IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

THE FINNEY COMPANY, a partnership,	)	
	)	
Plaintiff,	)	CIVIL ACTION NOS.
	)	
vs.	)	65 C 220
	)	
JFD ELECTRONICS CORPORATION, a corporation, and THE UNIVERSITY OF ILLINOIS FOUNDATION, a non-profit corporation,	)	and
	)	65 C 671
	)	(Consl.)
Defendants.	)	

PLAINTIFF'S MOTION FOR SUMMARY JUDGMENT

Now comes the plaintiff, by its attorneys, and moves under the provisions of Rule 56, F.R.C.P., for a summary judgment that two of the three patents in suit are invalid in their entireties, and that one of the two is unenforceable for unclean hands in the procurement thereof, said patents in suit being:

I. U. S. patent No. 3,210,767 (PX-A)*
Inventor: Dwight E. Isbell
Application filed: May 3, 1960
Patent granted: October 5, 1965

II. U. S. patent No. Re. 25,740 (PX-B)**
Inventors: Paul E. Mayes and Robert L. Carrel
Original application filed: September 30, 1960
Original patent No. 3,108,280 granted: October 22, 1963
Reissue application filed: March 5, 1964
Reissue patent granted: March 9, 1965

I. ISBELL PATENT NO. 3,210,767

The ground for invalidity of the claims of the Isbell patent is that the subject matter of said claims was described in a printed publication (PX-4)*** published April 30, 1959 (more than one year prior to the May 3, 1960, date of application for the patent) in contravention of §102 of Title 35, United States Code [35 U.S.C. 102(b)].

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* Hereafter called "Isbell patent."

** Hereafter called "Mayes et al. reissue patent," the original patent replaced thereby being hereafter called "Mayes et al. original patent."

*** Antenna Laboratory Quarterly Engineering Report No. 2, "RESEARCH STUDIES ON PROBLEMS RELATED TO ECM ANTENNAS," Electrical Engineering Research Laboratory, Engineering Experiment Station, University of Illinois, Urbana, Illinois. This report has heretofore been identified as plaintiff's Exhibit 4 (PX-4) and will hereafter be so referred to.

II. MAYES ET AL. REISSUE PATENT NO. RE. 25,740

A.

The ground for invalidity of the claims of the Mayes et al. reissue patent is that the alleged inventors did not themselves invent the subject matter of said claims, but derived the same from another,* so that the patent was granted in contravention of §102(f) and §103 of Title 35, United States Code [35 U.S.C. 102(f) and 103].

B.

The Mayes et al. reissue patent is unenforceable because it and the Mayes et al. original patent on which the reissue was based were both procured by the Foundation defendant by presenting the Patent Office with deceptive and misleading evidence to the effect that the earlier work of Dwight E. Isbell was not a part of the prior art, whereas it was in fact a part of the prior art and had been described in printed publications** more than one year prior to the date of the application for the Mayes et al. original patent. As a result, the Patent Office dropped the earlier work of Isbell from consideration as prior art against Mayes et al., which it otherwise would not have done, and was

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* Edwin M. Turner of Wright Patterson Air Force Base, Dayton, Ohio.

** The publication PX-4 and Antenna Laboratory Technical Report No. 39, "LOG PERIODIC DIPOLE ARRAYS," Electrical Engineering Research Laboratory, Engineering Experiment Station, University of Illinois, Urbana, Illinois. The latter report has heretofore been identified as Plaintiff's Exhibit 17 (PX-17) and will hereafter be so referred to.

thereby influenced to grant the Mayes et al. original and reissue patents. Because defendant knew the pertinent facts, or should have known them, they have come into court with unclean hands with respect to the Mayes et al. reissue patent and are not entitled to enforce that patent, and the patent is invalid. Hazel-Atlas Glass Co. v. Hartford-Empire Co., 322 U.S. 238 (1944); Precision Instrument Manufacturing Co. v. Automotive Maintenance Machinery Co., 324 U.S. 806 (1945); Walker Process Equipment, Inc. v. Food Machinery and Chemical Corp., 322 U.S. 172 (1965).

SUPPORTING EVIDENCE AND MEMORANDUM

Affidavits supporting the foregoing motion as to each of the grounds thereof are attached hereto as a part hereof, together with copies of depositions, answers to interrogatories, and admissions that are on file or are filed herewith, and copies of prior patents and publications that are also relied upon in support of this motion.

A separate memorandum in support of this motion further explains each of the grounds therefor and is being filed by plaintiff concurrently therewith.

Respectfully submitted,

MASON, KOLEHMAINEN, RATHBURN & WYSS

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PLAINTIFF'S MEMORANDUM IN SUPPORT OF
ITS MOTION FOR SUMMARY JUDGMENT

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PX-4 .....University of Illinois Quarterly Report No. 2 under the Air Force antenna research contract, PX-1A

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* Plaintiff's exhibits are designated throughout as "PX _____." Those exhibits introduced specifically for the purposes of plaintiff's motion have been identified by alphabetical symbols and others by numerical symbols.

PX-5 .....University of Illinois Quarterly Report No. 1 under the Air Force antenna research contract, PX-1A

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PX-34 ....."Radio Engineers' Handbook," by Frederick Emmons Terman, 1943 (selected portions)

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PX-36 .....Patent Office file history of Isbell application for his patent in suit, PX-A

LIST OF AUTHORITIES CITED

LIST OF STATUTES AND RULES CITED

NATURE AND SUBJECT MATTER OF THE SUIT

This suit is a consolidation of (1) a suit by The Finney Co. for declaratory judgment that three patents of the Foundation defendant are invalid and not infringed, and wherein the Foundation has counterclaimed that plaintiff has infringed all three patents,* and (2) an earlier filed suit by the Foundation against The Finney Co. (and another defendant as to whom the earlier suit has been dismissed). Issue has been joined by the pleadings in both suits, and jurisdiction and venue are conceded.

All three patents in suit relate to radio frequency antennas having certain design and performance characteristics in common. From those common characteristics, the antennas of all three of the patents in suit are known as "log periodic antennas."

NATURE OF THE MOTION

Plaintiff's motion attacks the validity of all claims of two of the three patents in suit, namely, Isbell patent No. 3,210,767 (PX-A) and Mayes et al. reissue patent No. Re. 25,740 (PX-B). The motion also attacks the enforceability of the Mayes et al. reissue patent by the Foundation defendant on the ground that this patent is invalid because it was procured by presenting deceptive and misleading evidence to the Patent Office so that the Foundation comes into court with unclean hands.

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* Other causes of action against defendant JFD are not involved in plaintiff's motion.

RELATED LITIGATION

The importance of this motion and the urgency of having it considered and decided on its merits are abnormally great in view of three related suits pending in this Court and involving validity and infringement of one or both of the same two patents attacked by the motion.* In practical effect, the granting of this motion will dispose of all of the issues of patent validity and infringement of two of those related suits, will eliminate one of the two patents involved in the third of those related suits, and will reduce the patent issues in the present suit from a suit on three patents against 17 different antennas charged to infringe to a suit on only one patent against only 8 of the antennas charged to infringe.

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* The University of Illinois Foundation v. Blonder-Tongue Laboratories, Inc. et al., Doc. 66 C 567 (involving the Isbell patent and the Mayes et al. reissue patent); The University of Illinois Foundation v. Jerrold Electronics Corp., Doc. 66 C 636 (involving the Isbell patent and the Carrel et al. patent); The University of Illinois Foundation v. Channel Master Corporation et al., Doc. 65 C 568 (involving the Isbell patent).

SYNOPSIS OF MOTION

I.

Isbell Patent No. 3,210,767 Invalid Because the Application Therefor was Not Timely Filed as Required by 35 U.S.C. 102(b)*

The printed publication PX-4 is a University of Illinois report that admittedly describes the antennas of the invention of this Isbell patent (Stipulation PX-C, par. 5-9).

The Report PX-4 was published April 30, 1959, by virtue of--

(a) Its availability to the public in the "Local Library," Electrical Engineering Department, University of Illinois (Johnson Affid. PX-D; Lawler dep. PX-E), and

(b) Extra copies thereof being available to the public, for the asking, at the "Publications Office," Electrical Engineering Department, University of Illinois (Johnson Affid. PX-D; Lawler dep. PX-E).

The "Local Library" as a source of similar technical publications was available to faculty and students of the University of Illinois and to members of the public since prior to April 30, 1959. The

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* 35 U.S.C. 102:
"A person shall be entitled to a patent unless--
* * *
(b) the invention was * * * described in a printed publication in this or a foreign country * * * more than one year prior to the date of the application for patent in the United States * * *."

"Publications Office" as a source of similar technical publications had been well known to and used by interested members of the public, including persons in industry and faculty and students of the University of Illinois, since prior to April 30, 1959. (Johnson Affid. PX-D;* Lawler dep. PX-E;** Mayes dep., PX-F)

The application for the Isbell patent (PX-A) was not filed in the Patent Office until May 3, 1960 (PX-A - caption data). By the terms of 35 U.S.C. 102(b), the publication of PX-4 more than one year earlier (on April 30, 1959) renders that patent invalid.

As 35 U.S.C. 102(b) has been interpreted by the courts, without an applicable exception, the availability of PX-4 on April 30, 1959, from either source (a) or source (b), above, constitutes "publication" on that date.

Since a patent exists only by statutory authority, there can be no exception to the express prohibition in the patent

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* Johnson testified entirely consistently with her affidavit PX-D on direct and cross-examination in related litigation. The pertinent parts of that sworn testimony are submitted herewith as PX-DD and are mentioned further below.

** Lawler testified entirely consistently with his deposition PX-C in related litigation as a witness for the present Foundation defendant. The pertinent parts of that sworn testimony are submitted herewith as PX-EE and are mentioned further below.

statute to the patenting of an invention published more than one year prior to the application for the patent. Isbell patent No. 3,210,767, therefore, must be held invalid because the application therefor was not filed within the time requirement of 35 U.S.C. 102(b).

II.

A. Mayes et al. Reissue Patent No. Re. 25,740 Invalid Under 35 U.S.C. 102(f) Because Mayes et al. Did Not Themselves Invent the Subject Matter Thereof as Required by 35 U.S.C. 102(f)*

Mayes and Carrel, when reporting the subject matter of their reissue patent in the form of a "RECORD OF INVENTION" (PX-15), made reference in item 9 thereof to a suggestion they received from a Mr. E. M. Turner of Wright Air Development Center. In his deposition (PX-F, pp. 113-115), Mayes acknowledged his understanding that Turner was referring to moving the arms of the simple dipoles of the Isbell patent into the form of V-dipoles.** This change in the dipoles produced only the results which the prior literature taught Mayes et al. to expect (Mayes dep. PX-F, pp. 116-121); and

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* 35 U.S.C. 102:
"A person shall be entitled to a patent unless--
* * *
(f) he did not himself invent the subject matter sought to be patented * * *."

** Mayes also admitted that the use and operation of V-dipoles for the purposes described in the Mayes et al. reissue patent had been well known in the art prior to that time (Mayes dep. PX-F, pp. 48-51). How very well known it was is discussed hereinafter.

this is the only change in the earlier developed antennas of the Isbell patent that is disclosed in the specifications and drawings of the Mayes et al. original and reissue patents, as expressly stated in the latter at col. 2, lines 44-49, and confirmed by Mayes (Mayes dep., PX-F, pp. 121-123, 154-156). Thus, the Mayes et al. reissue patent discloses the antennas earlier developed by Isbell when modified only according to the suggestion of Turner.

It follows that, at most, all Mayes and Carrel contributed to the invention disclosed and claimed in their reissue patent was a mere recognition of the expected attributes of what was conceived and suggested to them by Turner. As a matter of established law, what was done by Mayes and Carrel does not constitute the making of an invention; and any invention made was the invention of Turner, not of Mayes and Carrel. The Mayes et al. reissue patent, therefore, must be held invalid under 35 U.S.C. 102(f) because the patentees did not invent the subject matter thereof.

B. Mayes et al. Reissue Patent No. Re. 25,740 Unenforceable for "Unclean Hands" of the Foundation Defendant, Who Furnished the Patent Office with Deceptive and Misleading Evidence in Procuring the Patent

During the prosecution of the application for the Mayes et al. original patent, the Patent Office rejected the claims thereof on a May, 1960, publication (PX-28)* of an article by

* IRE Transactions on Antennas and Propagation, May, 1960, Vol. AP-8, No. 3, pp. 260-267.

Dwight E. Isbell entitled "Log Periodic Dipole Arrays," in view of a previously cited patent to Rowland (file history, PX-29, p. 30).

Mayes et al. responded to that rejection by filing in the Patent Office an affidavit and attorney's argument asserting and documenting completion of their V-dipole development prior to the May, 1960, date of the cited IRE publication and prior to the May 3, 1960, filing date of the application for the Isbell patent covering the log periodic dipole arrays described in the cited IRE publication. That was done for the stated purpose of removing both the IRE publication and the prior Isbell application from consideration by the Patent Office as prior art against Mayes et al. (file history PX-29, pp. 31-43).

That procedure for antedating the description of an invention in a publication is permissible, in view of the grace period provided by 35 U.S.C. 102(b), only if the earliest such publication was not more than a year before the filing date of the application against which the publication is cited (Pat. Off. Rule 131, 35 U.S.C.A., pp. 685-686). However, that Isbell development was described in a printed report by the University of Illinois (PX-4) that was published April 30, 1959,* and in another printed report by the University of Illinois (PX-17) published at least by September 23,

* See Part I of this motion and admitted distribution date of May 5, 1958, in stipulation, PX-C, par. 10.

1959,* both publication dates being more than one year before the filing of the application for the Mayes et al. original patent.** To the extent that any of these facts might not have been known to any particular person in the organizations of the Foundation defendant and its counsel at the time of filing the above-mentioned Mayes affidavit, that information was clearly available and readily ascertainable (discussed and documented in detail hereinafter).

The foregoing facts, known or available to Mayes et al. and to the Foundation defendant and to their counsel, made Isbell's log periodic dipole development prior art having a material bearing on patentability of the Mayes et al. claims in the respects stated in the aforementioned rejection. However, the Mayes affidavit necessarily implied no knowledge by any of them of those facts. Therefore, the filing of the Mayes affidavit was either a deliberate effort to mislead the Patent Office regarding the prior art status of Isbell's work or was done in a reckless and irresponsible disregard of the above-stated facts.

The Patent Office, having thus been misled by the Mayes affidavit, expressly accepted it for the purpose for which it was offered and withdrew the rejection of the Mayes et al. claims on the IRE publication. Concurrently, the Patent Office allowed the first seven claims of the Mayes et al. original patent and, in due

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* Stipulation, PX-C, par. 11.

** September 30, 1960. See cover page of file history, PX-29.

course, the remaining claims thereof and the additional claims of their reissue patent, without ever again citing the prior Isbell work as prior art. Had the Patent Office known the foregoing facts, the Mayes affidavit would have been ineffective and would not have been accepted for the purpose for which it was offered. (File histories, PX-29 and PX-30)

The Foundation defendant, having been a party to the foregoing, "is in no position to dispute" the effectiveness of its deception in persuading the Patent Office to grant the Mayes et al. original and reissue patents; and the total effect of this "calls for nothing less than a complete denial of relief * * * for the claimed infringement of the patent thereby procured * * *." Hazel-Atlas Glass Co. v. Hartford-Empire Co., 322 U.S. 238, 247, 259 (1944) and additional cases cited in the more detailed discussion of the law hereinafter.

