computer scientists are more aware of the potential of the present systems and are willing to put more effort into using them, while pure scientists, for whom the computer is another tool, have a lower level of pain. If this is the case, it may be only a matter of time before everybody operates in the same mode. However, one can make the following observation: scientists, either in the laboratory or in computing, have shown that they will push their systems or tools to the limit in order to get to the results. In computing they are willing to learn to program in machine language if that gives the performance they need for a specific problem. We are now seeing physicists developing and building their own special-purpose calculating machines at a great cost in time and effort. In the laboratory it is common for scientists to take commercial instruments apart and rebuild them to improve performance, again at a great cost in time and effort.

In our laboratories, pure and applied scientists have access to the same facilities, but their patterns of collaboration are very different. It may well be that we are dealing here with subtle but strong cultural factors. It is easy to develop theories of why this is so, but it is difficult to decide one way or the other. This is a fascinating and important subject but more work, and perhaps more experience, is required to understand the reasons. Similar questions arise in connection with other fields that have proved intractable. For example, will education, that crude process in the classroom that has withstood every technical assault for the past 2000 or 3000 years, finally crumble before the impact of electronic progress? Some people think so and have projected that the interaction of computers with instruction will do it, but still we do not know. Will the availability of terminals in the home, the ability to program at home, and the ability to interact with others over wires, over glass, or possibly through satellites fundamentally change the working patterns of people? That is certainly possible, and again we do not know. Our inability to understand and predict the qualitative effects of computer technology is great. But even the straight-line projection, from what we have experienced to what we can reasonably expect to be the impact on science, is impressive.

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# Protection of Plant Varieties and Parts as Intellectual Property


Sidney B. Williams, Jr.


The coming of age of the biological sciences has raised new questions about the protection of technology under the intellectual property laws. Intellectual property, as opposed to tangible property such as real estate or personal property, includes subject matter that is protected by patents, trademarks, copyrights, trade secrets, and more recently, patent-like plant variety protection for varieties reproduced by seed. The protection of intellectual property is not a new concept since its availability can be traced back to Greece as early as 200 B.C. (*1*). However, because the rewards for intellectual property have been high, the requirements for obtaining it have also been quite high. It is the question of what must be given in exchange for patent protection, together with the question of what scope should be given to such protection, that creates many problems in patent law. Nowhere is this more evident than in the protection of plant varieties and their parts.

The importance of protecting plant varieties is evidenced by the number of countries that have passed plant breeders' rights legislation and by the formation of the International Union for the Protection of Plant Varieties (UPOV) (*2*). UPOV administers the treaty that, among other things, requires member states to provide the same rights to plant breeders of other member states as it provides its own nationals.

## Protecting Intellectual Property

Intellectual property is protected in two primary ways. The first is by statutory grants such as patents, trademarks, and copyrights. The second is by maintaining the subject matter a trade secret. Unlike patents, trademarks, and copyrights, which are mandated by federal statutory law, trade secret rights arise primarily from state court decisions or laws.

Trademarks are used to distinguish one's goods from those manufactured by others. They indicate the source of goods. The mark can be a word, symbol, name, device, or combination thereof. Examples include the Xerox, Coca-Cola, and Kodak brands.

Copyrights protect the manner of expression but not the ideas embodied in the expression. Examples are books, music, operas, maps. A copyright can only prevent others from copying the mode of expression. Independent creation is not an infringement of the copyright.

Utility (general) patents exclude others from making, using, or selling the invention and actually protect the embodied idea. They do not necessarily mean that the patentee can use his invention because it could be dominated by another patent. To be patentable the invention must be useful, novel, and unobvious (unobviousness requires a step that is not merely a technique within the scope of a person with ordinary skills in the art).

Plant patents provide protection for plant varieties that are reproduced asexually (by budding, grafting, tissue culture, and so on). Uncultivated and tuber-propagated plants (such as Irish potatoes and Jerusalem artichokes) are excluded from protection.

