Analysis of Patent Referencing to IEEE Papers, Conferences, and Standards 1997-2007

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Executive Summary

IEEE engaged 1790 Analytics in this project to assess the impact of IEEE publications on developments in various technologies. This impact is measured by examining the extent to which patented inventions build upon papers from IEEE journals, IEEE-sponsored conferences, and IEEE standards. This is an update of previous reports, and examines patents issued from 1997 through 2007.

The main findings of this report are:

- New technology continues to build upon science, and the dependence is increasing. When we did a similar study last year we found that the top 25 companies were granted 41,915 patents in 2006. These patents made a total of 112,605 non-patent references, an average of 2.69 non-patent references per patent. In this study, the top 25 companies in 2007 were granted 35,859 patents. These patents made a total of 103,520 non-patent references, an average of 2.89 non-patent references per patent. In other words, while the number of patents granted to the top 25 largest patent holders decreased slightly, the number of non-patent references upon which the patents build has increased. Since a large number of these non-patent references are to scientific articles and conference papers, this suggests that today's technology developments are increasingly linked to developments in published science.

- A large portion of this science base comes from papers presented at IEEE sponsored conferences and published in IEEE journals. The top 25 patenting companies in 2007 have referenced nearly 270,000 articles in the last 11 years. About 38% (more than 100,000) of those articles appeared in IEEE journals or IEEE sponsored conferences.

- In this study, we also went beyond the top 25 patenting companies and analyzed all patents from the last 11 years in several technology categories of interest to IEEE customers. For example, approximately 42% of all scientific references from Computer Hardware patents go to IEEE publications. To put this in perspective, the second most referenced publisher is ACM (Association for Computer Machinery) with just under 15% of the referenced publications. In other Information Technology areas, such as Information Storage, Semiconductor Manufacturing, and Telecom, the results are similar.

- IEEE is referenced a surprising amount in areas which are not central to its mission. For example, approximately 6% of the science references from patents in medical devices go to IEEE publications. This ranks IEEE third behind Elsevier and Lippincott. The latter publishers have 400+ and 100+ journals in the medical area, whereas IEEE has only a few, so the 6% figure is quite solid for a non-core area.

- Optics is also somewhat surprising. IEEE publications receive the most references from Optics patents, and IEEE is referenced significantly more than the two large Optics Societies: SPIE – The International Society of Optical Engineering, and OSA – The Optical Society of America.

- In this study, for the first time, we examined four new technology areas: Clocks & Timepieces, Measuring, Testing, and Control, Nuclear and X-Ray, and Robotics and Intelligent Manufacturing. In all but the Nuclear/X-Ray category, IEEE is the top referenced publisher. Nearly half of all references from clock related patents reference articles from IEEE. In Measuring, Testing, and Control, IEEE gets 18% of all references which is just ahead of Elsevier's 16% while, again, Elsevier has many more journal titles in the space. In the Nuclear category IEEE is referenced fourth most often behind Elsevier, The American Chemical Society, and The American Institute of Physics. In the Robotics and Intelligent Manufacturing category, more than half of the patent references are to articles published in IEEE journals or in proceedings of IEEE sponsored conferences. Second place Elsevier receives only one sixth as many references in the category.

- Last year, for the first time, we examined patents related to the generation and transmission of electricity. We found that these Power Systems patents also reference IEEE publications most frequently. The same is true this year, where we see that IEEE published articles receive nearly twice as many references as second place Elsevier.

- It has been shown that high-quality, high-impact, and valuable patents tend to be cited more frequently by later patents. Citation impact is thus often used as a quantitative measure for evaluating patents. In this study, we found that the patents that reference IEEE papers are cited more often than patents that do not. This was shown to be true for each of the twelve technology categories we examined. This suggests that, not only do IEEE publications frequently provide the science base for new inventions, but that inventions that build upon IEEE publications are more likely to be valuable in the future than inventions that do not build upon IEEE.