BACKGROUND

Historical Background

The developments that gave rise to the three patents in suit were made at the University of Illinois in the course of performing research for departments of the United States Government, particularly the Air Force. Specifically, the developments of those three patents were made under an Air Force contract dated August 28, 1958 (PX-1A), which required the University to perform

"antenna research" directed to a variety of antenna problems including, inter alia, continuing work on so-called "broad band antennas" that had been in progress under an earlier contract. The purpose was to devise antennas "for which the patterns and impedance are independent of frequency." Such antennas are commonly termed "frequency independent antennas," and the antennas of both of the patents attacked by this motion fall in that broad category. (PX-1A; PX-A; PX-B; Mayes dep. PX-F, pp. 19-30, 52-53)

Frequency independent operation is especially important where the radio frequencies being used may fall anywhere within, or vary over, a broad range or band of frequencies and uniform response over such range or band is required by the particular antenna application. Frequency independent antennas find practical application, for example, in specialized military operations termed "electronic countermeasures" (abbreviated "ECM"), as well as in many other operations involving the transmission and reception of widely varying frequencies. (Mayes dep., PX-F, pp. 177-179; Finneburgh affidavit, PX-G, par. 12)

The type of frequency independent antennas to which the three patents in suit relate involves certain progressively varying dimensional relationships that render the antennas cyclical or "periodic" in performance as the frequency of operation is varied progressively over the bands of frequencies for which the antennas are designed. The cycles or periods repeat according to a simple proportional relationship that is called "logarithmic" in mathematical terminology. Thus, such antennas are called

"logarithmically periodic antennas" or, using an abbreviated term, "log periodic antennas." (Finneburgh affidavit, PX-G, par. 13; Mayes article, PX-H, p. 3)

The two patents in suit attacked by this motion are directed to log periodic antennas which are roughly "unidirectional," i.e., when used as transmitting antennas, they transmit energy as a "unidirectional" beam of radiation with only relatively little radiation being emitted in other directions, or conversely, when used as receiving antennas, they receive radiation efficiently from essentially only one direction while being relatively ineffective in receiving radiation from other directions. (Finneburgh affidavit, PX-G, par. 13; PX-A; PX-B)

Development of the particular forms of log periodic antennas to which the three patents in suit relate was based upon earlier work at the University of Illinois by V. H. Rumsey, Raymond H. DuHamel, Dwight E. Isbell, and possibly others. Additional work was done by DuHamel and others at Collins Radio Company of Cedar Rapids, Iowa, after DuHamel left the University about the latter part of 1957. The sequential relationship of the log periodic antenna developments made in the course of all of that work is described in the article (PX-12) entitled "Logarithmically Periodic Antenna Designs" by DuHamel and Ore, published by Collins Radio at least by May 14, 1958. (Mayes dep., PX-F, pp. 18-19, 27-30, 52-54; Mayes article PX-H, pp. 3-4; Stipulation PX-C, par. 14)

The first of that related series of log periodic antenna developments was made by DuHamel (Mayes article PX-H, pp. 1-2) and was patented by the University of Illinois Foundation on an application filed July 9, 1958, which issued as patent No. 2,985,879 (PX-31). It is illustrated in Fig. 1a and described on pp. 1 and 2 of both PX-12 and PX-H.

The second of that related series of log periodic antenna developments was made by Isbell (Mayes article PX-H, pp. 3-5) and was also patented by the University of Illinois Foundation, on an application filed October 20, 1958, which issued as patent No. 3,011,168 (PX-32). That Isbell patent is not here in suit and is to be distinguished from the Isbell patent in suit No. 3,210,767 (PX-A). That development is illustrated in Fig. 1b and described on p. 2 of PX-12 (as well as in PX-H, pp. 3-5).

The next several of that related series of log periodic antenna developments were made at Collins Radio by DuHamel and Ore (Mayes article, PX-H, pp. 4 and 6) and were patented by Collins Radio on a single application filed March 14, 1958, which issued as patent No. 3,079,602 (PX-33). Those developments, their objectives, and their structural and functional relationships are described in PX-12, beginning on p. 2. The resulting antenna forms of particular present interest are shown in Figures 2, 9, and 15 of PX-12 and in Figs. 1-7 and 15 of the patent PX-33.

That related series of prior developments, from the first (by DuHamel) through the last-mentioned group (developed by DuHamel and Ore), illustrates the evolution of log periodic antennas from sheet metal structures through a sequence of rod and wire structures, leading progressively closer to the rod dipole forms of the Isbell patent in suit (PX-A), both in physical structure and in performance characteristics (Mayes article PX-H, pp. 4 and 7). All involved the same kind of mathematical progression of dimensions from one end to the other. All were developed and described in the printed publication PX-12 by May of 1958, prior to the earliest work on any of the developments of the three patents in suit (which were made between the fall of 1958 and January of 1960, as summarized below).

The work of Isbell, Mayes et al., and Carrel et al. that gave rise to their three patents in suit was performed at the University of Illinois under the Air Force contract PX-1A dated August 28, 1958 (Mayes dep. PX-F, pp. 21-23). According to Isbell's report to the University, PX-3, and his Preliminary Statement in a Patent Office interference, PX-I, his earliest conception of the log periodic dipole antennas of his patent in suit was in September, 1958, and such antennas were first built and tested by December, 1958.*

* See colloquy between counsel and stipulation re Isbell's invention dates in Mayes deposition, PX-F, at pp. 35-37.

Thus, as should be understood at the outset, and contrary to what one might gather from the three patents in suit alone, Isbell did not originate the log periodic principle of antenna design. On the contrary, the antennas of the three patents in suit followed a sequence of log periodic antennas developed earlier at the University of Illinois and at Collins Radio Company and separately patented by the University and by Collins Radio in the names of DuHamel, Isbell, and DuHamel and Ore. (Mayes dep. PX-F, pp. 27-30, 52-54; PX-H; PX-I; PX-31; PX-32; PX-33)

The prior art status of the DuHamel patent, PX-31, and the DuHamel and Ore patent, PX-33, are established by their filing dates in the Patent Office (shown on the face of the patents) prior to the earliest alleged conception by Isbell of the subject matter of the Isbell patent in suit. Except as it indicates an intermediate development step between the disclosures of those two patents, the Isbell patent No. 3,011,168, PX-32 (not in suit) is of only historical interest here.

It is primarily in the light of the foregoing prior art background that the subsequent developments of the three patents in suit should be viewed. Although the obviousness of the latter developments has been placed in issue by the pleadings, it should be clearly understood that it is not an issue of this motion. On the other hand, it should also be understood from the foregoing that the antennas of the patents in suit were not the first log

periodic antennas, or the first to provide unidirectional operation with substantially uniform radiation patterns and input impedance over theoretically unlimited frequency bands. The similarities between the prior art log periodic antennas of the DuHamel and Ore patent (PX-33) and the later antennas of the Isbell patent in suit will be further clarified below in explaining the respective structures and performance characteristics of those patents and of the Mayes et al. reissue patent, in accordance with their respective disclosures.

Technical Background

The issues raised by this motion are such as to require no special knowledge of technical facts. On the other hand, an understanding of a few uniformly accepted, basic principles of radio frequency wave transmission and reception may be helpful to the Court, and those principles are briefly explained in the Finneburgh affidavit (PX-G) for reference by the Court for that purpose.

Also, it is assumed that, for its own satisfaction, the Court would like to know more about the alleged inventions of the Isbell and Mayes et al. patents in suit and about the immediately preceding prior art patent of DuHamel and Ore. Accordingly, primarily for that background purpose, each of those patents and their relationship to each other will be described further in the ensuing six pages before dealing in detail with the merits of this motion.

The Isbell Patent in Suit

The Isbell patent in suit (PX-A) discloses two physically different forms of antennas that are electrically equivalent. As shown in Fig. 1 of the patent and described in the specification, the antennas of the patent may comprise a planar array of dipoles* 10, 11, 12, etc. of progressively diminishing lengths L_1, L_2, L_3, etc., with dipole spacings that similarly diminish in the same direction (col. 1, lines 33-36). As further disclosed in the specification, "the ends of the dipoles fall on a pair of straight lines which intersect and form an angle α **" (col. 1, lines 36-40); and the successive lengths and spacings of the dipoles "are related by a constant scale factor τ,"*** i.e., a multiplier stated to be "less than 1" (col. 1, line 56). Thus, the length of each successive smaller dipole is equal to the length of the adjacent larger one multiplied by the decimal fraction τ, and each successive smaller space between dipoles is equal to the adjacent larger space multiplied by the same decimal fraction τ.

As also shown in Fig. 1 and described in the specification of the patent, the several dipoles are "fed" or driven at the "narrow" or small dipole end of the array by an "alternator" or

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* A dipole is an active antenna element. In its simplest form, it is a straight conductor having a center gap, as shown in Fig. 1 of PX-A.(Mayes dep., PX-F, pp. 39-43)

** Greek letter "alpha."

***Greek letter "tau."

transmitter, shown diagrammatically at 13 as being connected to the antenna by balanced feeder lines (two-wire transmission line) 14 and 16. The feeder lines 14 and 16 continue through the array so as to interconnect the several dipoles with the feeders, and the feeders are "alternated" or transposed between dipoles so as to produce a "phase reversal" between the successive pairs of dipole connections (col. 1, lines 43-49).

The radiation pattern of such antennas is essentially "unidirectional" to the left (forward direction) as viewed in Fig. 1, typical radiation patterns being shown in the "E plane" (plane of the dipoles) in Fig. 3 and "H plane" (longitudinal of and perpendicular to the plane of the dipoles) in Fig. 4. The scale of these patterns in Figs. 3 and 4 is such that only the radiation in a generally forward direction, or to the left as the antenna is viewed in Fig. 1, is shown (col. 2, lines 3-7 and 45-52). To some degree, one or more much smaller radiation lobes in another or several other directions would appear in Figs. 3 and 4 if they were drawn to a larger scale (or on what is commonly called a logarithmic scale). This is indicated by the reference to a front-to-back ratio of "17db" at col. 2, lines 49-50. (Finneburgh affidavit, PX-G, par. 17)

As shown in Fig. 2 of the patent and described at col. 2, lines 8-45, the physical form of the antenna of Fig. 1 may be

modified by substituting closely spaced parallel feeder conductors 17 and 18 of Fig. 2 for the repeatedly transposed feeders 14 and 16 of Fig. 1. By alternating the connections of the dipole halves (e.g., 19 and 19a, 21 and 21a, etc.) to the feeder conductors of Fig. 2, essentially the same alternation in phase between successive dipoles is obtained as with the transposed feeders of Fig. 1 (col. 2, lines 21-23). Although the two halves of each dipole and, hence, the several dipoles of the array of Fig. 2 are not precisely coplanar, the spacing of the feeder conductors is so small that the effect of the planar arrangement of Fig. 1 is not lost in the structure of Fig. 2, and the previously described operating characteristics are maintained (col. 2, lines 24-28). Thus, for practical purposes, the dipole array of Fig. 2 may be considered to be a substantially planar array and, electrically, essentially the same as the array of Fig. 1.

The Prior Art DuHamel and Ore Patent

The DuHamel and Ore patent (PX-33), in Figs. 3, 4, and 5, discloses three forms of log periodic antennas made of straight rods in different configurations that were successively derived from the sheet metal antenna of Figs. 1 and 2 of the patent. All four of those forms include two tapered, planar assemblies that are slightly spaced apart at their apices 28 and that diverge by an angle ψ (Greek letter psi). All four forms have essentially

uniform radiation patterns and input impedance "over a very broad operating (frequency) range, which may be greater than ten-to-one" (col. 1, lines 11-15). As the patent discloses (col. 2, lines 51-53), the angle ψ may be reduced to 0° so that the center conducting rods 46 and 47 of the two planar assemblies are slightly spaced apart and parallel, as in Fig. 2 of the Isbell patent in suit; and as the angle ψ approaches 0°, the antennas become more nearly unidirectional (col. 9, lines 59-67).

When the angle ψ is thus reduced to 0° in the antenna of Figs. 1-2 of the DuHamel and Ore patent, its structural similarity to the form of antenna shown in Fig. 2 of the Isbell patent in suit is evident and was acknowledged by Mayes (Mayes dep., PX-F, p. 83).

How the antennas of the Isbell patent are derivable in a simple manner from the antennas of the DuHamel and Ore patent has been pointed out by Mayes (PX-H, p. 4, penultimate par.). As is evident, the antenna of Fig. 2 of the Isbell patent results merely from reducing the tooth widths in Fig. 1 of DuHamel and Ore (PX-33), when the angle ψ is 0°, as by substituting simple dipole rods for other dipole-like members, with no other change in physical or electrical structure.

The Mayes et al. Original and Reissue Patents

The entire content of the Mayes et al. original patent is given in the Mayes et al. reissue patent now in suit (PX-B). As stated in the latter (col. 1, lines 11-14)--

> "Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue."

The absence of either brackets or parentheses in the specification and first ten claims of the reissue patent shows that the original patent was changed only by addition to the reissue patent of claims 11-17, inclusive.

After briefly describing the subject matter of the previously filed application for the Isbell patent in suit, the Mayes et al. specification continues (col. 1, lines 40-55)--

> "In accordance with the present invention, it has been found that the directivity of an antenna of the type described in the aforementioned application may be increased and the effective frequency range of an antenna of fixed size may be extended by inclining the dipoles of Isbell to form V-elements, each of which consists of two straight arms of equal length defining an apex which points away from the direction of radiation of the antenna which is also the direction in which the element size decreases. The modification of the straight dipoles of Isbell to V-shaped elements permits the antenna to be operated over bands of frequencies higher than those established, as described above, by the length of the shortest dipole in the antenna, with increased directivity, thus obviously increasing the effective frequency range of a given antenna."

As the specification makes clear and as Mayes was forced to admit,* the Mayes et al. original and reissue patents

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* See PX-B, lines 44-49, col. 4, lines 19-21; Mayes deposition, PX-F, pp. 113-123, 154-155.

disclosed the prior Isbell invention as changed only by substituting known V-dipoles for the straight, simple dipoles of Isbell. As mentioned in the foregoing Synopsis (Part IA) and as explained in more detail hereinafter, that single change was admitted by Mayes et al. to have been suggested to them by another person and, therefore, was not their idea in the first place. The result of that change was to give the antenna only the expected and well known ability to operate in a similar manner over a number of additional frequency ranges that are higher harmonics of the range which would be covered by the corresponding straight dipole form of Isbell.*

* Such well known "multi-mode" operation is explained hereinafter at pp. 49-50 and in the affidavit of L. H. Finneburgh, Jr. (PX-G, par. 15, 16). That it was common knowledge in the art is shown by a 1943 "Handbook" (PX-34).

I.

ISBELL PATENT NO. 3,210,767
INVALID BECAUSE THE APPLICATION THEREFOR WAS NOT
TIMELY FILED AS REQUIRED BY 35 U.S.C. 102(b)

This ground for invalidity of the Isbell patent in suit (PX-A), summarized in Part I of the foregoing Synopsis, will now be fully presented with detailed reference to the facts, the supporting documents, and the applicable law. The absence of any genuine issue of material fact and invalidity of the patent as a matter of law will clearly appear from this presentation.

The Evidence

The controlling facts upon which this ground of the motion is based are contained in a stipulation of facts, PX-C; an affidavit, PX-D, by Miss Marjorie Johnson, a former employee of the University of Illinois; a deposition, PX-E, of Harold B. Lawler, another employee of the University of Illinois; and a Quarterly Engineering Report, PX-4, printed for the University of Illinois and describing the alleged invention of the Isbell patent. As shown

by the other mentioned documents, the report PX-4 became a "publication" within the meaning of 35 U.S.C. 102(b) on April 30, 1959, more than one year before the May 3, 1960, filing date of the application for the Isbell patent (PX-A).

The Johnson affidavit, PX-D, contains supporting documents from the records of the University of Illinois which need not be considered in view of the stipulation, PX-C, which covers many of the same facts set forth in the Johnson affidavit.

Long after the date of her affidavit, PX-D, Miss Johnson testified as a witness for the defendant in a related suit brought by the University of Illinois Foundation and charging infringement by the Winegard Co. of the same Isbell patent here in suit.* Her testimony having been given under oath and including cross-examination by counsel for the University of Illinois Foundation, is obviously at least the legal equivalent of an affidavit and, therefore, admissible for the purposes of this motion. A copy of that testimony, PX-DD, is appended to this motion merely as corroboration of the facts more succinctly stated with complete consistency in the Johnson affidavit PX-D. Accordingly, no further reference need be made herein to that testimony by Johnson in the related suit against Winegard Co.

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* The University of Illinois Foundation, plaintiff, vs. Winegard Company, defendant, Civil Action No. 3-695-D, United States District Court, Southern District of Iowa, Davenport Division, tried February 13-17, 1967.

The Lawler deposition, PX-E, was taken in the present suit in the form of cross-examination by counsel for the plaintiff with redirect examination by counsel for defendant, The University of Illinois Foundation. The same witness, called on behalf of the University of Illinois Foundation in the aforementioned, related suit against Winegard Company, later testified consistently with his deposition PX-E, with only one immaterial qualification noted hereinafter. Like the Johnson testimony in the related suit mentioned above, the Lawler testimony in that suit is at least the equivalent of an affidavit and, therefore, admissible for the purposes of this motion. A copy thereof, PX-EE, is appended to this motion merely as corroboration of the facts more fully covered in the Lawler deposition PX-E. Accordingly, with the one minor exception noted, no further reference need be made herein to that testimony by Lawler in the related suit against Winegard Company.