Plant variety protection provides patent-like protection for plant varieties re-


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produced by seed. Fungi, bacteria, and first-generation hybrids are excluded from protection.

Trade secret law protects against unauthorized appropriation or disclosure of the proprietary information.

The systems for granting intellectual property rights vary. The two broad classes are registration and examination systems. Protection under a registration system is easier to obtain because usually the only requirement is that of either novelty or originality. Novelty requires that the subject matter be different from existing subject matter that is known. The extent of the difference is irrelevant. Originality means that the applicant created the subject matter. In other words, the subject matter was not copied. Examples of registration systems are the U.S. copyright, trademark, and plant variety protection schemes.

Protection under an examination system is more difficult to obtain because there is generally a requirement for unobviousness or an "inventive step" as it is referred to in some foreign patent laws. Unobviousness requires a step or result that is beyond that expected of a person with ordinary skills and knowledge in the field of the invention for which protection is being sought. Examples of examination systems are the patent systems of the United States, United Kingdom, Federal Republic of Germany, the Netherlands, and Japan. Patents obtained under examination systems generally provide a broader range of protection than those obtained under registration systems.

The claims of an invention define what is protected. The claims can be analogized to a real estate deed. Instead of using distances and landmarks the claims contain works that outline the boundaries of the invention claimed. For example, Fig. 1 shows the boundaries of a claim to a group of chemical compounds. The boundaries surround any use of the compounds and any method of making them. Therefore, if someone else either discovers a new use of the compounds or a new method of making them, he will have to cross the boundary to compound A to practice the new use or method. Crossing the boundary without the owner's permission is a trespass or, in intellectual property terms, an infringement.

## Protecting Plant Varieties and Their Parts

*Plant varieties.* It is established that plant varieties that are reproduced asexually can be protected under the Plant Patent Law, the Townsend-Purnell Act of 1930 (*3*). It is also clear that plant varieties that are reproduced by seed are protectable under the Plant Variety Protection Act of 1970 (*4*). It is not so clear, however, whether asexually or sexually reproducible plant varieties can be protected under the general patent statute. Even though patents issued under the general patent law (*5*) have covered material containing living matter, the general patent law has most often been applied to inanimate subject matter. As a matter of fact, a great body of technology in which living material was utilized to produce chemicals provided the fertilizer for the production of steroids and antibiotics. However, a great deal of controversy arose when attempts were made to claim living organisms per se. Part of this controversy culminated in the case of *Chakrabarty* v. *Diamond, Commissioner of Patents and Trademarks* (*6*), in which the U.S. Supreme Court held that the fact that the claimed invention encompassed living matter did not preclude general patent protection. Specifically the Court held that the important fact in determining whether or not subject matter is patentable subject matter is whether or not there has been human intervention. *Chakrabarty* involved claims to certain human-modified microorganisms that were capable of "eating" oil. The case did not change the criteria of patentability (usefulness, novelty, and unobviousness). The Court specifically ruled on what was patentable subject matter. In other words, before the criteria of usefulness, novelty, and unobviousness can be applied to an invention it must first meet the criteria of being patentable subject matter.

Answering the question of whether the general patent statute can be used to protect plant varieties that are also protectable under the Plant Patent Law or the Plant Variety Protection Act requires a considerable amount of statutory construction. Statutory construction is a procedure used to interpret laws. One of its objectives is to determine which law among several laws dealing with the same subject matter is applicable when the laws conflict. Although such an analysis is beyond the scope of this article (*7*), it is clear that some thought will have to be given to whether or not there should be different treatment of food crop varieties as opposed to nonfood crop plant varieties. For example, the Plant Variety Protection Act contains express provisions for research (experimental use) and crop exemptions, whereas the general patent statute contains no such provision. Since the Plant Variety Protection Act was an attempt to correct the inequity of there being no patent-like protection for seed-reproduced plant varieties and since many of the varieties reproduced by seed are food crops, did Congress, by providing expressly for a research and crop exemption, articulate a different policy for food crop varieties than other plant varieties?