- Although this study concentrates on patents in specific technology areas, it should be noted that the importance of scientific and technical literature to patented technology is increasing in all areas. Our research shows that the average US patent had only 2.76 non-patent references back in 1997. That number jumped to 4.95 by 2007 – a 79% increase. However, patent referencing to IEEE has increased at an even faster rate with a 294% increase in the same time period. This suggests that IEEE published materials provide much of the science base in all areas of patenting, and not the just the technology categories examined in this report.

Table of Contents

I. Introduction

In previous studies, it was found that patents reference papers from IEEE journals much more often than papers from other journal publishers. In this report, we update the previous results, and study US patents issued from 1997 through 2007. Although this report is an update of previous results, we have made our best efforts to make this report self-contained. The aim of this report, as in previous reports, is to analyze references from patents to journal articles, conferences and standards documents, in order to assess IEEE's impact upon technological developments.

It is worth noting that, in addition to the categories of Information Technology examined in the prior studies; this study contains an analysis of a number of categories not related to Information Technology, some for the first time. The categories, with patent counts are shown below in Table 1.

Table 1: Number of Patents for Each Category Covered in this Study

Category	# Patents 1997-2007
Clocks/Watches/Time Pieces	1857
Computer Hardware	121620
Computer Software	55946
Diagnosis/Surgery/Medical Instruments	76964
Information Storage	61003
Measuring, Testing and Control Devices	82208
Nuclear/X-Ray/Radiant Energy	17586
Optics/Photography/Electrophotography	74565
Power Systems	36333
Robotics and Intelligent Manufacturing	12127
Semiconductors/Solid-State Devices/Electronics	106601
Telecom and Other Communications	175995

II. Methodology

This study is based on referencing patterns from patents to prior art documents. When an inventor files a patent for a new invention, he/she will typically reference earlier documents to show that the new invention either builds upon, or improves upon, what came earlier. The inventor's patent attorney and/or the examiner may also add prior art references to either clarify or limit the claims of the new invention.

As an example, Figure 1 shows the front page of a General Electric patent. The prior art references on this patent come in two forms - references to earlier patents, and "other references". These other references are often to scientific publications, such as those produced by IEEE. In this report we are primarily concerned with these other references, which are also sometimes called "Non-Patent References".

It has been suggested that patents with many non-patent references are likely to contain new leading-edge ideas, whereas patents that only reference earlier patents are likely to be incremental improvements on earlier patented technologies. For a comprehensive study on various hypotheses surrounding the motivations of inventors in citing other references, see [1].

Patent Sets used in the Analysis

This study is based on two patent sets. Our analysis is based on determining the number of references from these patent sets to publications from publishers such as IEEE, Elsevier, the American Institute of Physics, and others.

The first set contains patents from the top 25 patenting companies in 2007. Analysis of this patent set provides an insight into how the top tier companies rely upon science from IEEE and other publishers. The second set contains all patents in ten technology categories from all companies, universities, government agencies, and individuals. The ten technology categories examined are shown in Table 1 above. Analysis of this patent set reveals the wider influence of IEEE science in these technologies.

Identifying Relevant Non-Patent References

Non-patent references can be to any published document, from comic strips and brochures, to scientific articles and standards documents. The main difficulty in identifying relevant non-patent references for a study such as this is that inventors do not use a standard form for listing references. As an example, Table 2 contains eight different variants for the IEEE Global Telecom Conference. Note that some inventors just use the GLOBECOM shorthand, while others list the entire name. Sometimes IEEE is mentioned and sometimes it is not. When abbreviation variations are included such as Telecom, Tele, Tcom, Proc., Proceed., the number of variants increases further. The same issue exists for variants in journal names and standards documents. For example there are more than 30 variant spellings of the journal title *Journal Of Thoracic And Cardiovascular Surgery* including numerous mis-spellings of thoracic and every conceivable way of abbreviating cardiovascular.