Another University of Illinois report, PX-5, published prior to April 1, 1959, gave advance notice that the work covered in PX-4 would be covered in that report. Therefore, the document PX-5 is also pertinent to the issue raised by this ground of the motion and is supplied as one of the supporting documents.

Agreement by the University of Illinois that the report PX-4 was a "publication" by April 30, 1959, is shown by an

additional document, PX-27, and by a pertinent part of the Mayes deposition, PX-F, also taken in the present suit.

The present defendant, the University of Illinois Foundation, had the opportunity to present evidence rebutting the controlling facts relied upon in this part of this motion when presented with the same issue and most of the same facts in the above-mentioned suit against Winegard Company. Because it produced no material evidence of such character in that suit, and because no additional facts which defendant might now urge could alter the legal effect of those relied upon herein, it is respectfully submitted that only a simple, basic question of law as to the validity of the Isbell patent in suit is presented hereby.

The significance of the controlling facts, so established for the purposes of this motion, will be better appreciated as they are developed below if the specific question of law to be decided is first briefly explained.

The Specific Question of Law Presented

As detailed below, the publication PX-4 was made accessible to the public on or before April 30, 1959, in two distinct ways. By that date, copies thereof were available (1) for reference or borrowing at a so-called "Local Library" in the Electrical Engineering Research Laboratory of the University of Illinois, and

(2) for distribution, for the asking, to any responsible, interested person or concern within the University or outside of the University. The intent of such handling of reports like PX-4 was to make their contents available "to the people most genuinely and seriously interested in the subject matter." (See Mayes dep., PX-F, p. 56, line 13, to p. 57, line 10; Lawler dep., p. 24, lines 20-24, and p. 40, line 1, to p. 41, line 13, and The Hamilton Laboratories, Inc. v. Massengill, cited and quoted, infra, under the heading "The Law on Publication.")

The specific question of law presented is whether or not such accessibility of the publication PX-4 to the public on April 30, 1959, coupled with such intent, constituted "publication" within the meaning of 35 U.S.C. 102(b). That it did constitute such publication is supported by all known authorities dealing with similar or comparable fact situations, as will be pointed out below after a more detailed presentation and documentation of the facts.

Uncontested Facts

(a) Library Accessibility

The facts enumerated in the succeeding numbered paragraphs and supported as indicated therein establish, beyond dispute, that a printed copy of the publication PX-4 was in the "Local Library" of the Electrical Engineering Research Laboratory of the University of Illinois (sometimes referred to as the "Local

Library EERL") and was available for borrowing and reference by the faculty, other employees, and students of the University and by the general public no later than April 30, 1959.

1. The publication PX-4 was printed and 148 copies thereof were delivered to Miss Marjorie Johnson, the acting Technical Editor of the Publications Office of the Electrical Engineering Department of the University of Illinois, at her office at the University on or before April 30, 1959 (Stipulation, PX-C, par. 4).

2. Miss Johnson in addition to being the acting Technical Editor of the Publications Office, was also the Librarian of the "Local Library EERL" during April, 1959 (Johnson Affidavit, PX-D, par. 20; Lawler dep., PX-E, p. 39, line 17, to p. 40, line 1).

3. In April, 1959, the "Local Library" was located in a "reading room" of the Electrical Engineering Research Laboratory on the same floor of the building as the Publications Office (Johnson Affidavit, PX-D, par. 21). That library and "reading room" were maintained by the Publications Office to assure having at least one copy of every report it produced, as well as copies of publications of other research groups, both at the University and elsewhere in the country (Lawler dep., PX-E, p. 37, line 17, to p. 38, line 5; Johnson affid., PX-D, pars. 21-22).

4. The "Local Library" and the "reading room" in which it was located in April, 1959, were maintained as part of the

operations of the "Publications Office" of the Electrical Engineering Department; and the same employee, Miss Marjorie Johnson, was responsible for all of the operations of the Publications Office, including the printing and distribution of publications by the Electrical Engineering Department and operation of the "Local Library." As Librarian, she had custody of the contents of the "Local Library" and responsibility for the loan and return of such contents. (Johnson Affidavit, PX-D, pars. 2-4, 20, and 22-26; Lawler dep., PX-E, p. 38)

5. The printed material contained in the "Local Library" was available for borrowing and use by many thousands of people at the University of Illinois, including those not directly connected with the Antenna Laboratory, and also by the general public (Lawler dep., PX-E, p. 36, line 3, to p. 37, line 4, and p. 39, lines 10-16; Johnson Affidavit, PX-D, par. 35 (c)).

6. The publications in the "Local Library" were normally kept in one of several locked file cabinets, not to prevent use of such material by the public, but only to maintain control of that material, so that it would not be lost and so that records could be maintained of the names of borrowers and the dates on which material was borrowed (Johnson Affidavit, PX-D, pars. 23, 25, Lawler dep., PX-E, p. 37, line 7, to p. 39, line 9). Those publications were entered on a card index of the contents of the "Local Library," and the report PX-4 is shown thereby to have been a part of those contents (Lawler dep., PX-E, p. 44, lines 9-20).

When anyone wanted to borrow a copy of a publication from the "Local Library," he came to the Publications Office and requested the report from Miss Johnson or one of her assistants, who unlocked and opened the file cabinet and signed-out the requested publication. (Johnson Affidavit, PX-D, par. 24; Lawler dep., PX-E, p. 39, lines 10-16).

7. In order to inform people of the availability of publications received by the "Local Library," a magazine-type rack was maintained in a hall of the Electrical Engineering Research Laboratory leading to Miss Johnson's office, copies of publications were placed on display on the rack for that purpose soon after they were received by her, and a notice was maintained on that rack indicating that displayed materials could be borrowed by signing them out with Miss Johnson or one of the other employees of the Publications Office (Johnson Affidavit, PX-D, pars. 27-29; Lawler dep., PX-E, p. 40, line 2, to p. 41, line 13). When publications were received in the Publications Office, they were in the possession of Miss Johnson as Librarian and were immediately available for borrowing by anyone requesting the library copy (Johnson Affidavit, PX-D, par. 26).

8. Thus, on or before April 30, 1959, the "Local Library" copy of the publication PX-4 was in the possession of Miss Johnson, the librarian of that library, and was available for borrowing or use by the general public (Johnson Affidavit, PX-D, par. 31(a) and (c)). Lawler, as business manager of the Department of Electrical

Engineering of the University of Illinois, when called as a witness for the Foundation in its related suit against Winegard,* stated that the "reading room" of the Publications Office was an "unofficial reading room used by the department"; and that "it was not a library" in the sense that the department had "tried to obtain library status for it, but couldn't" because "they [the University] said it wasn't large enough" (Lawler testimony, PX-K, pp. 675-676). However, he confirmed on cross-examination that Miss Johnson had charge of that facility, that it was designated by the department as the "Local Library" in the "local distribution list" (PX-35) for reports of the department, and that both students having some laboratory connection at the University and faculty members of the University were aware of the fact that research publications were available there (Lawler testimony, PX-K, pp. 687-689). In addition, in his earlier deposition PX-E, Lawler repeatedly referred to the "Local Library" by that term and expressly confirmed many of the details of its character and functions as related by the references to his testimony in the preceding numbered paragraphs, while contradicting none of them. Thus, his only qualification of his own prior deposition (PX-E) and the affidavit and testimony of Miss Johnson (PX-D and PX-DD) was that the "Local Library," though publicized and functioning as

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* See p. 25, supra.

a library for students and faculty of the University and available for use by the public, as well, was not "officially" recognized as having "library status" in the University classification of its facilities.

(b) Copies Available For Sale or at No Charge

The facts enumerated in the next succeeding numbered paragraphs and supported as indicated therein establish, beyond dispute, that "extra" printed copies of the publication PX-4 were available to the public at the Publications Office by April 30, 1959; that the public had knowledge of the availability of such copies for sale or at no charge so long as the supply lasted; that such copies were commonly requested by outsiders and were supplied so far as they were available; and that the prospective availability of a report on the subject of present interest contained in PX-4 had been announced in another, earlier report of a similar character, PX-5, published prior to April 1, 1959.

9. Some of the 148 copies of PX-4 received by Miss Marjorie Johnson (par. 1, supra) had been printed so that the Publications Office would have a supply of extra copies not required for specific distribution and so that such extra copies would be available for internal reference and for distribution to any responsible person requesting a copy until a minimum number of internal reference copies remained on hand (Johnson Affidavit, PX-D, pars. 9-12; Lawler dep., PX-E, p. 23, line 13, to p. 24, line 10).

10. Requests for extra copies of publications, such as PX-4, were regularly received by the Publications Office of the Electrical Engineering Department of the University from people outside the University who were interested in antenna developments, and such requests were normally filled by the Publications Office by supplying such extra copies to the requesting party until only a specified minimum number of copies remained on hand (Johnson Affidavit, PX-D, pars. 9-13; Lawler dep., p. 7, line 17, to p. 10, line 8; Mayes dep., PX-F, p. 55, line 22, to p. 56, line 5).

11. In some instances, a person requesting one of the "extra copies" was charged for such a copy, but in most instances it was given away without charge (Lawler dep., PX-E, p. 28, lines 10-17).

12. As soon as copies of reports, such as PX-4, were received in the Publications Office, the extra copies were given to any responsible party requesting a copy, at least in the case of reports prepared pursuant to the contract, PX-1A, under which the reports PX-4 and PX-5 of present interest were rendered (Johnson Affidavit, PX-D, par. 16, 17, 19; Lawler dep., PX-E, p. 5, line 18, to p. 6, line 6, and p. 23, line 21, to p. 29, line 12)

13. In April of 1959, many people were aware of the fact that extra copies of publications prepared by the Antenna Laboratory of the University of Illinois could be obtained from the Publications Office of the Electrical Engineering Department of the University. Such people included faculty and students at the University, not connected with the Antenna Laboratory, and members of industry and others who were not connected with the University or with the United States Government. (Johnson Affidavit, PX-D, pars. 18-19; Lawler dep., PX-E, p. 7, line 17 to p. 10, line 8; Mayes dep., PX-F, p. 55, line 22, to p. 56, line 5)

14. Copies of the Quarterly Engineering Report No. 1 (PX-5) for the period from September 1 to December 1, 1958 (see title page) were printed and published by the University of Illinois before April 1, 1959 (Stipulation, PX-C, pars. 2-3). That report contained a statement appearing on page 2--

> "2.3 Plans for Next Interval
>
> "An investigation of log periodic structures of thin linear elements (zero tooth width) is planned."

The subject matter disclosed in the Isbell patent in suit and described in the report PX-4 for the next "interval" (December 1, 1958, to March 1, 1959 -- see title page) results from reducing

the tooth widths "to zero" in the prior toothed structure of DuHamel and Ore (PX-33, Fig. 1) when the angle is 0° (pp. 18-19, supra), as explained by Mayes (PX-H, p. 4). Thus, the coming availability of the next report PX-4 on the subject matter of interest was announced in PX-5, which was published and available before April 1, 1959.

(c) PX-4 Described the Invention of the Isbell Patent

The additional facts enumerated in the next succeeding numbered paragraphs and supported as indicated therein established, beyond dispute, that the publication PX-4, which was accessible to the public by April 30, 1959, as related above, actually described the alleged invention of the Isbell patent in suit with sufficient clarity to be understood and used by a person having ordinary skill in the relevant art at the time that alleged invention was made.

15. The publication PX-4, on pages 2 and 3, contains a written description and a schematic illustration of an antenna credited to Dwight E. Isbell, the same Dwight E. Isbell who was named the inventor in the Isbell patent in suit (Stipulation, PX-C, par. 5). That schematic illustration shows an antenna having the same dipole length and spacing relationships as the antenna illustrated in Fig. 1 of the Isbell patent in suit (Stipulation, PX-C, par. 6), and having the cross-over front feed that alternates in phase between successive dipoles as illustrated and described in that patent (Stipulation, PX-C, par. 7).

16. The written description and schematic illustration on pages 2 and 3 of PX-4 illustrate and describe an antenna having the same electrical structure, mode of operation, and performance as the antenna disclosed and claimed in the Isbell patent in suit (Stipulation, PX-C, par. 8), which illustration and description would be sufficient for anyone with antenna design experience to construct a successful antenna having a mode of operation and performance identical to the antenna disclosed in the Isbell patent (Stipulation, PX-C, par. 9).

17. As explained above (pp. 18-19), the structure of the antennas of Fig. 2 of the Isbell patent in suit, as well as the mode of operation thereof, results merely from reducing the teeth to thin-linear elements in the antennas of Figs. 1-4 of the prior art DuHamel and Ore patent PX-33 (or from substituting thin-linear elements for the triangular dipole-like members of Fig. 5 of that prior art patent) when the angle ψ is reduced to 0° as disclosed therein (each of those prior art forms having also been disclosed by May, 1958, in the prior art publication PX-12). PX-4, itself, calls attention to the "solid sheet, broad tooth, log periodic antennas" that were earlier shown in Figs. 1-2 of PX-33 and Fig. 2 of PX-12, and to the indicated "comparable" performance of the simple dipole form disclosed in PX-4. Therefore, while PX-4 "schematically" shows and describes only the form of antenna having the "cross-over" front feed of

Fig. 1 of the Isbell patent in suit, it is evident that the parallel feeder structure of Fig. 2 of that patent was old in the prior art developments of DuHamel and Ore and was merely carried over by Isbell into his patent in suit, so that any contribution over the prior art that is disclosed by the Isbell patent in suit was, in fact, disclosed by the publication PX-4 by April 30, 1959.

18. The coming availability of the report PX-4 on the particular subject of present interest was announced to the public in advance of its preparation in the earlier report PX-5, published prior to April 1, 1959, as detailed in paragraph 14, supra.

(d) "Publication" of PX-4 by April, 1959, Acknowledged by the University

PX-27 is a single sheet, printed form, dated June 12, 1959, and entitled "Research Project Report" by the "Engineering Experiment Station" of the "University of Illinois," the same group that prepared the Quarterly Engineering Report No. 2 (PX-4), as shown on the face of the latter. As testified by Mayes (Mayes dep., PX-F, p. 193, lines 5-19), the report PX-27 "was prepared to summarize the activities under a given research contract [PX-1A] to assist the engineering publications department in preparation of the research summary which is issued annually." Near the bottom of the front side of the single sheet report PX-27 is a printed heading that reads--

"Publications published * * *"

Under that heading is a list of items continuing onto the back side of the report and concluding, under the typed subheading "Progress Reports," with a listing, by title and report number, of the two Quarterly Engineering Reports No. 1 (PX-5) and No. 2 (PX-4). The latter report listing was designated "April 1959," the clear meaning being that PX-4 was "published" in April 1959. Mayes acknowledged that he, himself, probably compiled that list (Mayes dep., PX-F, p. 193, lines 20-24), and that, according to normal practice in citing publications, one would normally interpret the citation of PX-4 at the end of PX-27 to mean that the "publication date" of PX-4 was "April, 1959" (Mayes dep., PX-F, p. 195, line 22, to p. 196, line 3).

Thus, the report PX-27, prepared by the University in the regular course of its business on a form printed for the purpose and dated only about six weeks after the event, acknowledged that PX-4 was a "publication" that was "published" at least by the last day of "April 1959," i.e., by the April 30, 1959 date when (as detailed above) it was available for reference in the "Local Library" and for distribution to anyone, on request, by the "Publications Office."

(e) Summary of Controlling Facts

The printed publication PX-4 described the alleged invention of the Isbell patent in suit. For the purpose of disseminating knowledge of the development, that report was made accessible to the public both for reference or borrowing at the "Local Library" and by gift or sale from the Publications Office. Both occurred more than a year before the application for the Isbell patent in suit.

Accordingly, there remains only the legal question of whether such availability, coupled with such intent, constituted "publication" within the meaning of 35 U.S.C. 102(b) so as to render the Isbell patent in suit invalid.