*Plant parts.* Plant patent and plant variety protection laws provide for the protection of plant varieties, that is, whole plants. But how do we protect their parts? This question has to be analyzed from two perspectives. First, if protection of the whole plant is obtained, are parts of the plant also protected? Second, is it possible to protect parts of plants without protecting the whole plant?

The question of whether protection of plant parts is obtained when a plant patent is granted has received some attention, especially in the area of cut flowers. The problem with cut flowers is that a plant can be purchased in the United States and taken to a country where there is no plant variety protection; the variety is then reproduced and the flowers are cut and imported back into the United States. The question here is whether it is an infringement of the plant patent to so sell the import under section 337a. One view is that a plant

*Summary.* In view of the Supreme Court decision in *Chakrabarty* v. *Diamond, Commissioner of Patents and Trademarks*, it is possible that plant varieties can be protected under three different U.S. statutes: the Plant Variety Protection Act, the Plant Patent Law, and the General Patent Law. The Plant Variety Protection Act protects varieties that are reproduced by seed, whereas the Plant Patent Law protects varieties reproduced asexually. Varieties, irrespective of how they are reproduced, could be patentable under the General Patent Statute. It is not clear whether parts of plants can be protected by grants under the Plant Patent Law or Plant Variety Protection Act and it is possible that they will be best protected under the General Patent Statute and by maintaining them as trade secrets. Only time will show whether the existing statutes are sufficient to provide both guidance and adequate protection or whether changes in the law will be required.

patent does provide such protection. This view is not held universally, however, and some feel that legislation should be introduced to make it clear that plant parts are protected by plant patents and that their importation into the country would constitute infringement of the plant patent (*8*).

Other commentators suggest that protection against the importation of cut flowers obtained from a protected variety is available in the International Trade Commission (ITC) under section 1337(a) of the Tariff Act (*9*). This act affords a remedy against an importer who commits an unfair trade practice that injures an industry in the United States. The Tariff Act specifically provides that infringement of a patent can constitute an unfair trade practice. Section 1337(b) of the Act is applicable because under the General Tariff Act the infringing acts must fall within the infringement provisions of the U.S. patent laws (*10*). However, section 1337(b) makes it an infringement to utilize a patented U.S. process in a foreign country for the purpose of producing an article or a good that is introduced into the United States. Since a plant patent covers asexual reproduction of a plant, it is in the nature of a process patent. Therefore, it can be argued that proceedings under the Tariff Act should be based on section 1337(b). While the situation of cut flowers has been cited as an example, there is no reason that the same argument cannot be equally applied to other plant parts.

Unlike the patent laws, which define infringement generally in terms of sale, manufacture, and use, the Plant Variety Protection Act spells out what constitutes an infringement of a plant variety certificate (*11*). It is clear from 7 *U.S. Code*, section 2541(6), that the sale of plant parts that can be used for reproduction of the variety constitutes infringement.

Protection of plant parts per se (protection that is sought for the parts themselves without any protection for the whole plant) is questionable under the Plant Patent Law and the Plant Variety Protection Act since both statutes provide protection for plants. How, then, may plant parts be protected? There are parts of plants that are readily identifiable—for example, the visible parts such as fruits, leaves, stems, and roots. Then there are the more esoteric parts such as cells, segments of DNA, plasmids, genes, and combinations thereof.

Since neither of the specific plant variety protection laws clearly provides protection for all parts of plants, it would seem that protection could appropriately be sought under the general patent statute.

If the plant part itself can be used to reproduce a hybrid plant or as part of a process to produce another useful item, an alternative means of protecting the part would be by trade secret. Trade secret law, while not governed by federal legislation, is well defined and is governed by state law in the United States. The practice of protecting hybrid plants by controlling the release of their parental lines was the primary reason that hybrids were excluded from plant variety protection.