Table 2 – Variants for IEEE Global Telecom Conference

Proceedings of Globecom '96
IEEE Global Telecommunications Conference
GLOBECOM '90:IEEE
Proceedings of IEEE Globecom '94
Globecom '97
IEEE Globecom, Global Telecommunications Conference and Exhibiton
Proc of the Global Tele Conf, U.S. New York, IEEE

Conference Identification – to identify conference proceedings among the non-patent references, we first identified references containing keywords such as meeting, symposia, conference, etc. We then used parsing software to identify 2-word and 3-word phrases that

appear frequently in this set of papers. The full string was identified for these string sub-sequences in order to identify frequently cited conferences. In this way, we identified the top 200+ (up from 120 last year) conferences referenced in the patent sets, and standardized the names of these conferences (i.e. all of the different variants of a conference were collected under a single name). As an example, all of the variants shown in Table 2 are assigned to the name '<conf> IEEE Global Telecommunications Conference (GLOBECOM)'.

We then looked up each of these conferences on the web to determine who is listed as their primary sponsor. For example, many of the conferences are sponsored by organizations such as IEEE, ACM (Association for Computer Machinery) and ASME (American Society of Mechanical Engineers).

Standards Identification - There are relatively few standards referenced, and in general they are easy to identify by looking for strings such as 'standard' or 'std'. Once the records containing the standards were located, it was relatively easy to identify the organization that produced each standard (IEEE, ISO, JEDEC, ANSI, etc.). Further, once the standards bodies are identified, we then identify references to other documents that do not specifically list the words 'standard' or 'std.' The latter step is necessary since some references look like this "ISO/TC97/SC21/N2066" without a specific mention of the word "standard." As a consequence we also identify other non-standard documents released from these organizations including draft standards and "requests for comments" documents.

Journal Identification – identifying and standardizing journal names is a very difficult process because there are so many different journals, and their names can be abbreviated in many different ways. To make the problem more manageable, we restricted our analysis to the 14,000+ journals covered by the ISI/Thomson Scientific Database. This is not a severe limitation, since these 14,000+ journals include more than 100 IEEE journals, 1400+ Elsevier journals, and 350+ Wiley journals. In addition, we also identify some non-ISI journals if they appear very frequently in the patent references, but do not appear in the ISI database.

Once restricted to these 14,000 journals, we used software that transforms journal names into common abbreviations and then implements string matching. Care must be taken with string matching because, for example, searching for "Urology Journal" will also accidentally identify "Neurology Journal". Similarly, a search for the journal "Science" would accidentally pick up any reference with 'science' in the paper title as well as any of the 800+ journals with science in their titles such as "Game and Wildlife Science". Our proprietary software for journal identification deals with all of these problems, so that we generate an accurate match between the patent references and 14,000+ journals. After identifying all of the relevant journals, we then used the ISI database and web research to identify the publisher of each journal.

III. Results

References from Top 25 Patenting Organizations

Table 3 shows the 25 firms that were granted the largest number of US patents in 2007. It should be noted that many of these firms consist of multiple subsidiaries, and these firms patent under many names. We identified all of the subsidiary names for each company to ensure that our patent counts are accurate.

Table 3 – Top Patenting Firms in 2007

Assignee	2007 US Patent Count	1997-2007 US Patent Count
International Business Machines Corp	3149	33464
Samsung Electronics Co Ltd	2749	17645
Hitachi Ltd	2728	21916
Matsushita Electric Industrial Co. Ltd.	2129	19243
Canon Inc	2048	21766
Intel Corporation	1865	13281
Toshiba Corp	1844	15094
Microsoft Corporation	1649	7276
Sony Corp	1609	16110
Fujitsu Limited	1490	14959
Micron Technology Inc.	1484	14934
Hewlett-Packard Co	1466	16534
Siemens Aktiengesellschaft	1305	13022
Seiko Epson Corporation	1218	7427
General Electric Company	1130	13829
NEC Corp	972	16633
Nippondenso Co. Ltd.	899	6605
Infineon Technologies AG	888	5235
Sharp Corp	833	7074
Ricoh Co. Ltd.	763	5423
Texas Instruments Inc	755	8359
Honda Motor Co. Ltd.	730	6883
Nokia Corp	730	4532
Fuji Photo Film Co. Ltd	721	10788
AT&T Inc	705	4621