The Law on "Publication"

While a considerable number of court decisions have considered what constitutes a "printed publication" under 35 U.S.C. 102(b), many of those decisions deal only with what constitutes "printed" within the meaning of that section of the statute, rather than what constitutes "publication." Since it is evident on inspection that the document PX-4 was "printed," such decisions are not pertinent. The only question here is whether the availability of that document more than one year before the application for the Isbell patent in suit on May 3, 1960, constituted "publication" under the law.

The early decision in Cottier v. Stimson, 20 Fed. 906 (Cir. Ct., D. Ore., 1884) set forth the general requirements for a "publication," In that decision (p. 910), the Court said:

> "In Walk. Pat. 56, it is said that a 'printed publication is anything which is printed, and, without any injunction of secrecy, is distributed to any part of the public in any country. Indeed, it seems reasonable that no actual distribution need occur, but that exposure of printed matter for sale is enough to constitute a printed publication.'
>
> "But something besides printing is required. The statute goes upon the theory that the work has been made accessible to the public, and that the invention has thereby been given to the public, and is no longer patentable by any one. Publication means put into general circulation or on sale, where the work is accessible to the public. See Reeves v. Keystone Bridge Co. 5 Fisher, 467." (Emphasis added)

In substance that decision held that a printed work is a "publication" when it is accessible to the public. This accessibility to the public can occur in a number of different ways, many of which have been specifically considered by the courts.

(a) Deposit in a Library

One of the common ways in which a printed work is made accessible to the public is by placing a copy in a library where it is accessible to members of the public. In an early decision in John Crossley & Sons v. Hogg, 83 Fed. 488 (Cir. Ct., D. Mass., 1897), it was held that publication had been established by proof that a single copy of a book was received in a library and that such publication was sufficient to bar the grant of a valid patent.

There is no requirement that members of the public actually used the printed copy contained within a library. It is merely necessary to establish that a copy of the publication was received by the library. Thus, the Patent Office Board of Appeals held in Gulliksen v. Halberg v. Edgerton v. Scott, 75 USPQ 252 (1937) that "publication" of a thesis was established when it was proved that a copy of the thesis had been received by a college library. The Board said at page 257:

> "Since both affidavits referred to above clearly show that the thesis was received September 25, 1929, it is held that the dates when the same was bound or indexed is of no importance for the thesis became available to the public as soon as received in the library." (Emphasis added)

Subsequently, the Sixth Circuit Court of Appeals held in The Hamilton Laboratories, Inc. v. Massengill, 111 F.2d 584, 585, 45 USPQ 594, 595 (1940);

> "***the Weed thesis is in the prior art and marks a step in its development since it was put on file in the library of the college, available to students there and to other libraries having exchange arrangements with Iowa State. John Crossley and Sons v. Hogg, C. C., 83 Fed. 488, 490; Britton v. White Mfg. Co., C.C., 61 Fed. 93, 95. We think intent that the fruits of research be available to the public is determinative of publication under the statute***." (Emphasis added)

More recent decisions have followed and further clarified the foregoing statements of the law. For example, the sufficiency of the deposit in a library of a single copy of printed matter and the immateriality of the obscurity of the library were commented on by the Court of Customs and Patent Appeals in the case of In re Tenney, Frank and Knox, 254 F.2d 619, 627, 117 USPQ 348, 354 (1958). In that case, the Court observed--

> "It is no doubt true that our present law is anomolous, as evidenced by our conclusion that a microfilm is not 'printed.' A foreign patent file, laid open for public inspection, is not a printed publication because typewritten, while a printed publication available to the public only in a Southern Rhodesian library would be."

Still more recently, the District Court for the Southern District of California held that the filing of a copy of a thesis in a college library on October 9, 1950, barred a patent applied for October 30, 1951 (21 days over the permissible

one year). Indiana General Corp. v. Lockheed Aircraft Corp., 249 F. Supp. 809, 815, 816 (1966). In that decision, the Court cited the Hamilton Laboratories v. Massengill case, supra, as an authority "squarely in point."

About the same time, the District Court for the Southern District of New York (while denying a motion for summary judgment because of unresolved questions of fact in the particular case) reviewed the same and related questions of law in some detail and concluded that a "'printed publication' as contemplated by Congress in 35 U.S.C. 102"--

> "can include a document printed, reproduced or duplicated by modern day methods, including microfilming, upon a satisfactory showing that such document has been disseminated or otherwise made available to the extent that persons interested and ordinarily skilled in the subject matter or art, exercising reasonable diligence, can locate it and recognize and comprehend therefrom the essentials of the claimed invention without need of further research or experimentation." (Emphasis added)

I.C.E. Corporation v. Armco Steel Corporation, 250 F. Supp. 738, 743 (1966).

(b) Availability to the Public by Sale or Without Charge

The "publication" of a printed work also occurs when copies of the work are first accessible to the public, by purchase or without cost. In the above-cited case of In re Tenney, Frank & Knox, 254 F.2d 619, 628, 117 USPQ 348, 355 (C.C.P.A., 1958), in a concurring opinion, Judge Rich stated his view of the law to be that--

> "When a book has been printed and copies are available for delivery, an advertisement offering it for sale would bring about its 'publication' even before any copies are actually sold."

In its majority opinion in that case (at 254 F.2d 624), the Court stated--

> "The essence of all we have quoted is that, in consideration for the patent grant, something must be given to the public which it did not have before (Albeit that the enjoyment of this 'something' may be postponed for seventeen years). If the public is already possessed of that 'something', or if it is accessible to the public, there is a failure of consideration and no patent may be granted."

Explaining what "accessible to the public" means, the Court stated further (at 254 F.2d 626-627)--

> "But though the law has in mind the probability of public knowledge of the contents of the publication, the law does not go further and require that the probability must have become an actuality. In other words, once it has been established that the item has been both printed and published, it is not necessary to further show that any given number of people actually saw it or that any specific number of copies have been circulated. The law sets up a conclusive presumption to the effect that the public has knowledge of the publication when a single printed copy is proved to have been so published. See Evans v. Eaton, 1818, 3 Wheat. 454, 514, 4 L.Ed. 433; Curtis, Law of Patents, pp. 500-03 (4th ed. 1873)." (Emphasis added)

The Tenney case, supra, is consistent with the law as previously stated by other courts and text writers over the years. Thus, as far back as 1884, when the substance of the present statute on this point was also in force, the Court specifically stated in

Cottier v. Stimson (cited and quoted at p. 37, supra) that--

> "exposure of printed matter for sale is enough to constitute a printed publication," [Quoted from Walk. Pat. 56]

and that, in the Court's own words--

> "Publication means put into circulation or on sale***." (Emphasis added)

No contrary decision throughout the history of the United States Patent System has been found.

Clearly, if it is enough that copies of printed material be "on sale" or exposed "for sale", availability to the public is still greater where, as here, such printed matter was known to be available without charge and had frequently been so supplied on request.

Summary

Summarizing the facts and the law affecting the Isbell patent in suit, as presented above, each of two independent, but simultaneous occurrences constituted legal "publication" of PX-4 by April 30, 1959. Those occurrences were: (1) the "Local Library" copy was available to the public in a repository for technical publications that was both used as a "library" and called a "library", and that was clearly established and operated to perform the function of a "library," and (2) "extra copies" of the publication were available for sale or free distribution, with public knowledge

of this availability. That publication, and others of similar character were made accessible to the public in both of those ways with the clear intent to make the fruits of the University research available to all.

While both of those two occurrences independently constituted legal "publication" by April 30, 1959, it is also evident that the same physical organization under the supervision of the same individual, Miss Marjorie Johnson, made the publication PX-4 available both through its library reference and loan facility and through the Publications Office facility for furnishing copies of the publication for sale or at no charge. Thus, that same physical organization actually performed more than the normal functions of a library in making possible and facilitating both modes of making the publication accessible to the public.

By all of the standards derivable from pertinent court decisions and other recognized authorities, the publication PX-4 was legally "published" on or before April 30, 1959, and was so considered by the University of Illinois, itself, in the nearly contemporaneous report PX-27. Since PX-4 clearly described the alleged invention of the Isbell patent in suit and was published more than a year prior to the application for the patent, that patent must be held invalid under the provisions of 35 U.S.C. 102(b).

II.A.

MAYES ET AL. REISSUE PATENT NO. 25,740 INVALID UNDER 35 U.S.C. 102(f) BECAUSE MAYES ET AL. DID NOT THEMSELVES INVENT THE SUBJECT MATTER THEREOF AS REQUIRED BY 35 U.S.C. 102(f)

This ground for invalidity of the Mayes et al. reissue patent in suit (PX-B), summarized in Part II.A. of the foregoing Synopsis, will now be fully presented with detailed reference to the facts, the supporting documents, and the applicable law. The absence of any genuine issue of material fact and invalidity of the patent as a matter of law will clearly appear from this presentation.

The Evidence

The controlling facts upon which this ground of the motion is based are contained in the deposition (PX-F) of Paul E. Mayes and the "RECORD OF INVENTION" (PX-15) signed by both Paul E. Mayes and Robert L. Carrel and identified by Mayes in his deposition.

The University of Illinois report, PX-4, on which Part I of this motion was primarily based and another report, PX-17, are also relied upon to confirm the priority of the work of Isbell over that of Mayes et al.; and portions (PX-34) of a 1943 radio handbook are relied upon merely to demonstrate what had long been known in the art about the design and operation of V-dipoles.

The significance of the controlling facts, so established for the purposes of this motion, and the immateriality of any additional facts that defendants might conceivably assert in response thereto, will be better appreciated as they are developed below if the specific question of law to be decided is first briefly explained.

The Specific Question of Law Presented

As summarized in the background discussion above (pp. 20-21) and as documented in more detail in the ensuing development of the uncontested facts, the only departure from the prior invention covered by the Isbell patent in suit (PX-A) that is disclosed in the Mayes et al. original and reissue patents is the mere substitution of known V-dipoles for the straight, simple dipoles of Isbell; such substitution of V-dipoles was suggested to Mayes and Carrel by Mr. E. M. Turner of Wright Air Development Center; and such substitution of V-dipoles gave to the antenna only the expected and well known operation over a number of additional, higher, harmonic, frequency ranges. Thus, the only departure from the prior Isbell invention was the substitution suggested by Turner; the inherent results of such substitution were well known, and expected; and nothing was left as a possible contribution by Mayes and Carrel but a recognition of those well known and expected results.

The specific question of law presented is whether or not Mayes and Carrel made an invention entitling them to patent the identical structure suggested by Turner merely because they recognized and verified the inherent, well known, and expected results obtainable with that structure. That they were not entitled to do so is supported by all known authorities dealing with similar or comparable fact situations, as will be pointed out below following a more detailed presentation and documentation of the facts.

Uncontested Facts

The alleged invention of the Isbell patent in suit was described in a printed report by the University of Illinois (PX-4) that was dated "31 March 1959" on the title page and signed thereon by Mayes, himself, and that was published April 30, 1959, as established in Part I of this motion and, in any event, by the admitted mailing of that report by May 5, 1958, to the entire distribution list filling the last five and one-half pages of the report (Stipulation, PX-C, par. 10). That alleged invention was necessarily made sometime prior to the description thereof in the "31 March 1959" report, PX-4.

The later dates and the place of making the alleged V-dipole invention of the Mayes et al. reissue patent in suit are detailed in a "RECORD OF INVENTION" (PX-15), over the signature of both Mayes and Carrel.* That document, in the items numbered 9-11,

* Produced by the Foundation defendant and identified by Mayes (Mayes dep., PX-F, p. 113, line 2, to p. 114, line 5).

13, and 15 on the first page thereof, fixes the date and place of making the invention between June 11 and June 23, 1959, at the Antenna Laboratory of the University of Illinois. By specific reference thereto in items 19 and 20 on page 2 thereof, that document also refers to the related, prior, invention of the Isbell patent in suit and to its description in the University of Illinois Antenna Laboratory Technical Report No. 39 (PX-17) of "1 June 1959" (title page) or "10 June 1959" (front cover). On its face, PX-17 includes every detail of the Isbell patent disclosure. It became a "publication" at least by September 21, 1959 (Stipulation, PX-C, par. 11).

Mayes admitted in his deposition (p. 7, line 19, to p. 8, line 5), that he was familiar with the work on which the Isbell patent in suit was based at the time that work was going on and with the records of that work as they were prepared.

As shown by item 9 on page 1 of the "RECORD OF INVENTION" (PX-15), the first occurrence leading to the alleged invention of the Mayes et al. patent in suit was a question, asked by Mr. E. M. Turner of Wright Air Development Center, "if the angle of dipoles on a log-periodic dipole array had been used as a design parameter." Mayes stated his understanding that, in asking that question, Mr. Turner "was referring to moving the dipole arms of the simple dipoles in antennas of the type disclosed in the Isbell 767 patent (PX-A), forwardly so that they would be in effect a V-dipole" (Mayes dep., PX-F, p. 114, line 6, to p. 115, line 20). Mayes further testified that he understood that Mr. Turner's suggestion

had reference only to operation of the antenna on the fundamental one-half wave mode; that it would have been apparent prior to that time to anyone familiar with V-dipoles and their operation that this would not improve the gain and would detract from the directivity on the one-half wave mode operation; but that, nevertheless, Mayes and Carrel tested an antenna of the Isbell type after V'ing the elements forwardly and verified that there was no significant difference in operation on the one-half wave mode of operation (Mayes dep. PX-F, p. 116, line 7, to p. 117, line 15). Mayes then testified further that they took a similar antenna and tested it on higher modes of operation; that the gain was increased and the directivity was sharper than when using the Isbell antenna on the half-wave mode; that, as was well known prior to June 1959, the same improvement was obtained with V-dipoles generally; and that such improvement from substituting V-dipoles in the Isbell antenna resulted "as expected" (Mayes dep. PX-F, p. 117, line 16, to p. 120, line 24).

Finally, Mayes testified (consistently with the clear disclosure of the Mayes et al. patent in suit*), that the prior antennas of the Isbell patent and the V-dipole antennas of Mayes et al. reissue patent "are identical" other than for the smaller

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* PX-B, col. 1, lines 40-55; col. 2, lines 44-49; and col. 4, lines 9-21, the first of these citations being quoted in full at p. 20, supra.

included angle between the two elements of each dipole in the V-dipole antennas of the Mayes et al. patent.

The suggestion of using V-dipoles necessarily required some determination of the proper included angle to be used between the diverging arms or elements of each V-dipole. How to determine this parameter of the design of the V-dipole form of the antenna appears at column 3, lines 19-34 with the general suggestion that it range from "about 114° for the [three] half-wavelength mode to about 62° for the 9/2 wavelengths mode."* However, essentially that same range of V-angles would have been implicit to one skilled in the art from the mere suggestion of using V-dipoles and is clearly the only parameter data for such an antenna that Mayes could have compared with "some of the references of previous literature," as he stated in his deposition (PX-F, p. 117, line 22, to p. 118, line 7).

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* Omission from the patent of the word "three" enclosed in brackets in this quotation is an obvious typographical error in the patent. As Mayes testified (Mayes dep., PX-F, pp. 50, 116-117), any Veeing of the dipole arms is disadvantageous for operation in the half-wavelength mode, for which one would use the straight dipoles of the Isbell patent in suit, but that the improvement in operation occurs when the V-dipoles are "1.5 times the wavelength, i.e., three half-wavelengths). See Finneburgh affidavit, PX-G, par. 16 .

At least as early as 1943, handbook information gave essentially the same V-angle information, as is evidenced by the "Radio Engineers' Handbook" by Frederick Emmons Terman (1943) pp. 788 and 807-808 (PX-34). As explained in the Finneburgh affidavit (PX-G, par. 15-16), use of that handbook information to determine the included angles for diverging arms of V-dipoles for 3/2 wavelengths mode operation and for 9/2 wavelengths mode operation would result in selecting, respectively, a little less than 120° (corresponding closely to the 114° in the Mayes et al. patent) and a little less than 70° (corresponding closely to the 62° in the Mayes et al. patent). Thus, selection of the appropriate V-angle in accordance with the disclosure of the Mayes et al. patent in suit involved only normal, well known, engineering practice that would have been employed by anyone skilled in the art in following Turner's suggestion of using V-dipoles.

Summarizing the controlling facts, it is clear beyond dispute that Turner suggested the use of V-dipoles in place of the straight dipoles of the Isbell patent in suit, although he may have had in mind only half-wave mode operation. Mayes and Carrel merely tested the resulting V-dipole antenna on higher modes and verified that the previously well known and characteristic operation of V-dipoles resulted as one skilled in the art at that time would have expected; and the V-angles disclosed by Mayes et al. for use for that purpose were only those that had been customarily employed in the prior art for the same purpose.