### Living Versus Inanimate Matter

The basic policy behind any type of protection system for intellectual property law is the granting of an exclusive right to the inventor for a clear description of the subject matter so that it can be useful to the public when it is disclosed. In other words, the individual is rewarded for disclosing new information that can be put into the general pool of knowledge and used to advance technology and benefit mankind. It is on the question of adequate disclosure that much controversy has arisen regarding patent-like protection for technical products in general and plant variety and their parts specifically. To help ensure that this general public policy of disclosure is carried out, the general patent statute has very stringent requirements for the content of the patent application. These requirements are set forth in 35 *U.S. Code*, section 112, which reads in part as follows:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

This section states in essence that the specification shall contain a written description that clearly defines the invention in terms that can be followed by one having ordinary skill in the art. It requires that the invention be reproducible, that is, when one skilled in the art follows the description contained in the application, the results obtained by the patentee can be duplicated. A person having ordinary skill in the art is a person who understands and is knowledgeable about prior inventions in the field to which the invention relates.

Because plant materials can change form without intervention by man, questions have been raised as to the ability of the inventor to describe an invention in such a manner that it can be duplicated by those skilled in the art. Specifically, the concern is that even though techniques are followed as set forth, changes or slight variations may cause changes in results.

Discussed below are ways in which these concerns for adequacy of description and reproducibility have been addressed.

*The Plant Patent Law.* In the legislative hearings preceding passage of the Plant Patent Law the questions of description and reproducibility were approached in two ways. Plant patent applications would not have to meet the stringent requirements of 35 *U.S. Code*, section 112. Specifically, 35 *U.S. Code*, section 162, expressly states that plant patent applications are exempt from the requirements of 35 *U.S. Code*, section 112, and that all the breeder has to do is describe the plants to the best of his ability. Another aspect that has more to do with reproducibility than description is the requirement for asexual reproduction. When the Townsend-Purnell Act was being considered, it was felt that plants could not be reproduced true to form by seed and that the only way to do this was by some form of asexual reproduction. Thus, the limitation.

*The General Patent Law.* Questions about reproducibility increased during the growth of the fermentation industry. The fermentation industry has been important in the development of antibiotic and steroid technology. The intensity of the questions heightened when attempts were made to claim specific organisms. These organisms were important in producing various antibiotics. One of the important requirements of 35 *U.S. Code*, section 112, is that the patent application contain a description that is complete at the time of filing. That is, one skilled in the art should be able to pick up the application as it is filed and reproduce the invention. In the case *In re Argoudelis* (*12*) it was established that this disclosure requirement could be satisfied by indicating that the microorganism claimed or used in a claimed process has been deposited at a depository and that it would be made available upon the issuance of the patent. This method of meeting the disclosure requirements has been accepted by most of the patent systems throughout the world.

With respect to the protection of plant varieties under the general patent stat-

ute, it is probable that the disclosure requirements can be met by depositing seeds or other reproductive material for those varieties.

*The Plant Variety Protection Act.* It is already a requirement of the Plant Variety Protection Act that a sample consisting of 2500 seeds of the variety to be protected be deposited at the National Seed Laboratory at Fort Collins, Colorado. However, many questions linger with respect to depositing microorganisms or seeds. If the seed or microorganism mutates, are the requirements of reproducibility met? Is the mutant itself protected? Does the claimed process include use of the mutant?

To be protectable under the Plant Variety Protection Act a variety must be novel (*13*) and the right to the variety must not be precluded by the activities set forth in the section that defines the right to plant variety protection (*14*). A variety is novel under the Act if it is distinct, uniform, and stable. If a variety differs from all prior art varieties by one or more morphological, physiological, or other characteristic then it meets the criterion of distinctness (*15*). The degree to which a characteristic must differ to be distinct has not been addressed by either the Plant Variety Protection Office (PVPO) or the courts. This question has been raised by the International Union for the Protection of New Varieties of Plants (UPOV) under the categorization of minimum distance.

