *band* | 0.28*** | 0.49*** | -0.32*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *cancellation* | 0.69*** | 0.57*** | -0.27*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *CFR* | -0.02 | -0.05** | 0.01 |
| | *(0.03)* | *(0.02)* | *(0.02)* |
| *FCC* | 0.29*** | -0.17*** | -0.16*** |
| | *(0.02)* | *(0.01)* | *(0.02)* |
| *adjacent* | 0.43*** | 0.04*** | 0.31*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *collocation* | 0.43*** | 0.39*** | -0.07 |
| | *(0.12)* | *(0.11)* | *(0.12)* |
| *harmful* | 0.18*** | 0.31*** | 0.23*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *monitoring* | 0.05*** | 0.04*** | 0.88*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *enforcement* | -0.22*** | 0.44*** | 0.00 |
| | *(0.03)* | *(0.02)* | *(0.02)* |
| *property* | 0.00 | 0.20*** | 0.09*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *rights* | -0.10*** | 0.03** | -0.02 |

| | | | |
|---|---|---|---|
| | *(0.02)* | *(0.01)* | *(0.01)* |
| *1927* | 0.13*** | 0.12*** | 0.06** |
| | *(0.03)* | *(0.02)* | *(0.03)* |
| *1996* | 0.01 | 0.05*** | 0.19*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *AC* | 0.00 | -0.09*** | -0.07*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *AM* | -0.18*** | 0.12*** | -0.21*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *analog* | 0.02** | 0.63*** | 0.21*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *antenna* | 0.29*** | 0.02** | -0.05*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *auction* | -0.06 | 0.13*** | -0.16*** |
| | *(0.05)* | *(0.03)* | *(0.04)* |
| *base* | 0.01 | 0.23*** | 0.14*** |
| | *(0.02)* | *(0.01)* | *(0.01)* |
| *bluetooth* | 0.26*** | -0.28*** | 0.45*** |
| | *(0.04)* | *(0.04)* | *(0.04)* |
| *broadcast* | 0.09*** | -0.14*** | -0.26*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *carrier* | 0.20*** | 0.14*** | -0.23*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *cell* | 0.05*** | -0.01 | 0.02** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *cellular* | 0.11*** | 0.20*** | -0.13*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *channel* | 0.38*** | 0.10*** | -0.25*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *CINR* | 1.31*** | -0.78*** | -0.80*** |
| | *(0.09)* | *(0.08)* | *(0.14)* |
| *coaxial* | 0.01 | -0.08*** | -0.30*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *code* | -0.04*** | -0.06*** | -0.19*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *computer* | -0.13*** | -0.14*** | 0.28*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *consumer* | -0.01 | 0.01 | -0.02* |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *current* | -0.16*** | -0.03*** | 0.02** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *database* | -0.36*** | 0.11*** | -0.08*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *DC* | -0.06*** | 0.36*** | 0.07*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *digital* | -0.05*** | 0.22*** | -0.03*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *downlink* | 0.41*** | -0.24*** | -0.32*** |
| | *(0.02)* | *(0.02)* | *(0.03)* |
| *edge* | 0.18*** | 0.04*** | 0.06*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |

| | | | |
|---|---|---|---|
| *electromagnetic* | 0.46*** | -0.16*** | 0.17*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *error* | 0.35*** | 0.25*** | 0.00 |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *FDMA* | 0.20*** | -0.26*** | 0.01 |
| | *(0.03)* | *(0.02)* | *(0.03)* |
| *federal* | -0.10** | -0.20*** | 0.00 |
| | *(0.05)* | *(0.04)* | *(0.04)* |
| *fiber* | -0.03*** | -0.01 | -0.05*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *fixed* | 0.12*** | 0.04*** | 0.25*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *FM* | 0.10*** | 0.15*** | 0.11*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *frequency* | 0.35*** | 0.16*** | 0.05*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *GHz* | 0.15*** | -0.14*** | -0.24*** |
| | *(0.01)* | *(0.01)* | *(0.02)* |
| *gigahertz* | -0.07* | -0.16*** | -0.24*** |
| | *(0.04)* | *(0.04)* | *(0.04)* |
| *ground* | 0.11*** | 0.26*** | 0.08*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *GSM* | -0.32*** | 0.04*** | 0.00 |
| | *(0.01)* | *(0.01)* | *(0.02)* |
| *handover* | 0.21*** | -0.26*** | -0.73*** |
| | *(0.02)* | *(0.02)* | *(0.03)* |
| *HD* | -0.06*** | -0.08*** | -0.04*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *hertz* | 0.08*** | 0.11*** | -0.01 |
| | *(0.03)* | *(0.03)* | *(0.03)* |
| *high* | 0.20*** | 0.41*** | 0.08*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *Hz* | 0.06*** | 0.34*** | 0.05*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *IEEE* | 0.07*** | 0.09*** | -0.18*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *industrial* | 0.09*** | 0.06*** | 0.59*** |
| | *(0.02)* | *(0.01)* | *(0.01)* |
| *infrared* | -0.15*** | 0.04*** | 0.56*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *internet* | -0.19*** | 0.07*** | 0.00 |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *kHz* | 0.07*** | 0.18*** | 0.15*** |
| | *(0.02)* | *(0.01)* | *(0.02)* |
| *kilohertz* | 0.07* | 0.24*** | 0.07* |
| | *(0.04)* | *(0.04)* | *(0.04)* |
| *Kv* | 0.15*** | 0.30*** | -0.03 |
| | *(0.04)* | *(0.04)* | *(0.04)* |
| *laser* | 0.07*** | 0.18*** | 0.45*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *legal* | -0.09*** | -0.07*** | -0.27*** |

| | | | |
|---|---|---|---|
| | *(0.02)* | *(0.01)* | *(0.02)* |
| *load* | -0.09*** | 0.00 | 0.07*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *low* | 1.20*** | 1.45*** | 1.37*** |
| | *(0.11)* | *(0.1)* | *(0.1)* |
| *market* | -0.03*** | 0.05*** | -0.02* |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *medical* | 0.05*** | 0.17*** | 0.63*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *megahertz* | 0.05 | 0.08** | -0.04 |
| | *(0.03)* | *(0.03)* | *(0.04)* |
| *MHz* | 0.04*** | 0.04*** | -0.23*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *microphone* | -0.31*** | 0.05*** | 0.53*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *microwave* | -0.19*** | -0.17*** | -0.04*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *millisecond* | 0.04*** | 0.05*** | 0.07*** |
| | *(0.01)* | *(0.01)* | *(0.02)* |
| *mobile* | 0.09*** | 0 | -0.08*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *multiplex* | 0.28*** | 0.16*** | -0.22*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *OFDMA* | -0.26*** | 0.14*** | 0.10** |
| | *(0.03)* | *(0.03)* | *(0.04)* |
| *ohms* | 0.01 | -0.11*** | -0.03 |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *PCS* | -0.06*** | 0.11*** | -0.46*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *positioning* | 0.17*** | -0.05*** | 0.50*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *power* | 0.37*** | -0.05*** | 0.53*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *processor* | -0.20*** | 0.09*** | 0.22*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *radar* | 0.06*** | 0.11*** | 0.71*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *receiver* | 0.23*** | 0.18*** | 0.06*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *regulatory* | 0.31*** | 0.32*** | 0.07*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *relay* | 0.15*** | -0.13*** | 0.38*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *resistor* | 0.07*** | 0.39*** | 0.17*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *retail* | -0.11*** | -0.06*** | 0.16*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *RF* | -0.06*** | 0.04*** | -0.04*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *RSSI* | 0.68*** | 0.22*** | -0.03 |
| | *(0.02)* | *(0.02)* | *(0.03)* |