Thus, the particular antenna structures that are claimed in the Mayes et al. reissue patent in suit are only what were suggested by Turner; the design parameters employed were only those earlier taught by Isbell plus what was common practice in the prior art when using V-dipoles; and the mode of operation was only what was expected from the then well known operation of the Isbell antennas and of the prior art V-dipoles. Accordingly, there remains only the legal question of whether Mayes and Carrel themselves made an invention, if any is disclosed in their patent in suit, or merely derived the idea from another and added nothing patentable to it, so as to be barred from the right to a patent by 35 U.S.C. 102(f).*

The Law on Derivation of the Patented Invention from "Another"

An application of the law on patentability of inventions to the particular fact situation existing in this case may best be taken in two steps. It is first necessary to recognize what should be an obvious principle of law, i.e., what Turner admittedly suggested to Mayes et al. could not have been the invention of Mayes et al. That principle of law may have been first stated by the courts in the historic case of Stearns v. Davis, 22 Fed. Cases 1182, Fed. Case No. 13,338 (C.C., Dist. of Col., 1859). The

* Quoted in first footnote, p. 5, supra.

principle has never been better stated than in the headnote of the report of that case (fully supported by the opinion), which reads:

> "One who receives a 'suggestion' of a machine from another, and promptly reduces it to practical use, is not an inventor, and will acquire no right by reason of any laches of the original inventor in perfecting his invention. If the latter forfeits his rights, the forfeiture will be to the public."

The foregoing was, perhaps, the first authoritative statement of the law of "originality" or "derivation" that necessarily follows from the Constitutional provision for granting patents only to "Inventors," not to those who derived their ideas from others. Some 16 years later, the same thing was stated, in substance, by the Supreme Court in the noted case of Smith v. Nichols, 88 U.S. 112, 22 L.Ed. 566 (1875). In the words of the Supreme Court (22 L.Ed. at p. 567)--

> "A patentable invention is a mental result. It must be new and shown to be of practical utility. Everything within the domain of the conception belongs to him who conceived it. The machine, process or product is but its material reflex and embodiment."

The Court then explained that one may improve on the prior invention or idea of another and patent the improvement. However, it also pointed out that the improvement must itself amount to an invention in order to be patentable over the prior idea. Here Mayes et al. patented the precise structure conceived and suggested to them by Turner and which was necessarily "within the domain of" and "belongs to" Turner "who conceived it."

The same principle was applied a few years later by the Supreme Court in the equally well known case of Atlantic Works v. Brady, 107 U.S. 192, 27 L.Ed. 438 (1882). In that case, the Court first sought in vain for any inventive difference of Brady's claimed invention from the prior art. Then (at 27 L.Ed. 442) it detailed how, in any event, "Brady derived his whole idea from the suggestions of General McAlester" and concluded, for that additional reason, "that the patent sued on cannot be sustained."

Such "derivation" or "originality" questions most frequently arise in patent interferences between rival inventors in the Patent Office. Thus, in the case of Barba v. Brizzolara, 104 F.2d 198, 202-203, 41 USPQ 749, 752-753 (C.C.P.A., 1939), the Court found that the basic idea was derived by the appellant from the appellee and that the particular detail of construction employed by the appellant could have been worked out by one skilled in the art (for example, the included angle of the V-dipole arms, which is not even mentioned in most of the claims here in suit). Accordingly, the Court held the appellee to be the inventor, not the appellant who had merely used the skill of the art in producing an operable structure. See, also, Finch v. Dillenback, Jr., 121 F.2d 459, 466, 49 USPQ 731, 738 (C.C.P.A., 1941).

As the Court of Customs and Patent Appeals explained more fully in Applegate et al. v. Scherer et al., 332 F.2d 571, 141 USPQ 796, 798-799 (1964)--

> "An originality or derivation case, which this is, is quite unlike a case involving independent inventors, between whom true 'priority' must be decided.

> "Appellants seem to propose that there cannot be a conception of an invention of the type here involved in the absence of knowledge that the invention will work. Such knowledge, necessarily, can rest only on an actual reduction to practice. To adopt this proposition would mean, as a practical matter, that one could never communicate an invention thought up by him to another who is to try it out, for, when the tester succeeds, the one who does no more than exercise ordinary skill would be rewarded and the innovator would not be. Such cannot be the law. A contrary intent is implicit in the statutes and in a multitude of precedents."

Clearly, on the authority and reasoning of the above cases, Mayes et al. did not themselves invent the structure claimed in their patent, which was suggested to them by Turner. In that connection, the facts of those cases and of the present case must be distinguished from the many cases reaching the opposite result because the one making the suggestion did not suggest enough for one having ordinary skill in the art to make a complete and operative device. In the present case, Turner suggested precisely what Mayes et al. disclosed, namely, the prior Isbell antenna modified only by substituting V-dipoles for straight dipoles. What V-angle to use for any higher harmonic mode operation above the half-wave mode for which the Isbell antennas had been designed, being handbook information at least since 1943, was clearly implicit in the mere suggestion of the use of the well known V-dipoles.

The next step is to deal with what Turner did not suggest to Mayes et al., namely the use of the proposed V-dipole forms of the Isbell antennas on the 3/2 wavelengths and higher harmonic modes, which produced higher gain and sharper directivity (something which Turner may not have appreciated). The authorities are uniform in holding that when one merely makes a new or extended use of an old device, he is not entitled to a patent on the device itself, which he did not invent.

The last cited principle may have had its first clear statement in Roberts v. Ryer, 91 U.S. 150, 157, 23 L.Ed. 267, 270 (1875), in which the Supreme Court more specifically stated--

> "It is no new invention to use an old machine for a new purpose. The inventor of a machine is entitled to the benefit of all the uses to which it can be put, no matter whether he had conceived the idea of the use or not." (Emphasis added)

In that case, comparing the claimed machine of the Sanford patent in suit with the prior Lyman machine, the court continued--

> "There was no change in the machine: It was only put to a new use. If there was any change of construction suggested, it was only to increase its capacity for usefulness***Clearly, we think, therefore, the invention of Sanford was anticipated by Lyman and his patent is, on that account, void."

The logic of the decision in Roberts v. Ryer is clear and has constituted the cornerstone of a host of subsequent decisions involving countless variations of the particular facts involved in that case. However, a comment seems warranted on a related principle of patent law codified in the 1953 Patent Act,

namely, that "a new use of a known***machine" is embraced by the term "process" [35 U.S.C. 100(b)], and that "Whoever invents or discovers any new and useful process***may obtain a patent therefore, subject to the conditions and requirements of this title." [35 U.S.C. 101]. The distinction between the principle of Roberts v. Ryer and the quoted portions of 35 U.S.C. 100(b) and 101 is simply this: One who merely puts an old machine to a new use, or uses it in a different way, or for a new purpose, if his conception is inventive in character ("unobvious"), is entitled to patent his conception as a "new and useful process" by the terms of 35 U.S.C. 100(b) and 101. However, where there is no change in the construction of the machine, or any change made in the machine is not inventive, neither the machine nor its inherent functions is new and one who conceives only the new use for the machine is not entitled to claim the machine itself, as his invention, or to patent it, though he may be entitled to patent, in terms of a "process," the particular new steps or operations involved in the new use.

Thus, here, the claims of the Mayes et al. patent in suit improperly cover precisely the device that Turner suggested to Mayes et al., namely, the dipole antennas of Isbell modified only by substituting for Isbell's straight dipoles the well known V-dipoles of the prior art (even including the same V-angles for particular

higher modes of operation that were handbook standards in the prior art use of such V-dipoles).

The principle that discovering a new use for an old device does not entitle one to a patent on the old device, whether or not the new use was previously known, was re-emphasized again in 1892 in another historic case, Ansonia Brass & Copper Co. v. Electrical Supply Co., 144 U.S. 11, 36 L.Ed. 327, 329, citing and repeating the above-quoted language from Roberts v. Ryer.

This has been the law ever since. Thus, in General Electric Co. v. Jewel Incandescent Lamp Co., 326 U.S. 242 (1945), the Supreme Court said (at p. 249)--

> "Where there has been use of an article or the method of its manufacture has been known, more than a new advantage of the product must be discovered in order to claim invention. See DeForest Radio Co. v. General Electric Co., 283 US 664, 682, 75 L ed 1339, 1347, 51 S Ct 563. It is not invention to perceive that the product which others had discovered had qualities they failed to detect. See Corona Cord Tire Co. v. Dovan Chemical Corp. 276 US 358, 369, 72 L ed 610, 614, 48 S Ct 380."

Still more recently, this Court restated the principle and repeated the first part of the above quotation from General Electric v. Jewell. Armour Research Foundation of Illinois Institute of Technology et al. v. C. K. Williams & Co., Inc., 170 F. Supp. 871, 884, 121 USPQ 3, 13, (D.C., N.D. Ill., 1959); affirmed, 280 F. 2d 499.

The same principle has been applied by the Court of Appeals of the Seventh Circuit in the type of situations involved in the Ansonia case, supra. B.&M. Corp. v. Koolvent Aluminum Awning Corp. of Indiana, 257 F.2d 264, 267, 118 USPQ 191, 194 (1958). Armour & Co. v. Wilson & Co., 274 F.2d 143, 150, 124 USPQ 115, 120-121 (1960), citing 35 U.S.C. 102(f) on which this part of this motion is based.

Summary

In claiming only the V-dipole form of Isbell's log periodic antennas and the inherent functions or properties thereof when operating at higher harmonic frequencies, the Mayes et al. patent covers the precise antenna structure suggested to them by Turner. By the first principle of law discussed above, it is clear that such structure, per se could not be the invention of Mayes et al.; and by the second principle of law discussed above, it is equally clear that such structure was not rendered patentable to Mayes et al. by their concept of using it at higher frequencies, whether or not Turner knew that it could be so used or appreciated the advantages of doing so.

The factual premises upon which these legal conclusions are based, being admitted by Mayes in his testimony and by Mayes and Carrel in their Invention Record (PX-15), their patent is necessarily invalid as a matter of law, and no other facts which defendants might conceivably allege could alter this final legal conclusion.

II.B.

MAYES ET AL. REISSUE PATENT NO. 25,740 UNENFORCEABLE FOR "UNCLEAN HANDS" OF THE FOUNDATION DEFENDANT, WHO FURNISHED THE PATENT OFFICE WITH DECEPTIVE AND MISLEADING EVIDENCE IN PROCURING THE PATENT

This ground for unenforceability of the Mayes et al. reissue patent in suit (PX-B), summarized in Part II.B. of the foregoing Synopsis, will now be fully presented with detailed reference to the facts, the supporting documents, and the applicable law. The absence of any genuine issue of material fact and the unenforceability of the patent as a matter of law will clearly appear from this presentation.

The Evidence

The controlling facts upon which this ground of the motion is based are contained in the file history (PX-29) of the Mayes et al. original patent and the file history (PX-30) of the Mayes et al. reissue patent in suit; the University of Illinois reports PX-4 and PX-17, which disclose the Isbell invention; the Stipulation PX-C as it refers to those two reports; the deposition (PX-F) of Paul E. Mayes; and the "RECORD OF INVENTION" (PX-15) signed by both Paul E. Mayes and Robert L. Carrel and identified by Mayes in his deposition.

The significance of the controlling facts, so established for the purposes of this motion, and the immateriality of any additional facts that defendants might conceivably assert in response thereto, will be better appreciated as the controlling

facts are developed in detail below if the specific question of law to be decided is first briefly explained.

The Specific Question of Law Presented

As explained and documented in Parts I and II.A. of this memorandum (pp. 34 to 36, and 46 to 47, supra), the log periodic dipole antennas of the Isbell patent in suit (PX-A) were described in the reports PX-4 and PX-17 prior to any conception of the subject matter of the Mayes et al. reissue patent in suit, and those reports were both published more than one year prior to the first application of Mayes et al. for a patent on that subject matter. It is evident that, if this was not known to the Foundation defendant, it should have been so known and could have been readily ascertained by it.

Despite those facts, when the Patent Office cited another article describing the prior Isbell antennas and published prior to the first Mayes et al. application, but less than a year prior, the applicants filed an affidavit by Mayes to eliminate that publication from consideration as a reference against them. Admittedly, that affidavit was filed to establish that Mayes et al. made their alleged invention prior to the publication date of that particular cited article, so as to eliminate the article from consideration as prior art, but said nothing about the fact that the same information had been earlier published in PX-4 and PX-17. Yet, those two earlier publications, if known, could not have been eliminated from consideration because they had both been published more than one year prior to the first application for the Mayes et al. patent.

Based on those facts, the specific question of law presented is the right of the Foundation defendant to enforce the patent (or the reissue patent in suit that replaced it) which was procured by misleading the Patent Office in that manner, inducing it to withdraw a rejection of the Mayes et al. claims based on the prior work of Isbell, and securing the Mayes et al. patent and subsequent reissue thereof without the prior art work of Isbell ever again being considered by the Patent Office. That the Foundation defendant is not entitled to enforce the Mayes et al. reissue patent in suit after such deception was employed in procuring the patent, is supported by the most fundamental principles of equity and by a series of Supreme Court decisions rendered over the last 23 years.

Uncontested Facts

The Mayes et al. original and reissue patents, by their express terms and as confirmed by Mayes (Part II.A., pp. 48-49, supra), are directed to log periodic dipole antennas of the type described in a patent application of Dwight E. Isbell, Serial No. 26,589, filed May 3, 1960,* and differing only in the use by Mayes et al. of "V-shaped elements" instead of the straight dipoles disclosed in that Isbell application. However, the Mayes et al. original and reissue patents and the applications on which they were based did not state that the work of Isbell was completed or known to Mayes et al. before they made their alleged V-dipole invention (see Mayes et al. reissue patent, PX-B).

* See application Serial No. and filing date given in the heading of the Isbell patent in suit, PX-A.

The application for the Mayes et al. original patent was filed September 30, 1960 (see heading of that patent, PX-B). During the prosecution of that application, the Patent Office rejected the claims thereof on a May, 1960, publication* of an article by Isbell entitled "Log Periodic Dipole Arrays," in view of a previously cited patent to Rowland (file history, PX-29, p. 30).

Prior to the conception by Mayes et al. of their V-dipole modification of the Isbell antennas, the development work by Isbell had been completed and described in the reports PX-4 and PX-17, and those reports were published more than one year prior to the application for the Mayes et al. original patent (Part II.A., pp. 46-47, supra). Moreover, Mayes was familiar with the work of Isbell at the time it was going on and with the records of that work as they were prepared (Part II.A., p. 47, supra).

Mayes, himself, was familiar with the requirement that an application must be made within one year of the date of publication of the invention thereof (Mayes dep., PX-F, p. 173). As Associate Director of the Antenna Laboratory of the University of Illinois, it is inconceivable that Mayes did not have knowledge of the fact of the early publication of PX-4 and PX-17 at the time he executed his affidavit, as counsel for the Foundation defendant conceded (Mayes dep., PX-F, p. 177, lines 5-9).

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* IRE Transactions on Antennas and Propagation, May, 1960, vol. AP-8, No. 3, pp. 260-267.

Yet, Mayes et al. responded to the above-mentioned rejection of their application by filing in the Patent Office an affidavit by Mayes and an attorney's argument asserting and documenting completion of their V-dipole development prior to the May, 1960, date of the cited IRE publication and prior to the May 3, 1960, filing date of the Isbell log periodic dipole application. That was done without disclosing or suggesting the much earlier publication of the reports PX-4 and PX-17 or the priority of the work of Isbell. Counsel's own argument to the Patent Office stated that Mayes was "fully and completely familiar with***Mr. Isbell's work," and the same counsel had previously filed and were still prosecuting the Isbell application.* Nevertheless, as stated in their argument accompanying the Mayes affidavit, it was filed for the purpose of removing both the IRE publication and the Isbell application from consideration as prior art against Mayes et al. (file history, PX-29, pp. 31-43) The necessary (but untrue) implication of the affidavit and argument was that Mayes et al. knew of no other facts making Isbell's work prior art against them.

The fact that the Isbell work had been published much earlier in PX-4 and PX-17 and more than a year before the original application of Mayes et al. should have prevented any such removal of Isbell's prior work from consideration as prior art against

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* Isbell file history, PX-36.