We identified the top 25 patenting firms because we want to understand the extent to which the current technology leaders use IEEE science. Figure 2 shows the 20 publishers of science whose publications are referenced most frequently by the 25 firms shown in Table 3. This figure shows that patents issued to the top 25 firms between 1997 and 2007 reference IEEE papers, conferences, and standards more than 100,000 times. This is nearly four times as many references as the second placed publisher (Reed/Elsevier). Also, if conference publications that are jointly sponsored are counted, such as the conferences jointly sponsored between IEEE and

the Japanese Society of Applied Physics, or IEEE and ACM, then the number of references from the top 25 companies to IEEE increases by almost 10,000 references.

Overall, IEEE receives more than 37% of the science references from the patents of the top 25 companies. Only a few publishers receive more than 6% of the total, and IEEE's share of references is more than the next 10 publishers combined.

About 1/3 of the 100,000+ patent references to IEEE are to IEEE sponsored conferences. Even if conference proceedings are removed, the IEEE still has a nearly 3-fold lead over second placed Reed/Elsevier.

Table 4 illustrates the reference distribution of Texas Instruments, one of the top 25 firms. This reference distribution is fairly typical of the top 25 firms. The references from Texas Instruments to IEEE are actually to a number of different IEEE journals and conferences. In this table, IEEE journals are highlighted in yellow, IEEE conferences are highlighted in orange, and IEEE standards are highlighted in green. The top referenced journal from Intel is the *IEEE Transactions on Magnetics*, and the top referenced conference is the *IEEE International Test Conference*.

Notice that the top 7 journals and conferences referenced by Texas Instruments (TI) are published or sponsored by IEEE. Also 8 of the top 10 reference go to IEEE titles. In general, approximately 75% of TI's science references to IEEE are to papers that appear in IEEE journals. Approximately 25% of the references to IEEE are to conference papers, and about 0.5% of the references are to IEEE standards.

References from Companies in Twelve Technology Categories

In the previous section, we analyzed the use of IEEE science by the top patenting organizations. Out of all science publishers, IEEE was cited most often by these organizations by a wide margin. However, looking only at the top companies tells an incomplete story. IEEE publishes journals and runs conferences mainly in information technology, electronic and other areas. It is therefore useful to examine the extent to which IEEE science is referenced by all organizations that patent in specific technologies, not just the leading companies.

As mentioned in the methodology section, we identified all patents in the twelve technology categories shown above in Table 1. 1790 Analytics has developed a classification scheme that categorizes all patents into 50 broad technology areas, and this scheme was used to identify all relevant patents for this part of the analysis.