| | | | |
|---|---|---|---|
| *satellite* | -0.21*** | 0.08*** | -0.15*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *shared* | -0.03*** | 0.09*** | -0.15*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *signal* | 0.34*** | 0.13*** | 0.65*** |
| | *(0.02)* | *(0.01)* | *(0.01)* |
| *station* | 0.16*** | -0.09*** | 0.05*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *TDMA* | 0.19*** | -0.02 | 0.07*** |
| | *(0.02)* | *(0.01)* | *(0.02)* |
| *telephone* | -0.23*** | -0.14*** | -0.26*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *terrestrial* | -0.04** | -0.20*** | 0.01 |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *threshold* | 0.19*** | 0.30*** | 0.27*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *tower* | 0.01 | 0.05*** | 0.04** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *transceiver* | 0.11*** | -0.10*** | 0.11*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *transmitter* | 0.23*** | 0.13*** | 0.17*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *TV* | -0.09*** | 0 | 0.13*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *UMTS* | -0.10*** | 0.10*** | -0.28*** |
| | *(0.02)* | *(0.01)* | *(0.02)* |
| *uplink* | 0.20*** | -0.05** | -0.22*** |
| | *(0.02)* | *(0.02)* | *(0.03)* |
| *v* | -0.21*** | 0.18*** | 0.03 |
| | *(0.03)* | *-0.03* | *(0.03)* |
| *volts* | 0.09*** | (0.01) | 0.22*** |
| | *(0.02)* | *-0.02* | *(0.02)* |
| *wave* | 0.03*** | 0.26*** | 0.10*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *WCDMA* | -0.13*** | 0.06*** | 0.39*** |
| | *(0.02)* | *(0.02)* | *(0.02)* |
| *white space* | 0.52*** | 0.04 | -0.08 |
| | *(0.06)* | *(0.05)* | *(0.06)* |
| *wireless* | 0.00 | -0.31*** | 0.12*** |
| | *(0.01)* | *(0.01)* | *(0.01)* |
| *xray* | 0.04 | 0.24 | 0.30* |
| | *(0.18)* | *(0.16)* | *(0.17)* |
| Constant | -4.47*** | -4.48*** | -4.67*** |
| | *(0.11)* | *(0.10)* | *(0.10)* |
| Observations | 499,813 | 499,813 | 499,813 |

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

**Table A5** "Interference" citations in radio patents by firm

| Firm | Total | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Qualcomm Inc. | 5,709 | 313 | 345 | 553 | 692 | 704 | 582 | 504 | 543 | 352 | 115 | 8 |
| Various | 5,569 | 344 | 269 | 293 | 308 | 260 | 325 | 333 | 331 | 261 | 170 | 29 |