Mayes et al., by the express terms of the Patent Office Rule* under which the Mayes affidavit was filed.

The contents and prior publication of PX-4 and PX-17 by the University of Illinois must have been known to Mayes. Admittedly (see PX-15), he knew all about the priority of the work of Isbell, in any event. And all of that knowledge by Mayes was, at least readily available to the Foundation defendant and its counsel.

Thus, either the filing of the Mayes affidavit was a deliberate effort to deceive the Patent Office as to the proper status of the Isbell work as prior art, or that affidavit was filed with a reckless and irresponsible disregard of the fact that the prior work of Isbell was a part of the prior art. That such prior art was material to the issue of patentability of the claims of the Mayes et al. application is evident from the Examiner's reliance upon that prior art in rejecting those claims. It is also evident from the fact that Mayes et al. took steps to remove that prior art from consideration by the Patent Office, rather than rely on an argument that it was not material.

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* Section 1.131 [Rule 131(a)] of the "RULES OF PRACTICE IN PATENT CASES AS AMENDED TO AUGUST 23, 1954 [35 U.S.C.A., pp. 685-6] provides for the filing of affidavits to overcome cited publications "unless the date of such***printed publication be more than one year prior to the date on which the application was filed in this country." Having filed the Mayes affidavit under the provisions of this rule, counsel for Mayes et al. must have known of its limitation as herein quoted.

The Patent Office, having thus been misled by the Mayes affidavit, expressly accepted it for the purpose for which it was offered, withdrew the rejection of the Mayes et al. claims on the cited IRE publication, and concurrently allowed the first seven claims of the application, which became the first seven claims of the Mayes et al. original and reissue patents (file history PX-29, pp. 44-45). In due course, the remaining claims thereof and the additional claims of the Mayes et al. reissue patent were allowed by the Patent Office without ever again citing the prior Isbell work as pertinent prior art. (File history, PX-29, page 46 to the end; reissue file history, PX-30, in its entirety).

The Applicable Law

In Hazel-Atlas Glass Company v. Hartford-Empire Company, 322 U.S. 238 (1944), the Supreme Court clearly established the principle of law that "fraud" in obtaining a patent for an invention requires a complete denial of relief to the patentee against a claimed infringement. As the court stated (at p. 246)--

> "This matter does not concern only private parties. There are issues of great moment to the public in a patent suit. [citing prior decisions]. Furthermore, tampering with the administration of justice in the manner indisputably shown here involves far more than an injury to a single litigant. *It is a wrong against* the institutions set up to protect and safeguard the public, institutions in which fraud cannot complacently be tolerated consistently with the good order of society."

As regards the extent, if any, to which the wrongful acts committed in procuring the patent actually influenced the granting thereof, the court stated (at p. 247)--

> "Doubtless it is wholly impossible accurately to appraise the influence that the article exerted on the judges. But we do not think the circumstances call for such an attempted appraisal. Hartford's officials and lawyers thought the article material. They conceived it in an effort to persuade a hostile Patent Office to grant their patent application***. They are in no position now to dispute its effectiveness."

As to the particular relief to which a defendant is entitled when sued on a patent so procured, the court had this to say (at p. 250)--

> "Had the District Court learned of the fraud on the Patent Office at the original infringement trial, it would have been warranted in dismissing Hartford's case. In a patent case where the fraud certainly was not more flagrant than here, this court said: 'Had the corruption of Clutter been disclosed at the trial***, the court undoubtedly would have been warranted in holding it sufficient to require dismissal of the cause of action there alleged for the infringement of the Downie patent.' [citing cases] The total effect of all this fraud, practiced both on the Patent Office and the courts, calls for nothing less than a complete denial of relief to Hartford for the claimed infringement of the patent thereby procured and enforced."

Shortly after its decision in the Hazel-Atlas case, in Precision Instrument Manufacturing Co. v. Automotive Maintenance Machinery Co., 324 U.S. 806 (1945), the Supreme Court clarified the kinds of misconduct that fall within the rule of Hazel-Atlas. In the later case, the court explained that it is the "unclean hands" maxim of equity that constitutes the guiding doctrine, and

that anyone "tainted with inequitableness or bad faith relative to the matter in which he seeks relief" must be denied that relief. More specifically, in that regard, the court stated (at p. 815)--

> "Accordingly one's misconduct need not necessarily have been of such a nature as to be punishable as a crime or as to justify legal proceedings of any character. Any willful act concerning the cause of action which rightfully can be said to transgress equitable standards of conduct is sufficient cause for the invocation of the maxim by the chancellor."

What is required "to transgress equitable standards of conduct" and call for the denial of relief was further explained by the court (at p. 818) as follows:

> "We need not speculate as to whether there was sufficient proof to present the matter to the District Attorney. But it is clear that Automotive knew and suppressed facts that, at the very least, should have been brought in some way to the attention of the Patent Office***. Those who have applications pending with the Patent Office or who are parties to Patent Office proceedings have an uncompromising duty to report to it all facts concerning possible fraud or inequitableness underlying the applications in issue. [Case citation] This duty is not excused by reasonable doubts as to the sufficiency of the proof of the inequitable conduct nor by resort to independent legal advice. Public interest demands that all facts relevant to such matters be submitted formally or informally to the Patent Office, which can then pass upon the sufficiency of the evidence. Only in this way can that agency act to safeguard the public in the first instance against fraudulent patent monopolies. Only in that way can the Patent Office and the public escape from being classed among the 'mute and helpless victims of deception and fraud.'"

In the most recent Supreme Court decision on this subject, on writ of certiorari to the Court of Appeals of the Seventh Circuit in Walker Process Equipment Inc. v. Food Machinery and Chemical Corp., 322 U.S. 172 (1965), the court cited its prior decisions in the Hazel-Atlas and Precision Instrument cases for the proposition that a person sued for infringement may challenge the validity of the patent on various grounds, including fraudulent procurement. Clarifying the breadth of that rule, the court further stated (at p. 176)--

> "In fact, one need not await the filing of a threatened suit by the patentee; the validity of the patent may be tested under the Declaratory Judgment Act, 28 U.S.C. §2201 (1964 Ed.)."

Thus, the defense asserted here against the Mayes et al. reissue patent in suit applies equally well to plaintiff's declaratory judgment suit and to the earlier suit by the Foundation with which the declaratory judgment suit has been consolidated.

Summary

Summarizing and applying the principles of the three Supreme Court cases reviewed above to the facts of the present case, there can be no doubt that--

1. The Mayes affidavit was filed in the application for the original Mayes et al. patent at a time when all parties concerned knew or should have known that the prior work of Isbell preceded the work of Mayes et al, and was known to Mayes et al. before they conceived the subject matter of their own patent application.

2. Mayes and Carrel both knew of the prior report PX-17, which most fully described the Isbell work, and to which they referred in their invention record, PX-15.

3. As counsel for the Foundation defendant acknowledged, Mayes undoubtedly had knowledge of the fact that both of the reports PX-4 and PX-17 that disclosed the results of Isbell's prior work had been published more than one year before the Mayes et al. application.

4. Mayes, admitted his own knowledge that publication of the subject matter of a patent application more than a year before filing it bars the grant of a valid patent.

Thus, whether or not any particular individual involved in the procurement of the Mayes et al. original and reissue patents knew all of the foregoing facts, it is evident that all of those facts could readily have been ascertained and that the Mayes affidavit was filed either with knowledge of those facts or in a reckless and irresponsible disregard for those facts. Clearly, such conduct does not meet the standard required of parties engaged in the procurement of patents from the Patent Office, as so clearly prescribed by the Supreme Court in the Precision Instrument case (p. 66, supra). That conduct was obviously "willful" and, since it transgressed the equitable standards so prescribed, it "is sufficient cause for the invocation of the maxim by the chancellor" and a declaration, on this motion for summary judgment, that the Mayes et al. reissue patent in suit is unenforceable and invalid.

CONCLUSIONS

1. The Isbell patent, No. 3,210,767 (PX-A), is invalid because the subject matter thereof was described in a printed publication (PX-4) by April 30, 1959, more than one year prior to the May, 1960, date of application for the patent [35 U.S.C. 102(b)].

2. The Mayes et al. reissue patent, No. Re. 25,740, is invalid because Mayes et al. did not themselves invent the subject matter thereof [35 U.S.C. 102(f)].

3. The Mayes et al. reissue patent, No. Re. 25,740 is unenforceable because it and the original patent upon which it was based were procured by presenting the Patent Office with deceptive and misleading evidence to the effect that the earlier work of Dwight E. Isbell was not a part of the prior art, whereas it was in fact a part of the prior art, was known to the applicants before they made their alleged invention, and had been described in printed publications (that were not before the Patent Office) more than one year prior to the date of the application for the Mayes et al. original patent. Hazel-Atlas Glass Co. v. Hartford-Empire Co., 322 U.S. 238 (1944); Precision Instrument Manufacturing Co. v. Automotive Maintenance Machinery Co., 324 U.S. 806 (1945); Walker Process Equipment, Inc. v. Food Machinery and Chemical Corp., 322 U. S. 172 (1965).

Respectfully submitted,

MASON, KOLEHMAINEN, RATHBURN & WYSS

By _____
One of the Attorneys for Plaintiff
20 North Wacker Drive
Chicago, Illinois 60606
FInancial 6-1677

OF COUNSEL:
John F. Pearne
William A. Gail
McNenny, Farrington, Pearne & Gordon
920 Midland Building
Cleveland, Ohio 44115
623-1040

A P P E N D I X

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

THE FINNEY COMPANY, a partnership, Plaintiff	
v.	CIVIL ACTION NOS.
JFD ELECTRONICS CORPORATION, a corporation,	65 C 220
and	and
THE UNIVERSITY OF ILLINOIS FOUNDATION, a non-profit corporation,	65 C 671 (Consl.)
Defendants.	

STIPULATION OF FACTS

IT IS HEREBY STIPULATED AND AGREED by and between the parties to this cause, by their undersigned counsel, that, for all purposes in this suit:

1. Printed copies, photostats, Xerox copies, photocopies, and the like of printed documents may be introduced and received in evidence in lieu of original copies or certified copies and with the same force and effect, but subject to correction if discrepancies should later appear and to objection on any ground other than authenticity.

2. Copies of other papers and documents produced by any of the parties in response to formal or informal discovery by an adverse party may be introduced by such adverse party, and received in evidence in lieu of the originals, and shall be accepted as authentic papers and documents of the character indicated thereby, subject to correction if discrepancies should later appear and to objection by any other party on any ground other than authenticity.

Respectfully submitted,

McNENNY, FARRINGTON, PEARNE & GORDON

By _____
One of the Attorneys for Plaintiff
920 Midland Building
Cleveland, Ohio 44115
623-1040

MERRIAM, MARSHALL, SHAPIRO & KLOSE

By /s/ Basil P. Manno
One of the Attorneys for Defendant
The University of Illinois Foundation
30 West Monroe Street
Chicago, Illinois 60603
FInancial 6-5750

OSTROLENK, FABER, GERB & SOFFEN

By /s/ Jerome M. Berkman
One of the Attorneys for Defendant
JFD Electronics Corporation
10 East 40th Street
New York, New York 10016
Murray Hill 5-8470

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

THE FINNEY COMPANY, a partnership, Plaintiff, vs. JFD ELECTRONICS CORPORATION, a corporation, and THE UNIVERSITY OF ILLINOIS FOUNDATION, a non-profit corporation, Defendants.	Civil Action Nos. 65 C 220 and 65 C 671 (Cons.)

AFFIDAVIT

STATE OF OHIO)
) SS:
COUNTY OF CUYAHOGA)

JOHN F. PEARNE, being duly sworn, deposes and says that the following pages are true and correct reproductions of selected portions of the deposition of Paul E. Mayes taken in the above-entitled suit January 17-19, 1967, as heretofore filed with the Court, except that corrections agreed upon by counsel and made in the original transcript filed with the Court are shown on the attached pages by longhand interlineations.

John F. Pearne
John F. Pearne

Subscribed and sworn to before me this 19th day of April, 1967.

/s/ Christine Alberts
Notary Public

Seal

PX-F

THE 20th NATIONAL ELECTRONICS CONFERENCE
SEMINAR ON

TOPICS IN MODERN ANTENNA THEORY

A. FREQUENCY INDEPENDENT ANTENNAS—

V. H. Rumsey, University of California, *"Frequency Independent Antennas"*

P. E. Mayes, University of Illinois, *"Some Recent Results in Frequency Independent Antenna Research"*

B. ARRAY THEORY

A. Ishimaru, University of Washington, *"Recent Advances in Antenna Theory—Unequally Spaced Arrays"*

A. L. Maffett, Conductron Corporation, *"Application of Some Techniques of Numerical Analysis to the Theory of Nonuniform Arrays"*

C. DATA-PROCESSING ANTENNAS

A. Ksienski, Hughes Aircraft Company, *"Recent Advances in Signal Processing Systems"*

Session Chairmen: R. E. Hiatt, University of Michigan
M. A. Plonus, Northwestern University

McCormick Place
October 19, 1964
Chicago, Illinois

PX-H

SOME RECENT RESULTS IN FREQUENCY INDEPENDENT ANTENNA RESEARCH

P. E. Mayes*

I. EARLY WORK

An antenna is said to be frequency independent if the principal characteristics (radiation pattern and input impedance) change negligibly with frequency over a band which is limited only by the construction of the antenna and if the band can be readily extended by adding to the structure in a manner which is apparent from the structure geometry. This definition is designed to distinguish the frequency independent antenna from that which is loosely termed broad-band. The above definition serves to separate the log-spiral and log-periodic antennas from the so-called broad-band antennas of the past, such as the biconical and its flat counterpart, the bow-tie. However, it was from these early broad-band types which followed the angle concept as outlined by Professor V. H. Rumsey that the development of log-periodic antennas has proceeded.[1,2]

The troublesome thing about the bow-tie could be termed "end effect." For, although this shape of triangular fins would have frequency independent properties when extended to infinity, the truncation which is necessary in the practical antenna produces a length in the defining parameters and this length produces variations in the radiation pattern. DuHamel theorized that the end effect in a bow-tie might be eliminated if the energy could be removed by radiation in the region between feed point and truncation.[2] This reasoning led to the first successful log-periodic antennas, with a shape which is shown in Figure 1. The serrations were designed to produce the desired radiation. They were also designed to improve the chances that the resulting structure would be frequency independent. First, the shape is self-complementary; that is, if we consider the outlined region to be a flat sheet of conductor, the open region between the elements has a

*Antenna Laboratory, Department of Electrical Engineering, University of Illinois, Urbana, Illinois.