Table 4 – Reference Distribution from Texas Instrumenst Patents 1997-2007

# Refes	Journal/Conference/Standard
941	IEEE TRANSACTIONS ON MAGNETICS
831	IEEE Unseparated
537	IEEE JOURNAL OF SOLID-STATE CIRCUITS
261	<conf> IEEE int Test conf
223	<conf> IEEE Int Electron Devices Meeting (IEDM)
218	IEEE TRANSACTIONS ON COMMUNICATIONS
214	PROCEEDINGS OF THE IEEE
174	APPLIED PHYSICS LETTERS
159	<conf> proc IEEE int Solid State Circuits Conf (ISSCC)
156	ELECTRONICS
141	J Vac Sci tech
136	IEEE TRANSACTIONS ON ELECTRON DEVICES
128	HIGH PERFORMANCE SYSTEMS-THE MAGAZINE FOR TECH CHAMPIONS
127	JOURNAL OF APPLIED PHYSICS
116	<conf> IEEE Int Conf Acous, Speech, and Sig Proc (ICASSP)
103	IEEE ELECTRON DEVICE LETTERS
102	IBM JOURNAL OF RESEARCH AND DEVELOPMENT
99	<std> ANSI Std
99	JOURNAL OF THE ELECTROCHEMICAL SOCIETY
96	<conf> IEEE/JPN Soc App Phys - symp on VLSI tech
93	<conf> IEEE Custom Integrated Circuits conf
78	<conf> Mat Res Soc Misc Conf
78	IEEE TRANSACTIONS ON INFORMATION THEORY
75	IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS
75	<conf> IEEE Misc Conf
74	IEEE tr Circuits and sys
68	Proc SPIE
68	Misc ACM
67	IEEE TRANSACTIONS ON CONSUMER ELECTRONICS
64	Misc SPIE
63	ELECTRONICS LETTERS
61	<conf> IEEE Global Telecommunications Conference (GLOBECOM)
61	THIN SOLID FILMS
54	ELECTRONIC DESIGN
52	TI tech j
49	<conf> IEEE int conf on comm (ICC)
49	IEEE tr comp
45	COMPUTER DESIGN
43	JAPANESE JOURNAL OF APPLIED PHYSICS
43	<conf> IEEE int symp on Circuits and sys (SCAS)
42	SOLID STATE TECHNOLOGY
38	Elec Eng Times
37	Computer (IEEE)
36	Misc ISA
36	IEEE SPECTRUM
34	CONTROL ENGINEERING
33	IEEE TRANSACTIONS ON ACOUSTICS SPEECH AND SIGNAL PROCESSING
30	<std> IEEE Std
28	IEEE COMMUNICATIONS MAGAZINE
28	JOURNAL OF NON-CRYSTALLINE SOLIDS

We examined each of the twelve technology areas separately, and the results are summarized in Figures 3-14. The first category shown (in Figure 3) is Clocks, Watches, and Timepieces. We identified all non-patent references on patents related to this technology issued between 1997 and 2007. We then determined the science publishers responsible for the largest number of these non-patent references. Figure 3 shows the result of this analysis, namely that IEEE science is referenced far more by clock and watch related patents than science from any other publisher. Almost half of all science references from these patents go to IEEE journal papers or IEEE sponsored conference papers (the graphs also include standards documents, but the vast majority of the references are to journal or conference papers). When joint IEEE/ACM conferences are included the share of IEEE papers referenced rises to over 50%.

Figures 4 and 5 are analogous to Figure 3 except they show referencing patterns from Computer Hardware and Software patents. Here IEEE once again receives far more references than the other publishers. In both cases, ACM is the second most referenced publisher, but it receives less than half of the references that IEEE does.

Figure 6 examines the top referenced publishers in the Medical Device field, which covers devices as well as diagnostic tools and surgical instruments. Here, IEEE is a respectable third in an area that is somewhat outside its core competency. When we first started covering this category in our 2005 report, the top publisher in this area was Lippincott Williams and Wilkins, which publishes more than 100 health and diagnostic related journals, including *Circulation, Neurosurgery, Investigative Radiology, Anesthesiology,* and *Annals of Surgery*. In recent years Lippincott had been surpassed by Elsevier, which has more than 400 journals in the field, such as *Annals of Thoracic Surgery*, and the *Journal of the American College of Cardiology*. In this report, we see that Elsevier's lead in references has further increased so that it now has almost double the references of Lippincott.

The huge increase in references to Elsevier in this (and other) categories is due to several factors. First, the number of science references in the medical field is much higher for recent patents than for older patents, so a leading publisher in 2006 is likely to have a larger lead in 2007. Secondly, Elsevier has been rather acquisitive in recent years and continues to acquire other publishers. Finally, Elsevier has a lot of journal titles, so that as ISI/Thomson has increased the number of journals it covers in its database, Elsevier has benefited the most.