| LG Electronics Inc. | 3,771 | 77 | 132 | 266 | 427 | 532 | 570 | 534 | 481 | 328 | 179 | 31 |
| Broadcom Corp. | 2,468 | 199 | 227 | 162 | 195 | 203 | 293 | 206 | 232 | 72 | 41 | 3 |
| Samsung Electronics | 2,070 | 135 | 179 | 224 | 166 | 188 | 151 | 161 | 180 | 154 | 102 | 9 |
| Intel Corp. | 1,777 | 103 | 113 | 92 | 119 | 104 | 132 | 241 | 164 | 108 | 44 | 3 |
| Nokia Corp. | 1,437 | 133 | 100 | 107 | 95 | 78 | 61 | 20 | 11 | 1 | | |
| Apple Inc. | 1,249 | 24 | 69 | 107 | 89 | 134 | 151 | 253 | 186 | 138 | 70 | 11 |
| Fujitsu Ltd. | 1,241 | 59 | 98 | 72 | 115 | 89 | 89 | 114 | 86 | 71 | 35 | 3 |
| Sony Corp. | 1,206 | 61 | 70 | 56 | 85 | 118 | 103 | 116 | 90 | 59 | 20 | 3 |
| Motorola Inc. | 1,114 | 68 | 24 | 9 | 2 | | | | | | | |
| NEC Corp. | 1,058 | 65 | 57 | 63 | 60 | 65 | 51 | 73 | 35 | 16 | 12 | 1 |
| NTT Docomo Inc. | 1,030 | 114 | 83 | 114 | 126 | 71 | 102 | 83 | 61 | 6 | 3 | |
| Interdigital Technology | 904 | 58 | 53 | 56 | 37 | 16 | 29 | 34 | 29 | 21 | 12 | 3 |
| Panasonic Corp. | 884 | 122 | 116 | 107 | 87 | 76 | 77 | 54 | 24 | 7 | 9 | 3 |
| IBM Corp. | 830 | 37 | 55 | 79 | 35 | 37 | 29 | 53 | 40 | 55 | 54 | 13 |
| Cisco Technology Inc. | 805 | 47 | 53 | 59 | 57 | 44 | 85 | 68 | 64 | 78 | 14 | 2 |
| Silverbrook Research | 727 | 32 | 63 | 117 | 67 | 59 | 18 | 3 | | | | |
| Lucent Technologies | 699 | 4 | | | | | | | | | | |
| Blackberry Ltd. | 691 | 9 | 15 | 18 | 33 | 99 | 113 | 212 | 131 | 42 | 13 | 4 |
| Texas Instruments Inc. | 688 | 40 | 58 | 70 | 40 | 56 | 39 | 22 | 23 | 5 | 3 | |
| Matsushita Electric | 642 | 16 | 2 | | | | | | | | | |
| Kabushiki Kaisha Toshiba | 577 | 28 | 61 | 46 | 44 | 35 | 31 | 35 | 20 | 14 | 7 | |
| Elec. Telecom. Res. Inst. | 554 | 30 | 39 | 59 | 45 | 80 | 59 | 68 | 58 | 31 | 5 | 2 |
| Huawei Technologies | 551 | 8 | 14 | 20 | 30 | 32 | 68 | 86 | 92 | 127 | 48 | 8 |
| Siemens Aktiengesells | 548 | 28 | 21 | 21 | 19 | 27 | 26 | 18 | 19 | 3 | | |
| Alcatel Lucent | 543 | 59 | 51 | 53 | 53 | 62 | 73 | 71 | 43 | 24 | 8 | |
| Microsoft Corp. | 539 | 49 | 54 | 53 | 32 | 33 | 48 | 18 | 12 | 1 | | |
| Marvell International | 517 | 20 | 38 | 60 | 38 | 45 | 42 | 73 | 88 | 50 | 18 | 1 |
| Hitachi Ltd. | 514 | 25 | 40 | 28 | 31 | 33 | 39 | 29 | 12 | 5 | | |
| Nortel Networks Ltd. | 509 | 22 | 12 | 7 | 3 | 4 | | | | | | |