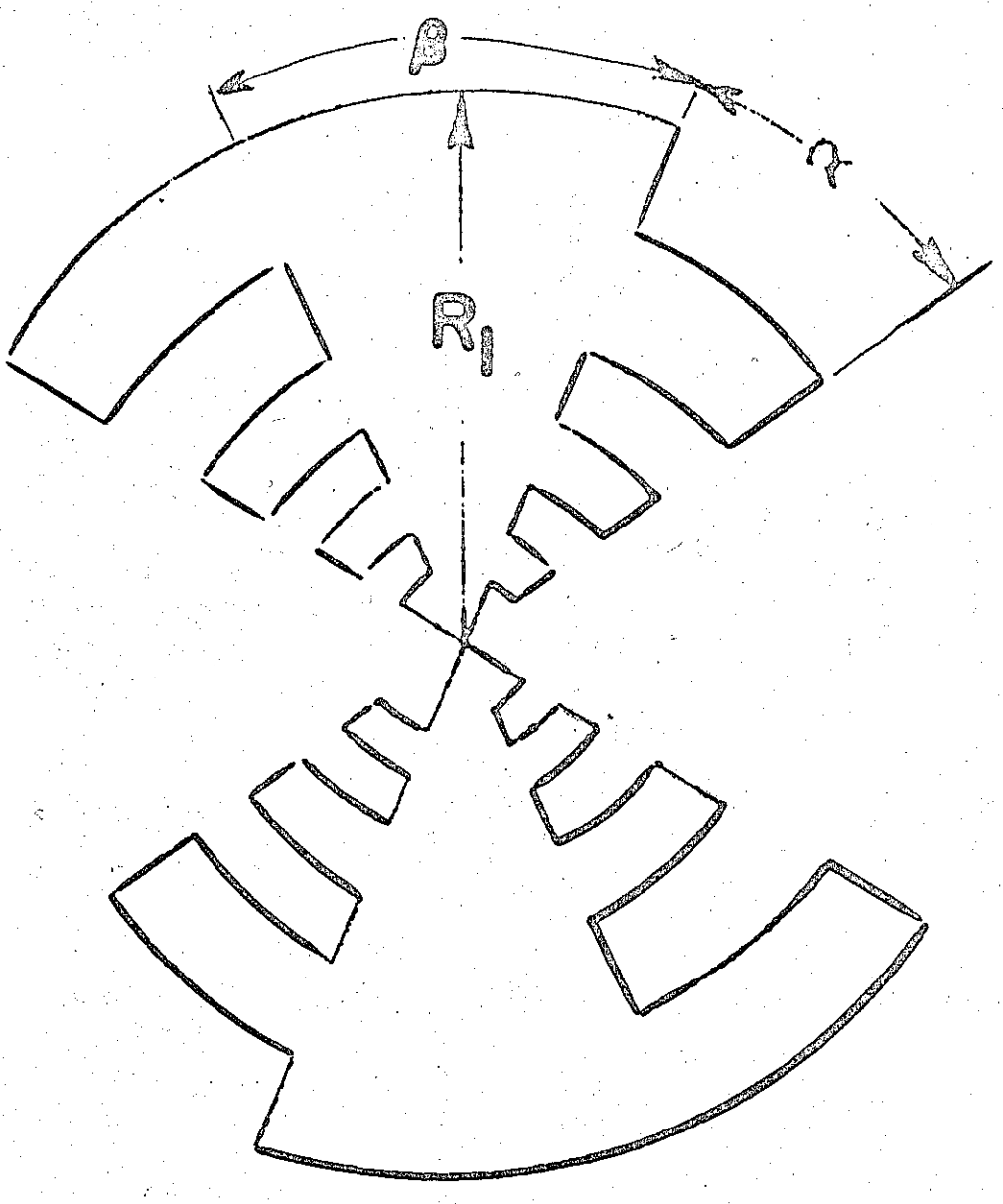

Figure 1. An early planar log-periodic structure.

shape which is identical to the shape of the conducting region. When such a self-complementary structure is infinite, Babinet's principle tells us that the input impedance is constant at 189 ohms regardless of the frequency. If the end effect is truly eliminated by the serrations, the antenna will appear infinite at the input terminals, and the impedance will be frequency independent. Although it was later found that this was not a necessary condition for frequency independent input impedance, it no doubt played an important part in the success of the first models.

The second general principle follows from similitude, which has been used for many years as a basis for testing antennas by using a scale model. The shape shown in Figure 1 is such that the application of a certain scale factor to this figure would result in the same figure except in the area near the truncation of the large and small ends of the structure. Hence, insofar as the truncations are unimportant to the antenna performance, the electrical characteristics of the antenna must be repeated at frequencies which are related by the scale factor, which is usually called τ. Since the same results could be obtained by many successive applications of the same scale factor (when the truncation effects are negligible), the performance should repeat at frequencies related by any integral power of the scale factor τ. This property of the geometry, that the electrical performance should repeat periodically with the logarithm of the frequency, was the motivation for the name "logarithmically periodic" or "log-periodic" structures.

The flat sheet metal antenna shown in Figure 1 produced a bi-directional beam which was linearly polarized with the electric vector parallel to the teeth. This latter observation confirmed that it was the currents flowing on the serrations which produced the radiation and the triangular fin merely acted as a transmission line to feed the radiating elements.

Important as they were, these first log-periodic antennas were not of great practical usefulness. The principal drawback was the bi-directional characteristic of the radiation which would naturally result from the symmetry of a planar structure. For most applications, a uni-directional radiation pattern is preferable. The obvious thing to try, then, is to spoil the symmetry of the structure in order to change the radiation pattern

from a bi-directional one to a uni-directional one. Figure 2 shows a log-periodic antenna with elements tilted toward each other that was first investigated by Isbell.[3] It indicates that the desired uni-directional radiation was achieved, but, instead of radiating in the direction of phase progression of the current along the fin, the beam was produced in the opposite direction -- that is, toward the feed point. This "backfire" characteristic has been found to be inherent in the operation of most successful uni-directional frequency independent antennas and will be discussed further later.

The first development of wire outline versions of log-periodic antennas was done primarily by DuHamel and his co-workers at Collins Radio.[4,5] Figure 3 shows some of the modifications which were made to convert the first uni-directional log-periodic antennas into structures which would be practical for applications in the high frequency communications band -- 6 to 30 megacycles. Most of the conductor has been eliminated from the elements leaving only a central boom and the edges of the elements. The element shape has been changed from circular arc to straight line. The essential properties are retained, however, due to the common scale factor associated with the dimensions of any two adjacent elements.

Another very practical form of the antenna was developed by Isbell.[6] Although he proceeded along a different line of reasoning, the same result is achieved if we apply several perturbations to the antenna in Figure 3. If we let the element widths become small and then allow the angle between the planes of elements to go to zero, the result is the familiar log-periodic array of dipole elements shown in Figure 4. The perturbation just described leads naturally to the transposed feeder line shown in Figure 4.

Rumsey has pointed out the common symmetry properties in a self-complementary structure and the dipole array with transposed feeder.[1] It is interesting to note that the shape of the first log-periodic antennas was governed by a desire to obtain a self-complementary structure, and this dictated the staggered location of the "teeth" on the antenna shown in Figure 1. Although the perturbations in the structure of Figure 1 which lead to the dipole array of Figure 4 are rather severe, the symmetry is maintained through the use of the transposed feeder.

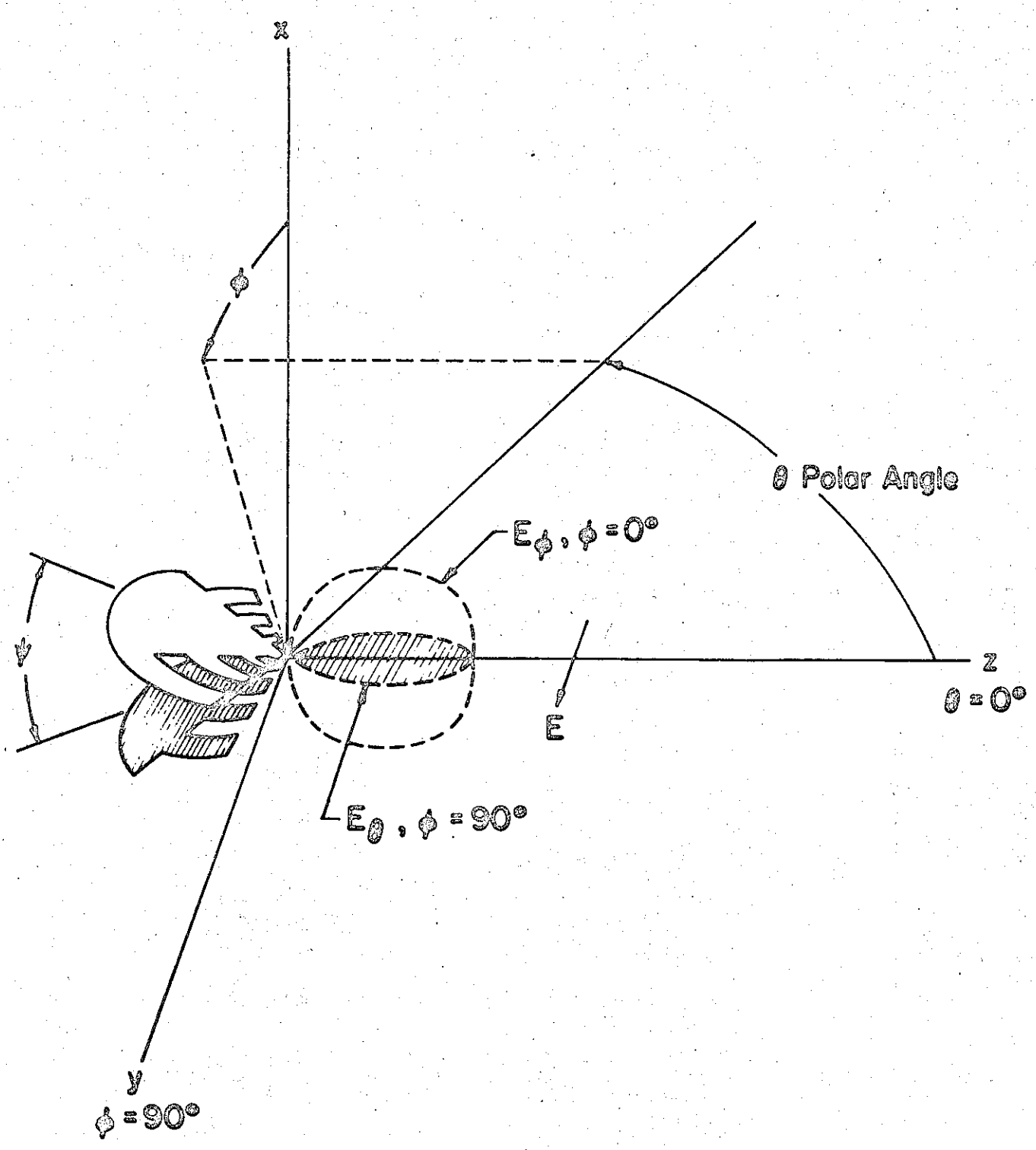

Figure 2. The first unidirectional log-periodic antenna showing the backfire beam.

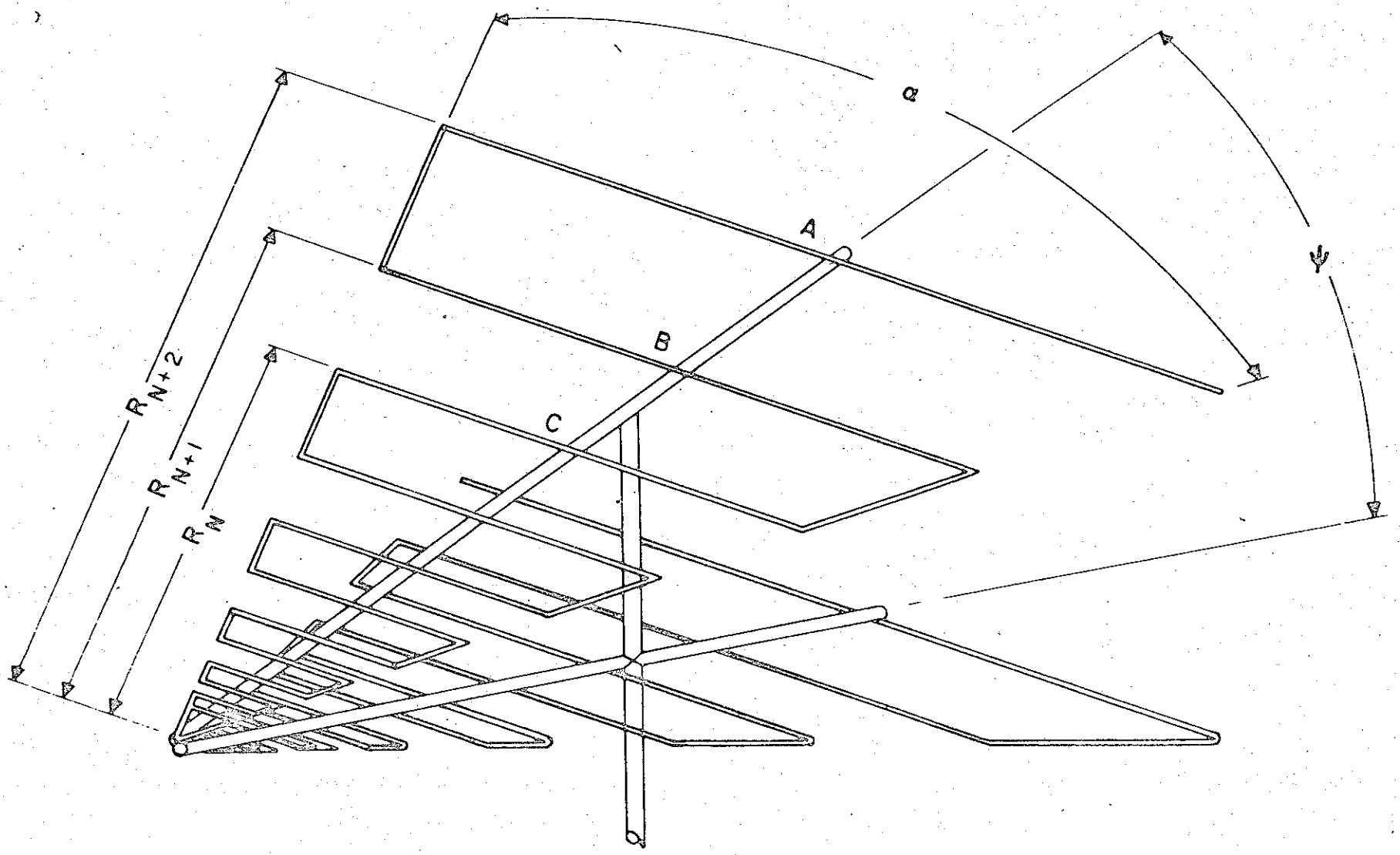

Figure 3. A wire-outline log-periodic antenna (Collins Radio Company).

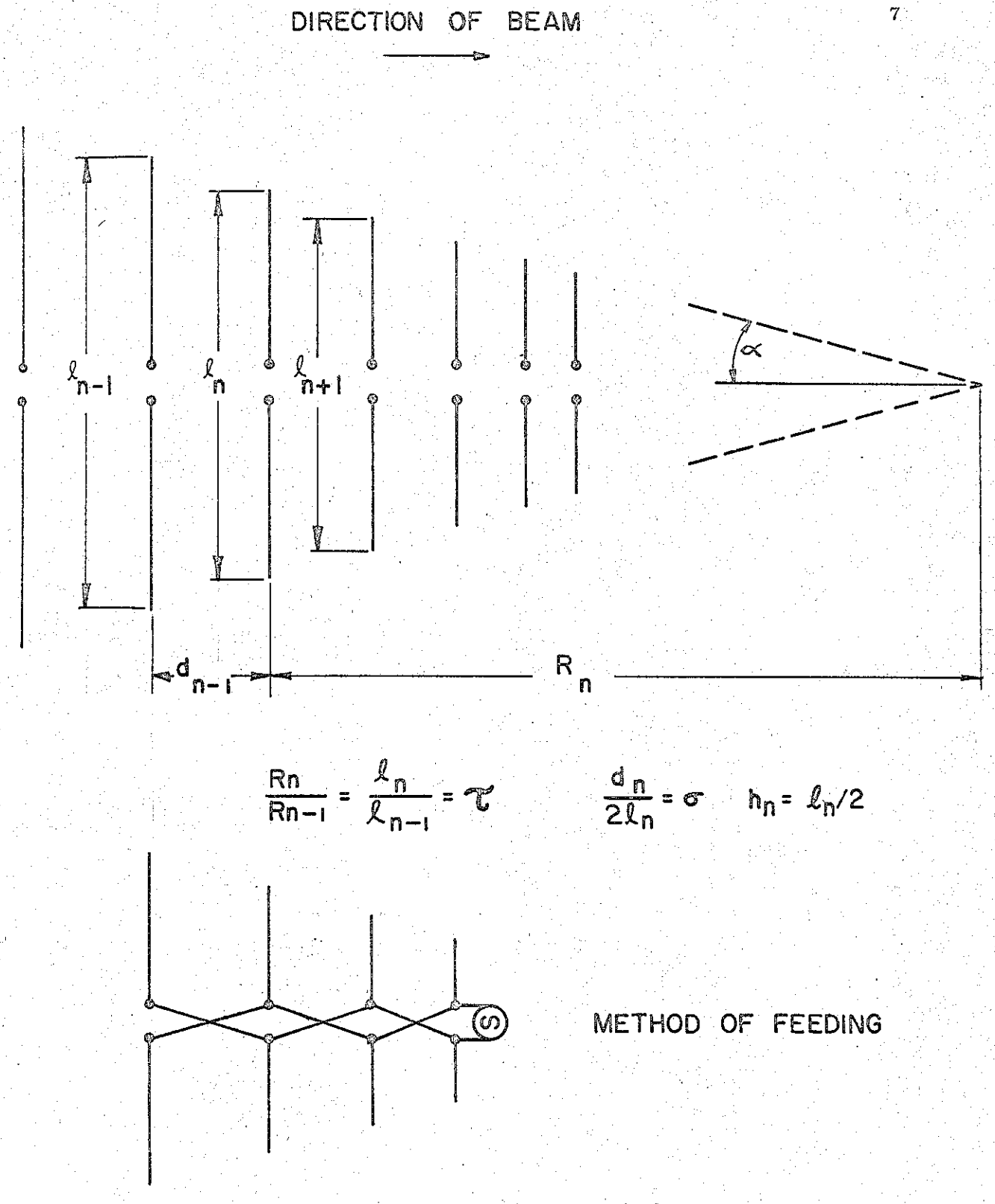

Figure 4. Schematic diagram of the log-periodic dipole array.