Figure 7 shows the results for the information storage category. In this area, IEEE is particularly dominant. Almost half (46%) of all of the science references from patents in information storage are to papers in IEEE journals or conferences. IEEE's 23,000+ references in this category are 5 times as many as second place Elsevier.

Figure 8 shows the results of the new category Measuring, Testing, and Control. Patents in this category are related to measuring or testing, force, pressure, weight, etc. as well as chemically measuring substances (e.g. measuring CO2 levels). The category also contains control devices since these technologies are often combined. For example a patent might be related to a valve

that adjusts at a certain pressure or at a certain pollution level. Since this type of measuring can be done both mechanically, magnetically, electrically, or chemically, it is not too surprising to see both IEEE and Elsevier and the American Chemical Society all near the top of Figure 8. IEEE receives the most references, but the lead is not as dominant as in the Information Technology related technology areas.

Figure 9 contains reference counts for Nuclear and X-Ray technology patents. Much of the patenting in this category is related to Nuclear Medicine so it is not surprising that the top referenced publisher is Elsevier. IEEE is fourth in referencing in this category behind the American Chemical Society and the American Institute of Physics.

Figure 10 contains the results for the Optics category. This is another area that is slightly outside the IEEE core. IEEE still has a substantial lead over the second and third place publishers - the International Society of Optical Engineering (SPIE) and the Optical Society of America (OSA). Since these latter two societies are Optical societies, it would be reasonable to assume that one of these societies would lead in the category but IEEE strong journals and conferences in the area receive more references.

Figure 11 shows reference counts for the patents related to power generation and transmission. Although this is a non-information technology category, IEEE leads in references in this category as well. About 36% of science references from patents in this category go to IEEE publications.

Figure 12 contains the results for a new technology covered for the first time in this study. Intelligent Manufacturing and Robotics contains patents related to robotics, and robotics and control systems related to manufacturing. According to Fortune Magazine (January 2005) the Robotics industry is a $5 billion global industry that is expected to triple in size within the next 5 years as a result of a population explosion in "service robots" that mow lawns, vacuum floors, and manufacture things.

As this industry grows, new innovations will be patented, and from Figure 12 it looks like those innovations will build upon ideas published in IEEE journal articles or presented at IEEE conferences. We see in Figure 12 that more than half of all science references from patents in this space refer to IEEE published articles. Elsevier is the second ranked publisher, but it has only one-sixth as many references as IEEE articles.

Figure 13 shows that IEEE is also very strong in the Semiconductor category. Here, the inclusion of conferences gives IEEE a substantial boost. Approximately one-third of the references to IEEE are to conference papers. With conferences excluded, IEEE would still hold a slight lead over the American Institute of Physics.

Figure 14 shows the results for the Telecommunications category. In this category, IEEE receives more than eleven times as many references as the second place publisher (IEE). Standards are referenced more frequently in telecommunications, but still not nearly as often as journal and conference papers. About 72% of the 190,000+ total references to all publishers are to journal articles; 18% of the references are to conference papers, and about 10% are to

standards documents. In terms of standards documents, the International Telecommunication Union received the most references in the category with 4,591. New telecommunications patents are referencing scientific articles to a larger extent than in the past. When we looked at this category last year, there were 83,450 references to IEEE. Now as we see in Figure 14, there are more than 100,000 references to IEEE for telecommunications patents from 1997-2007.

Figures 3-14 show aggregate counts of references from all patents in each technology category. Readers who wish to see the firms that reference IEEE publications in each category can consult Appendix B. This appendix contains the 100 organizations that reference IEEE most frequently in each category. Appendix C is similar, except that it contains the organizations that reference IEEE most frequently in the twelve technology categories combined.