**Table A6** “Filter” citations in radio patents by firm

| Firm | Total | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Various | 8,781 | 522 | 530 | 442 | 448 | 456 | 550 | 585 | 620 | 469 | 259 | 56 |
| Qualcomm Inc. | 7,325 | 384 | 468 | 691 | 854 | 793 | 715 | 749 | 876 | 519 | 179 | 14 |
| Broadcom Corp. | 3,561 | 304 | 342 | 248 | 293 | 298 | 325 | 300 | 308 | 93 | 56 | 4 |
| IBM Corp. | 2,905 | 112 | 191 | 255 | 130 | 95 | 130 | 255 | 182 | 249 | 204 | 91 |
| Intel Corp. | 2,264 | 149 | 103 | 82 | 100 | 106 | 149 | 337 | 231 | 182 | 54 | 8 |
| Samsung Electronics | 2,139 | 165 | 166 | 137 | 113 | 151 | 129 | 165 | 221 | 189 | 132 | 8 |
| Sony Corp. | 1,938 | 108 | 109 | 101 | 137 | 184 | 160 | 152 | 133 | 73 | 28 | 4 |
| Nokia Corp. | 1,937 | 173 | 139 | 152 | 138 | 92 | 86 | 40 | 17 | 5 | 1 | |
| Microsoft Corp. | 1,879 | 224 | 179 | 99 | 115 | 124 | 65 | 24 | 1 | | | |
| LG Electronics Inc. | 1,846 | 99 | 79 | 126 | 125 | 236 | 280 | 240 | 206 | 152 | 73 | 8 |
| Research In Motion | 1,783 | 187 | 183 | 247 | 234 | 183 | 108 | | | | | |
| Blackberry Ltd. | 1,684 | 23 | 45 | 46 | 99 | 208 | 292 | 461 | 313 | 114 | 43 | 6 |
| Apple Inc. | 1,642 | 71 | 106 | 110 | 123 | 140 | 192 | 321 | 228 | 194 | 105 | 10 |
| Google Inc. | 1,403 | 27 | 43 | 38 | 41 | 83 | 174 | 346 | 330 | 176 | 76 | 19 |
| Motorola Inc. | 1,285 | 63 | 30 | 4 | 1 | | | | | | | |
| Cisco Technology Inc. | 1,112 | 88 | 104 | 63 | 69 | 79 | 90 | 73 | 73 | 74 | 20 | 1 |
| Panasonic Corp. | 1,103 | 155 | 173 | 144 | 106 | 103 | 80 | 49 | 30 | 12 | 11 | 1 |
| Kabushiki Kaisha Toshiba | 1,099 | 85 | 76 | 76 | 76 | 69 | 58 | 71 | 35 | 23 | 5 | 2 |
| Silverbrook Research | 1,097 | 42 | 87 | 185 | 103 | 109 | 43 | 3 | | | | |
| Fujitsu Ltd. | 1,052 | 52 | 49 | 55 | 73 | 57 | 79 | 76 | 56 | 42 | 26 | 4 |
| Texas Instruments Inc. | 1,040 | 71 | 78 | 92 | 49 | 63 | 59 | 35 | 21 | 2 | 4 | 1 |
| Matsushita Electric | 834 | 31 | 4 | | | | | | | | | |
| NEC Corp. | 834 | 53 | 39 | 42 | 35 | 43 | 37 | 33 | 16 | 6 | 4 | |
| Canon Kabushiki Kaisha | 809 | 38 | 45 | 40 | 41 | 38 | 22 | 25 | 27 | 22 | 9 | |
| Medtronic Inc. | 806 | 70 | 32 | 101 | 67 | 34 | 27 | 35 | 25 | 15 | 1 | |
| General Electric | 803 | 35 | 59 | 51 | 59 | 68 | 72 | 72 | 25 | 24 | 8 | 2 |
| Marvell International | 760 | 36 | 60 | 99 | 69 | 53 | 65 | 102 | 96 | 60 | 25 | 1 |
| Hitachi Ltd. | 675 | 39 | 46 | 34 | 29 | 30 | 20 | 13 | 11 | 4 | 2 | 2 |
| Infineon Technologies | 675 | 65 | 75 | 49 | 26 | 21 | 20 | 22 | 18 | 19 | 9 | 1 |
| AT&T Intellectual Pro | 647 | 24 | 36 | 68 | 69 | 86 | 48 | 63 | 67 | 62 | 55 | 13 |
| Koninklijke Philips | 633 | 31 | 30 | 22 | 14 | 4 | 3 | 8 | | | | |
| Siemens Aktiengesells | 630 | 31 | 24 | 26 | 26 | 36 | 37 | 34 | 39 | 6 | 1 | |
| Lucent Technologies | 592 | 3 | | | | | | | | | | |
| Interdigital Technology | 557 | 32 | 26 | 37 | 27 | 11 | 14 | 17 | 14 | 9 | 8 | 1 |
| Honeywell International | 550 | 44 | 44 | 43 | 30 | 37 | 35 | 27 | 23 | 21 | 7 | |
| Sprint Communications | 533 | 21 | 27 | 29 | 59 | 86 | 61 | 52 | 91 | 40 | 16 | 3 |
| Sharp Kabushiki Kaisha | 529 | 35 | 30 | 41 | 57 | 35 | 51 | 46 | 29 | 23 | 12 | 2 |
| Raytheon Company | 517 | 10 | 21 | 30 | 43 | 55 | 36 | 42 | 35 | 28 | 9 | 2 |
| Cardiac Pacemakers | 508 | 37 | 23 | 24 | 50 | 45 | 41 | 35 | 31 | 20 | 6 | 1 |
| Harris Corp. | 504 | 50 | 71 | 42 | 31 | 17 | 24 | 26 | 23 | 11 | 5 | 2 |