A variety is uniform if its characteristics can be described and predicted and if they are commercially acceptable (*16*). In the case of *In re Waller* (*17*), PVPO had to consider an application in which the question of uniformity was involved. In reversing a denial of protection on the grounds of lack of uniformity, the secretary of agriculture held that PVPO could not deny protection for a dahlia solely on the ground that it did not have a uniform flower color "if the variations in flower color are describable, predictable and commercially acceptable" (*17*, p. 7).

The requirements of stability (*18*) are met if the variety's main and distinctive characteristics remain unchanged when it is reproduced by seed. While the definition of stability has not been specifically addressed by either PVPO or the courts, it has been addressed implicitly by PVPO because the denial of the application by PVPO in the *Waller* cases was on the ground that it did not meet the requirement of uniformity and stability (*16*).

*Difference between food and nonfood crops.* Both the Plant Patent Law and the Plant Variety Protection Act provide protection for food and nonfood crops. However, except for fruits and nuts, most nonfood crops have been protected under the Plant Patent Law, whereas most food crops have been protected under the Plant Variety Protection Act. This is probably more historical than by design. The flower nursery industry, whose primary concern is with ornamental varieties, was a strong proponent of the Plant Patent Law, whereas passage of the Plant Variety Protection Act was strongly supported by the seed industry.

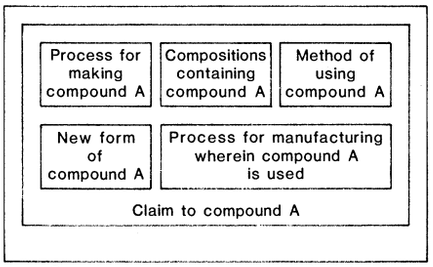


Fig. 1. Boundaries of a claim to a hypothetical group of chemical compounds. Compositions containing compound A include combination products having more than one ingredient.

As pointed out above, when the Plant Patent Law was enacted it was felt that the only way to reproduce varieties true to form was by asexual reproduction. Most ornamental plants (roses, chrysanthemums, and so forth) are reproduced asexually. They form the bulk of those plants covered by plant patents. Since most food crops are reproduced by seed, they cannot be protected by plant patents unless they are subsequently reproduced asexually. Because the technology has not yet developed to the point that most seed-produced crops can be produced more efficiently by asexual reproduction, food crops will probably continue to be protected under the Plant Variety Protection Act except when it is advantageous to attempt to do so under the general patent statute.

Protection of plant varieties under the general patent statute will raise some questions. One of the first is the question of experimental (research) use. Under the general patent statute there is no express provision for experimental use. However, a very narrow exception has evolved from case law. This exception excuses what would normally be considered infringing acts on the grounds that the acts were committed to satisfy scientific or philosophical curiosity. Acts have also been excused as being experimental on the grounds that they are considered to cause so little damage to the owner of the patent as to be meaningless. The Plant Variety Protection Act provides an express provision for a "research use" exception to infringement (*19*). Therefore, conflict could arise if a general patentee would attempt to prevent others from conducting research experiments with a protected variety. A question giving rise to the conflict is whether Congress expressed a public policy against suing researchers for infringement under the Plant Variety Protection Act that would override any rights under the general patent statute.

Another exemption that could create problems for the general patentee is the Farmers' Crop Exemption (*20*). This exemption gives a farmer who purchases a protected variety the right to use the variety to reproduce seed for production or use on his farm or to sell seed reproduced from the purchased seed. The right of a farmer to do this would appear to conflict with the provision under the General Patent Law under which the purchaser of a patented item can repair it but cannot reconstruct it. Also, at least one court has held that the Farmers' Crop Exemption does not entitle a farmer to promote or advertise the protected variety for sale (*21*).

Another difference between the General Patent Law and the Plant Variety Protection Act is that the former provides for compulsory licenses and the latter does not. Under the compulsory license provision the secretary of agriculture can permit others to produce a protected variety if he finds that to do so will be in the national interest. This difference, however, may be one of form rather than substance since the U.S. government (or a court when there has been an antitrust violation) can, under its powers of eminent domain, authorize others to use the patentee's invention. The patentee then has a remedy against the government in the U.S. Court of Claims (*22*).