Citation Index for Patents Referencing IEEE

In an earlier study (see [2]) it was shown that patents that reference specific IEEE journals perform better on a number of quality metrics. Moreover, it was shown that the results were statistically significant. In this report, we update a key figure from the previous study showing the citation index of patents that reference IEEE papers versus peer patents that do not.

The citation index is a normalized citation metric that takes the number of citations received by a particular set of patents, and divides it by the expected number of citations for patents of the same age and technology class. A random set of patents therefore should have a citation index of 1.0. Research has shown that patents cited by many later patents tend to contain important ideas upon which the later patents are building (see [3] and [6]). Citation indicators are also the basis for the patented financial models (see [4] and [7]) invented by the two 1790 founders Breitzman and Thomas.

Figure 15 shows the Citation Index for the patents in the twelve technology categories that reference IEEE papers and conferences. Also shown is Citation Index for the set of the remaining patents in each category that do not reference IEEE. Note that the set of all patents in each category should have a citation index near 1.0. Thus we see that the patents that reference IEEE are cited 19% to 99% more than expected, while the patents that do not reference IEEE are cited 1% to 8% less often than expected. This suggests that technologies that build upon IEEE published or sponsored science are more likely to be valuable than technologies that do not reference IEEE science.

IV. Conclusions

When a patent is filed, it must reference the prior art upon which it builds, as well as any prior art that limits the claims of the new invention. This study suggests that science published by IEEE forms a significant portion of this prior art for new patents.

In this study, we examined two separate patent sets. The first patent set consisted of patents granted between 1997 and 2007 to the 25 organizations with the largest number of US patents granted in 2007. The second patent set consisted of all US patents granted between 1997 and 2007 patents in twelve key technologies: clocks, computer hardware, software, nuclear/x-ray, robotics, semiconductors, measuring and testing, medical devices, telecommunications, optics, power systems, and information storage. In both of these patent sets, IEEE is the dominant source of non-patent prior art. This suggests that IEEE journals and conferences are key outlets for scientific discoveries relevant to cutting edge technology.

Finally, we conducted an analysis of citation indices for IEEE related patents and non-IEEE related patents. These types of metrics have been shown in validation studies to be good markers for the quality and impact of patents. In this study, it was shown that patents that build upon IEEE published science tend to have higher citation indices than patents that do not reference IEEE. This suggests that patents that build upon IEEE science are more likely to become high-quality, high-impact, valuable inventions than patents that do not build upon IEEE.