**Table A7** “Sensor” citations in radio patents by firm

| Firm | Total | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Various | 11,512 | 666 | 637 | 549 | 611 | 603 | 765 | 803 | 878 | 738 | 398 | 91 |
| Google Inc. | 3,035 | 13 | 70 | 65 | 85 | 173 | 450 | 758 | 690 | 460 | 214 | 43 |
| IBM Corp. | 2,176 | 89 | 138 | 241 | 82 | 81 | 99 | 191 | 138 | 206 | 223 | 88 |
| Apple Inc. | 2,141 | 49 | 118 | 181 | 166 | 256 | 244 | 414 | 304 | 242 | 119 | 12 |
| Qualcomm Inc. | 2,036 | 68 | 105 | 90 | 149 | 179 | 229 | 338 | 372 | 289 | 113 | 14 |
| LG Electronics Inc. | 1,958 | 91 | 232 | 287 | 336 | 334 | 272 | 185 | 86 | 9 | | |
| Samsung Electronics | 1,776 | 71 | 85 | 81 | 81 | 118 | 168 | 207 | 330 | 292 | 154 | 13 |
| Sony Corp. | 1,444 | 64 | 71 | 99 | 91 | 126 | 146 | 170 | 137 | 127 | 53 | 11 |
| Intel Corp. | 1,366 | 48 | 37 | 34 | 33 | 30 | 130 | 317 | 284 | 170 | 59 | 7 |
| Medtronic Inc. | 1,260 | 101 | 99 | 58 | 126 | 85 | 53 | 52 | 56 | 39 | 17 | 1 |
| Silverbrook Research | 1,144 | 53 | 93 | 195 | 110 | 110 | 43 | 5 | | | | |
| Microsoft Corp. | 1,112 | 109 | 121 | 118 | 65 | 92 | 114 | 72 | 25 | 3 | | |
| General Electric Comp. | 1,075 | 44 | 64 | 94 | 96 | 127 | 151 | 108 | 57 | 52 | 17 | 3 |
| Honeywell International | 1,059 | 86 | 87 | 127 | 88 | 76 | 65 | 51 | 64 | 53 | 19 | |
| Blackberry Ltd. | 984 | 6 | 19 | 22 | 54 | 117 | 180 | 288 | 194 | 71 | 26 | 6 |
| IGT | 970 | 102 | 114 | 67 | 41 | 26 | 120 | 151 | 173 | 41 | 50 | 8 |
| Cardiac Pacemakers | 878 | 84 | 82 | 71 | 77 | 65 | 38 | 12 | 5 | | | |
| Canon Kabushiki Kaisha | 837 | 55 | 47 | 44 | 49 | 46 | 41 | 57 | 52 | 50 | 16 | |
| Nokia Corp. | 830 | 72 | 70 | 90 | 102 | 105 | 88 | 47 | 15 | 3 | 1 | |
| The Boeing Company | 769 | 55 | 56 | 64 | 63 | 74 | 68 | 68 | 82 | 32 | 17 | 2 |
| Denso Corp. | 716 | 73 | 83 | 52 | 48 | 26 | 29 | 43 | 42 | 21 | 11 | |
| AT&T Intellectual Pro | 708 | 25 | 25 | 59 | 86 | 82 | 73 | 88 | 83 | 79 | 71 | 9 |
| Cisco Technology Inc. | 689 | 62 | 54 | 31 | 33 | 55 | 100 | 79 | 63 | 87 | 13 | |
| Broadcom Corp. | 665 | 43 | 42 | 66 | 52 | 57 | 83 | 68 | 88 | 50 | 22 | 1 |
| Microsoft Technology | 645 | 7 | 9 | 7 | 38 | 96 | 164 | 141 | 124 | 47 | 8 | |
| Kabushiki Kaisha Toshiba | 640 | 50 | 62 | 41 | 41 | 39 | 33 | 46 | 34 | 15 | 10 | 1 |
| Semiconductor Energy | 627 | 58 | 52 | 38 | 42 | 43 | 51 | 37 | 85 | 76 | 54 | 12 |
| Amazon Technologies | 592 | 7 | 8 | 15 | 4 | 50 | 60 | 108 | 113 | 159 | 51 | 9 |
| Applied Materials Inc. | 583 | 25 | 25 | 16 | 19 | 32 | 23 | 24 | 29 | 33 | 8 | 2 |
| Hitachi Ltd. | 576 | 42 | 51 | 29 | 29 | 32 | 22 | 17 | 9 | 3 | 3 | |
| Hewlett-Packard Dev. | 562 | 21 | 30 | 28 | 26 | 36 | 28 | 18 | 8 | 1 | 2 | |
| Fujitsu Ltd. | 542 | 25 | 27 | 27 | 38 | 44 | 49 | 63 | 44 | 45 | 21 | 1 |
| Covidien LP | 516 | 9 | 14 | 32 | 51 | 58 | 87 | 105 | 90 | 39 | 24 | 6 |