## Breadth of Protection

Two of the most interesting questions concerning the protection of plant varieties are (i) how different will the new variety have to be from the closest old variety in the prior art to obtain protection and (ii) how different will a variety have to be from a protected variety without infringing that variety?

*The Plant Variety Protection Act.* Many people in the seed industry contend that once a difference has been identified between a new variety and

prior art varieties, the question of how much difference or the type of difference cannot be looked into by PVPO. In other words, if there is any difference, plant variety protection must be granted. Although there is support in the seed industry for such a position, the time will come when PVPO and the courts will have to determine what constitutes a difference.

*The Plant Patent Law*. There are suggestions in the legislative history of the Plant Patent Law (*23*) that the importance of the distinction between the new variety and prior art varieties cannot be considered by the U.S. Patent and Trademark Office in its determination of whether a new plant is distinct. In other words, if there is any difference it is sufficient to meet the requirement of distinctiveness.

*The General Patent Law*. The general patent statute provides a situation different from that of the Plant Variety Protection Act since a variety, to be protectable under the general patent statute, will have to meet the additional requirement of unobviousness. The requirement of unobviousness inherently involves the question of how large a difference must exist for a variety to be unobvious in view of prior art varieties. It also differs from the Plant Patent Law in that it provides for multiple claims.

The requirement of difference between varieties for which protection is being applied and prior art varieties is being considered by UPOV under the concept of minimum distance between varieties. At a meeting sponsored by UPOV in Geneva, Switzerland, in November 1983, the question of minimum distance was discussed.

The breadth of protection provided by the patent or certificate is very important in an infringement suit. For example, the patent or certificate holder must show that the accused variety infringes the patent or certificate. One approach would be to have the breadth of protection tied to the ease of securing the protection. For example, if there is no requirement for minimum distance to obtain protection (which is the case under most registration systems) then there should be no doctrine of equivalents. The doctrine of equivalents is a principle of patent law that holds that a patent may be infringed even though the alleged infringing matter is not an exact duplicate of that claimed in the patent if it does the same thing in substantially the same way (*24*). This is a well-known principle in patent law, but it remains to be seen whether it will be applied in plant variety protection lawsuits or lawsuits under the general patent statute in which protection of plant varieties is sought.

In the case of *Ex parte Jackson* (*25*), it was held that even though three microorganism species of a genus were disclosed in the patent, 35 *U.S. Code*, section 112, was not met since the genus encompassed species other than those specifically exemplified. This raises the question of whether or not it would be possible to obtain generic coverage for similar plant varieties of a species under the general patent statute. Specifically, how many species will have to be disclosed to support the genus?

## Plant Variety Denominations

No discussion of patent-like protection would be complete without mention of plant variety denominations (names). One requirement of protection under the plant breeders' rights laws of most countries and UPOV is that the variety for which protection is sought must be given a varietal name. The varietal name of a variety is similar to the generic name of a chemical compound. It is not a brand name or a trademark. The varietal name is important because it identifies the new variety by name and it establishes a name for the variety that is separate and distinct from any trademark that may be associated with the variety. In most countries it is not possible to register varietal names as trademarks because a variety could first be protected under plant variety protection laws and then protected perpetually under trademark laws.

Under the UPOV Convention the same varietal name cannot be given to varieties of the same species or a "closely related species." The latter phrase has elicited considerable debate between UPOV member states and has resulted in the drafting of guidelines on varietal denominations. It is probable that there will be continued discussion of the draft guidelines before a final version is adopted.

The Plant Variety Protection Act requires the assignment of a varietal name to the variety for which protection is being sought. However, there was no requirement in the Plant Patent Law until the United States joined UPOV. The Patent and Trademark Office established guidelines for varietal names for varieties claimed in plant patent applications. The guidelines are based on the International Code of Nomenclature (*26*).