V. References

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Appendix A

Figure 1 – Sample patent that cites IEEE information

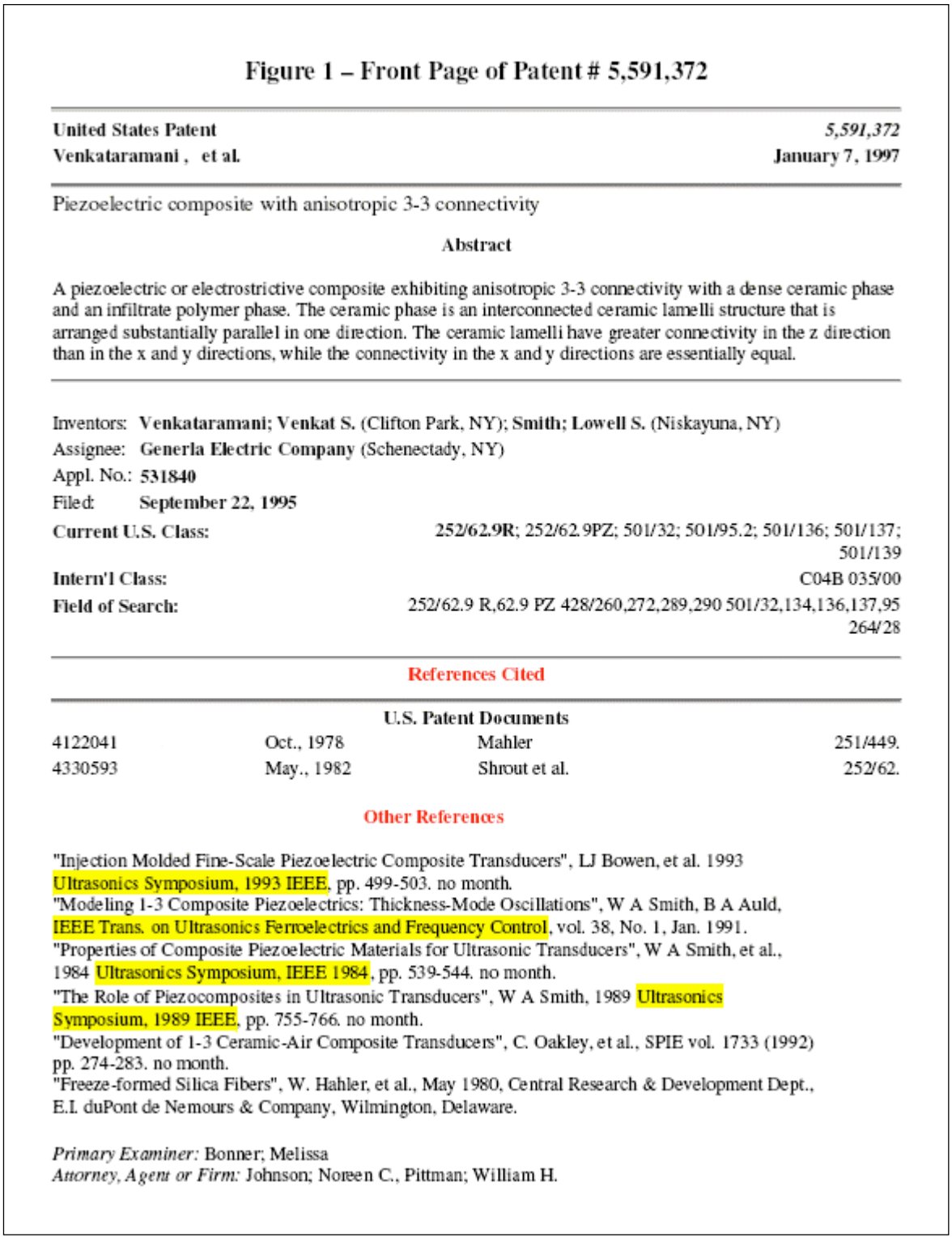

Figure 1 – Front Page of Patent # 5,591,372

United States Patent 5,591,372
Venkataramani , et al. January 7, 1997

Piezoelectric composite with anisotropic 3-3 connectivity

Abstract

A piezoelectric or electrostrictive composite exhibiting anisotropic 3-3 connectivity with a dense ceramic phase and an infiltrate polymer phase. The ceramic phase is an interconnected ceramic lamelli structure that is arranged substantially parallel in one direction. The ceramic lamelli have greater connectivity in the z direction than in the x and y directions, while the connectivity in the x and y directions are essentially equal.

Inventors: Venkataramani; Venkat S. (Clifton Park, NY); Smith; Lowell S. (Niskayuna, NY)
Assignee: Generla Electric Company (Schenectady, NY)
Appl. No.: 531840
Filed: September 22, 1995
Current U.S. Class: 252/62.9R; 252/62.9PZ; 501/32; 501/95.2; 501/136; 501/137; 501/139
Intern'l Class: C04B 035/00
Field of Search: 252/62.9 R,62.9 PZ 428/260,272,289,290 501/32,134,136,137,95 264/28

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Primary Examiner: Bonner; Melissa
Attorney, Agent or Firm: Johnson; Noreen C., Pittman; William H.

Appendix B

Figure 2 – Patent references from top 20 companies to top 20 publishers