## Conclusion

Because more and more private research funds are being poured into the development of plant varieties, stable and definitive protection for these varieties and parts thereof is very important. It remains to be seen whether adequate protection is available within the framework of the existing patent statutes or whether new legislation will be required.

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1. Frumkin, *J. Pat. Off. Soc.* **27**, 143 (1945).
2. International Convention for the Protection of New Varieties of Plants (2 December 1961; last amended 23 October 1978). There are 17 signatories to the treaty, including the United States, which became a member in 1980.
3. 35 *U.S. Code*, sect. 161 (patents for plants) (last amended 1952), states

   "Whoever invents or discovers and asexually reproduces any distinct and new variety of plant, including cultivated sports, mutants, hybrids, and newly found seedlings, other than a tuber propagated plant or a plant found in an uncultivated state, may obtain a patent therefor, subject to the conditions and requirements of title. (Amended September 3, 1954, 68 Stat. 1190.)

   The provisions of this title relating to patents for inventions shall apply to patents for plants, except as otherwise provided."
4. 7 *U.S. Code*, sect. 2321.
5. 35 *U.S. Code*, sect. 101 (inventions patentable), states

   "Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title."

   Section 102 (conditions for patentability; novelty and loss of right to patent) states

   "A person shall be entitled to a patent unless—

   (a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for patent, or

   (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of the application for patent in the United States, or

   (c) he has abandoned the invention, or

   (d) the invention was first patented or caused to be patented, or was the subject of an inventor's certificate, by the applicant or his legal representatives or assignees in a foreign country prior to the date of the application for patent in this country on an application for patent or inventor's certificate filed more than twelve months before the filing of the application in the United States, or

   (e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent, or

   (f) he did not himself invent the subject matter sought to be patented, or

   (g) before the applicant's invention thereof the invention was made in this country by another who had not abandoned, suppressed, or concealed it. In determining priority of invention there shall be considered not only the respective dates of conception and reduction to practice of the invention, but also the reasonable diligence of one who was first to conceive and last to reduce to practice, from a time prior to conception by the other."

   Section 103 (conditions for patentability; nonobvious subject matter) states

   "A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter

sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made."
6. *Chakrabarty* v. *Diamond*, 206 *U.S. Pat. Q.* 193 (U.S. Supreme Court, 1980).
7. A. Diepenbrock, C. Neagley, D. Jeffrey, *Am. Pat. Law Assoc. Sel. Leg. Pap.* 1 (No. 2), 81 (1983).
8. *American Patent Law Association Plant Variety Protection Committee Annual Report* (1981).
9. 19 *U.S. Code*, sects. 1337 and 1337a.
10. 35 *U.S. Code*, sect. 271.
11. 7 *U.S. Code*, sect. 2541.
12. *In re Argoudelis*, 168 *U.S. Pat. Q.* 99 (Court of Customs and Patent Appeals).
13. 7 *U.S. Code*, sect. 2401(a).
14. 7 *U.S. Code*, sect. 2402.
15. 7 *U.S. Code*, sect. 2401(a)(1).
16. 7 *U.S. Code*, sect. 2401(a)(2).
17. *In re Waller* (U.S. Secretary of Agriculture decision, 14 July 1981).
18. 7 *U.S. Code*, sect. 2401(a)(3).
19. 7 *U.S. Code*, sect. 2544.
20. 7 *U.S. Code*, sect. 2543.
21. *Delta and Pine Land Co.* v. *Peoples Gin Co.*, 694 *Fed. Rep.* 2nd ser. (Fifth Circuit Court, 1983).
22. 28 *U.S. Code*, sect. 1498.
23. U.S. House of Representatives, *House Rep. No. 1129* (71st Congress, Second Session, 10 April 1930; U.S. Senate, *Senate Rep. No. 315* (71st Congress, Second Session, 3 April 1930).
24. *Graver Tank & Mfg. Co.* v. *Linde Air Products Co.*, 339 *U.S. Rep.* 605 (U.S. Supreme Court, 1950).
25. *Ex parte Jackson*, 217 *U.S. Pat. Q.* 204 (Patent and Trademark Office Board of Appeals, 1982).
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**RESEARCH ARTICLE**

# A Deep 6-Centimeter Radio Source Survey

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Abstract. *The Very Large Array has been used to survey a small region of sky at a wavelength of 6 centimeters down to a completeness level of 60 microjanskys—about 100 times weaker than the faintest radio sources that have been detected with other instruments. The observed source count at flux densities below 100 millijanskys converges in a manner similar to the lower frequency counts, although there is some evidence for an excess of sources weaker than 100 microjanskys. The sources in the survey are preferentially identified with faint galaxies.*

The shortest wavelength at which extensive radio source surveys have been made is 6 cm. At this wavelength surveys by the National Radio Astronomy Observatory (NRAO) and Max-Planck-Institut (MPI) have covered most of the northern sky down to a limiting flux density of 600 millijanskys (mJy), while the various Parkes surveys provide complete samples of sources down to 1 Jy (*1*). Over limited regions of the sky other single-dish surveys made at NRAO and MPI are complete to 35 mJy (*2*), 20 mJy (*3*), 15 mJy (*4*), and 14 mJy (*5*). Synthesis surveys covering even smaller regions have reached levels of 4.5 mJy at Westerbork (*6*) and 0.5 mJy at the Very Large Array (VLA) (*7*). We have used the VLA to extend the surveys to sources that are as faint as 60 μJy at 6 cm, or about 100 times weaker than levels reached with other instruments at any wavelength. Source catalogs constructed from these surveys provide the basis for further studies in the radio region and in other parts of the spectrum. Further investigation is in progress on the nature of these weak radio sources, their spatial distribution and luminosity function, and how these properties change with cosmological epoch.

Counts of radio sources made at centimeter wavelengths are of particular interest since, for the stronger sources selected at this wavelength, flat-spectrum compact sources and steep-spectrum extended sources (which dominate the long-wavelength counts) are present in roughly equal numbers (*5, 8–10*). Previous surveys made at 6 cm for relatively bright sources show that for $S > 100$ mJy (approximately the 20,000 brightest sources in the sky) the counts are closely represented by the "Euclidean" law

$$\eta_0(S) = 90\ S^{-2.5} \qquad (1)$$

where $\eta_0(S)$ is the number of sources with flux density $S$ per unit flux density interval.

Between 10 and 100 mJy the 6-cm counts begin to decrease in a manner qualitatively similar to the long-wavelength counts of the steep-spectrum sources (*5, 8, 9*). However, the extended Euclidean plateau at 6 cm differs dramatically from the long-wavelength count, which is characterized by a steep rise for strong sources (the brightest 1000 or so) followed by a rapid decrease in the density of the weaker sources.

In this article we report on observations of very weak radio sources at 6 cm, and we discuss the angular size, spectra, and optical identification of these weak sources.

## Observations and Reductions

In order to investigate the number density of very faint radio sources, we have mapped a small area of sky, using the VLA to detect all sources with a flux density greater than 60 μJy. These new observations include the weakest radio sources yet cataloged and reach a source density of $6 \times 10^5$ sources per steradian. Supplemental information concerning this sample of sources was obtained through (i) VLA observations at 20 cm to determine the spectral index of the sources and (ii) optical observations with the 4-m telescope at Kitt Peak National Observatory (KPNO) to aid in the identification of the sources.

The 6-cm observations were made in the D configuration of the VLA to synthesize a 700-m-diameter antenna on a field centered at right ascension ($\alpha$) = $00^h15^m24^s$ and declination ($\delta$) = 15°33′00″ (epoch 1950.0). The resolution is about 18 arc sec and no emission will be missing for sources less than 120 arc sec in size. The general area of the field

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