IN THE UNITED STATES PATENT OFFICE
BEFORE THE EXAMINER OF INTERFERENCES

ISBELL

v.

KRAVIS ET AL.

Interference No. 92,150

AMENDED PRELIMINARY STATEMENT
OF DWIGHT E. ISBELL

STATE OF WASHINGTON)
) SS.
COUNTY OF KING)

DWIGHT E. ISBELL, being duly sworn, deposes and says, that he is the sole applicant for the U. S. Letters Patent in application Serial No. 26,589, filed May 3, 1960, and entitled "Frequency Independent Unidirectional Antennas," which application is involved in the above-identified interference;

That the invention defined by the interference count was made by him in the United States of America;

That the first drawing of the invention was made on or about January 5, 1959;

That the first written description of the invention was made on or about January 5, 1959;

That the invention was first disclosed to another person during the month of October, 1958;

That the date on which the first act or acts susceptible of proof (other than the foregoing) which, if proved, might establish conception of the invention, is September 18, 1958, on which date the party Isbell performed certain experimental work in the University of Illinois Antenna Laboratory, and made a notebook entry in Isbell Notebook No. 1

A00152 PX-I

at page 130 concerning the invention;

That the invention was actually reduced to practice on or about December 31, 1958;

That reasonable diligence toward reducing the invention to practice began on or about September 18, 1958; and

That no application was filed by him disclosing the same invention in the United States or in any foreign country prior to the filing date of United States application Serial No. 26,589.

/s/ Dwight E. Isbell
Dwight E. Isbell

Subscribed and sworn to before me this 14th day of February, 1962.

/s/ Lee Byron
Notary Public

Seal

A00153

DEPARTMENT OF THE NEGOTIATED CONTRACT ENL/rg	DEPARTMENT OF THE AIR FORCE	CONTRACT NO. 0505, AF 33(616)-8079 Class: 16A

ISSUING OFFICE

NAME	ADDRESS
WRIGHT AIR DEVELOPMENT CENTER Buyer: Kenneth R. Lont, WCNCE	WRIGHT-PATTERSON AIR FORCE BASE, OHIO

CONTRACTOR

NAME	ADDRESS
THE BOARD OF TRUSTEES OF THE UNIVERSITY OF ILLINOIS	URBANA-CHAMPAIGN, ILLINOIS

CONTRACT FOR	AMOUNT
ANTENNA RESEARCH	Est. Cost: $100,000.00

APPROPRIATION AND OTHER ADMINISTRATIVE DATA

INITIATOR . . . . . Bernice K. Stout, WCNRO-3

PURCHASE REQUEST NO. 08715

PROJECT NO. . . . . 9-(13-6278)

TASK NO. 40572

MONITORING LABORATORY . . . . . Aerial Reconnaissance Laboratory, WCLR

DO RATING . . . . . C-9 Certified under DMS Regulation No. 1

PAYING OFFICE . . . . . Finance Officer, USAF, 5555 South Archer Avenue, Chicago 38, Illinois

ADMINISTRATIVE OFFICE . . . . . Director, Office of Naval Research Branch Office, The John Crerar Library Building, 86 East Randolph Street, Chicago 1, Illinois

Payment Vouchers should be mailed via Cognizant Auditing Agency to: Office of Naval Research, Resident Representative, 1209 West Illinois Street, Urbana, Illinois

PLAINTIFF'S EXHIBIT 1A

This negotiated contract is entered into pursuant to the provisions of 10 U.S.C. 2304 (a) (5) and any required determination and findings have been made.

THIS CONTRACT is entered into as of 28 August, 1958, by and between the United States of America, hereinafter called the Government, represented by the Contracting Officer executing this contract, and THE BOARD OF TRUSTEES OF THE UNIVERSITY OF ILLINOIS
(NAME OF CONTRACTOR)

(i) a corporation organized and existing under the laws of the State of ILLINOIS

hereinafter called the Contractor. The parties hereto agree that the Contractor shall furnish and deliver all the supplies and perform all the services set forth in the attached Schedule, for the considerations stated therein.

SCHEDULE | PAGE NO. | NO. OF PAGES

PART I - STATEMENT OF WORK

A. The Contractor shall, within the period of time set forth in PART II hereof, provide the necessary personnel, facilities, materials and supplies and shall perform antenna research in accordance with the following:

1. Attachment I, dated 7 July 1958, attached hereto and made a part hereof.

B. The Contractor shall, as a result of the work accomplished in accordance with the requirements of Paragraph A above, and in accordance with the schedule set forth in PART II hereof, submit the following ITEMS:

1. ITEM I - Monthly Progress Reports - in two (2) copies containing a brief outline of the status of the project and a discussion bearing upon the approach to the objectives specified herein, including both positive and negative results obtained during the reporting period.

2. ITEM II - Quarterly Engineering Reports - in ninety (90) copies, one (1) copy of which shall be in a reproducible form prepared in accordance with ARDC Manual 5-1, dated June 1957, and using as a guide Exhibit WCLR 519, dated 8 October 1957, both incorporated by reference. A copy of the distribution list mentioned in PART II hereof shall be bound into each copy of the report by the Contractor.

3. ITEM III - Final Engineering Report - in ninety (90) copies, one (1) copy of which shall be in a reproducible form prepared in accordance with ARDC Manual 5-1, and using as a guide Exhibit WCLR 519. A copy of the distribution list mentioned in PART II hereof shall be bound into each copy of the report by the Contractor.

C. The Contractor shall prepare in three (3) copies a letter of transmittal which shall be submitted concurrently with each Item delivered under this contract. The Letter of Transmittal which accompanies the Monthly Progress Report shall contain an indication as to the percentage of completion of the total work required as of the end of the reporting period. The Contractor shall certify in the letter of transmittal which accompanies the Quarterly and Final Engineering Reports that the other copies of the reports have been distributed to the destinations outlined in the distribution list. The Letter of Transmittal shall be submitted in accordance with instructions contained in PART II hereof.

D. All Items required herein shall bear the Contract Number and Task Number designated on the cover page of this contract.

PART II - TIME OF PERFORMANCE AND DELIVERY INSTRUCTIONS

A. The Contractor shall commence performance of the work set forth herein on or after 1 September 1958 and shall deliver the items required by PART I hereof in accordance with the following schedule:

1. ITEM I - Monthly Progress Reports - The first report shall be submitted no later than 20 October 1958 and each subsequent report shall be submitted monthly thereafter for the duration of the contract.

2. ITEM II - Quarterly Engineering Reports - The first report shall be submitted no later than 31 December 1958 and each subsequent report shall be submitted quarterly thereafter for the duration of the contract.

3. ITEM III - Final Engineering Report - shall be submitted on or before 31 October 1959.

B. The Contractor shall submit by prepaid mail all items required by PART I hereof as follows:

1. ITEM I to: Commander
Wright Air Development Center
ATTN: WCLRS-6, Contract AF 33(616)-6079
Wright-Patterson Air Force Base, Ohio

2. ITEM II and ITEM III shall be distributed in accordance with a distribution list to be furnished by the Aerial Reconnaissance Laboratory.

C. The Contractor shall forward the three (3) copies of the Letter of Transmittal called for herein to the following: One (1) copy to accompany the ITEM submitted to the Laboratory; one (1) copy to the Administrative Office designated on the cover page of this contract; and one (1) copy to Commander, Wright Air Development Center, ATTN: WCLRO-3, Wright-Patterson Air Force Base, Ohio

PART III - CONSIDERATION AND PAYMENT

A. The estimated cost of this contract as contemplated by the General Provisions is ONE HUNDRED THOUSAND DOLLARS AND NO CENTS ($100,000.00).

B. The Contractor shall be reimbursed for overhead expense during each overhead period at a provisional rate, applicable to direct salaries and wages, including vacation, holidays and sick leave allowance; subject, however, to the provisions of the Clause hereof entitled "Negotiated Overhead Rates". The rate for the first period is 37.25%. The first period shall extend from the inception of this Contract through 31 August 1959, and subsequent periods shall be of 12 months duration each.

PART IV - INSPECTION AND ACCEPTANCE

A. The Aerial Reconnaissance Laboratory, WCLR, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, is hereby designated as the point for final inspection and acceptance of all ITEMS required herein.

PART V - ADVANCE PAYMENTS

A. Advance Payments will be made for the work called for hereunder in accordance with the Findings and Authorization signed by the Assistant Secretary of the Air Force on 7 August 1953. Payments made pursuant to this clause shall be governed

05049

ATTACHMENT I

Statement of Work

PR 08715

7 July 1958

1. Continue Work on Broadband Antennas

The objective is to devise various types of antennas for which the pattern and impedance are independent of frequency. Successful designs to date have been achieved by specifying the antenna in terms of angles and by making the structure logarithmically periodic. Continue the effort of (a) extending these broadband techniques to three dimensional structures; (b) investigate unidirectional broadband techniques; (c) theoretical analysis of broadband antennas.

2. Increase of Effective Aperture

Investigate techniques of increasing the effective aperture by: (a) arrays of elements where the detector is an integral part of the element and the video outputs are combined such that the pattern of the array is that of one element and the video output is a function of the number of elements; (b) other methods of increasing the effective aperture while retaining RF information.

3. Antenna for MASER Amplifier

Investigate problems associated with coupling antennas or antenna systems to MASER Amplifiers. As an example, techniques for reducing the radiation from a hot antenna are required to make full use of the low noise figure of a MASER Amplifier.

4. Nested Antennas

Investigate techniques of obtaining extremely broadband antennas wherein antennas are placed within antennas. An example would be a helix inside of a helix, etc. It is desired to have only one output from these nested antennas; however, an output for each antenna within the group is acceptable.

5. Inter-satellite Ferret Antennas

Investigate techniques for antenna or antenna systems where essentially spherical coverage is required for use on satellite vehicles.

6. Perform such other tasks as may be mutually agreed upon by the contractor and the procuring agency.

Inventor's Copy
Patent Case # 144

UNIVERSITY OF ILLINOIS

5254

DISCLOSURE OF INVENTION AND
LETTER OF TRANSMITTAL

To the University of Illinois
Patent Committee

Date: 20 May 1959

Entered herein and attached hereto is information concerning a potentially patentable invention for your consideration.

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1. Descriptive Title of Invention

"Log Periodic Dipole Arrays"

2. Inventor

D. E. Isbell
Staff Member,
Antenna Research
Laboratory

University of Illinois
Electrical Engineering
Research Laboratory
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3. Description of Invention

(a) Description: For a complete description of the invention please refer to Antenna Laboratory Technical Report No. 39, "Log Periodic Dipole Arrays," by D. E. Isbell, Contract No. AF 33(616) - 6079, Project No. 9-(13-6278) Task 40572 Wright Air Development Center, Electrical Engineering Research Laboratory, University of Illinois

(b) Earliest date and place invention was conceived; The antenna was conceived in September of 1958 at the University of Illinois Antenna Laboratory.

(c) Date and place of first sketch, drawing, and written description: The first recorded sketches and drawings were given on pp. 2-3 of Quarterly Engineering Report No 2 "Research Studies on Problems related to EDM Antennas," Contract No. AF 33(616)-6079 Electrical Engineering Department, University of Illinois.

PLAINTIFF'S EXHIBIT 3

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4. Disclosure

(a) Disclosure of Invention to others: The invention was disclosed to other members of the Antenna Laboratory during its initial development and was also disclosed to some visitors to our Laboratory.

(b) Date and place of completion of the first operating model or full scale device: The first operating model was made in the University of Illinois Antenna Laboratory in December of 1958.

(c) Present Location of Model: It is still located at the Antenna Laboratory.

(d) Date, place, description and results of first test or operation: The first results were described in Technical Report No. 39 mentioned above.

5. Support of the University

The development of this invention was supported entirely by the University of Illinois facilities, with the dates the same as above.

6. This invention was made while working on research sponsored by the Wright Air Development Center under Contract AF 33(616)-6079 entitled, "Research Studies on Problems Related to ECM Antennas."

Note: This invention is unclassified.

7. If decision of the Patent Committee is to recommend release of interests of the University in this invention, the following is recommended:

Release to inventor, with recognition of contractual obligations of the University to sponsoring agency.

Respectfully submitted, 5256

Inventor Date May 21, 1959

It is certified that the statements made herein are correct to the best of my knowledge and belief.

Department Head, or other Administrative Officer Date June 24/59

CTR-198

LOGARITHMICALLY PERIODIC ANTENNA DESIGNS

R. H. DuHamel

and

F. R. Ore

31 March, 1958

A PUBLICATION OF
THE RESEARCH AND DEVELOPMENT DIVISION

COLLINS RADIO COMPANY

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COLLINS TECHNICAL REPORT

LOGARTHMICALLY PERIODIC ANTENNA DESIGNS

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LOGARITHMICALLY PERIODIC ANTENNA DESIGNS

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Collins Radio Company
Cedar Rapids, Iowa

Summary

Research on new types of broadband logarithmically periodic antenna structures is reported. The antennas have pattern and impedance characteristics which are essentially independent of frequency over theoretically unlimited bandwidths. Bandwidths of ten to one are readily achieved in practice. Structures are described which provide linearly polarized omnidirectional, bidirectional and unidirectional patterns as well as circularly polarized bidirectional and unidirectional patterns.

Introduction

The subject of this paper is a class of antennas, called logarithmically periodic antenna structures, for which the pattern and impedance are essentially independent of frequency over theoretically unlimited bandwidths. Research on one particular type of these structures which provided a linearly polarized bidirectional beam was previously reported.[1] Since that time, various types of these structures have been discovered which provide linearly polarized unidirectional and omnidirectional patterns as well as circularly polarized unidirectional patterns. The proven versatility and wide bandwidth of these structures leads to the conclusion that the applications are practically unlimited. Obvious applications are to high-frequency and ECM antennas as well as to primary feeds for reflector and lens-type antennas.

The only other known class of frequency independent antennas is the angular antenna described by V. H. Rumsey.[2] Common examples are the discone, biconical, and bow-tie antennas which have bandwidths of approximately 2 or 3 to 1 for which the pattern is essentially independent of frequency. The so-called "end effect" limits the bandwidth of these antennas. An example of a recent type of angular antenna which apparently has negligible "end effect" is the equiangular or logarithmic spiral antenna[3] which has a frequency independent bandwidth of better than 10 to 1.

Referring to figure 1, the geometry of logarithmically periodic antenna structures is defined so that the pattern and impedance repeat periodically with the logarithm of the frequency. For planar structures, this is accomplished by defining their shape such that θ equals a periodic function of ln r where r and θ are the polar coordinates in the plane. Then if ln τ is the period of ln r, the operation of a structure of infinite extent would be the same for any two frequencies related by some integral power of τ. For the simple structure in figure 1a:

$$\tau = \frac{R_{N+1}}{R_N}$$

If the shape of the structure and the factor τ can be made such that the variation of the pattern and impedance over one period is small, then this will hold true for all periods, the result being an extremely broadband antenna. For finite structures, it has been found that since the end effect is negligible, wide bandwidths are readily obtained.

The two halves of the antenna are fed at the vertices either with a balanced two-wire line or with a coaxial line running up one half of the structure with the outer conductor bonded to the structure. For the structure of figure 1a, it is found that the lower and higher frequency limits are obtained when the longest and shortest teeth respectively are approximately 1/4 wavelength long. By probing the structure, it is found that the currents on the structure die off quite rapidly after progressing past the region where a tooth 1/4 wavelength long is positioned. This accounts for the negligible end effect. This antenna has a horizontally polarized bidirectional pattern with approximately equal and constant principal

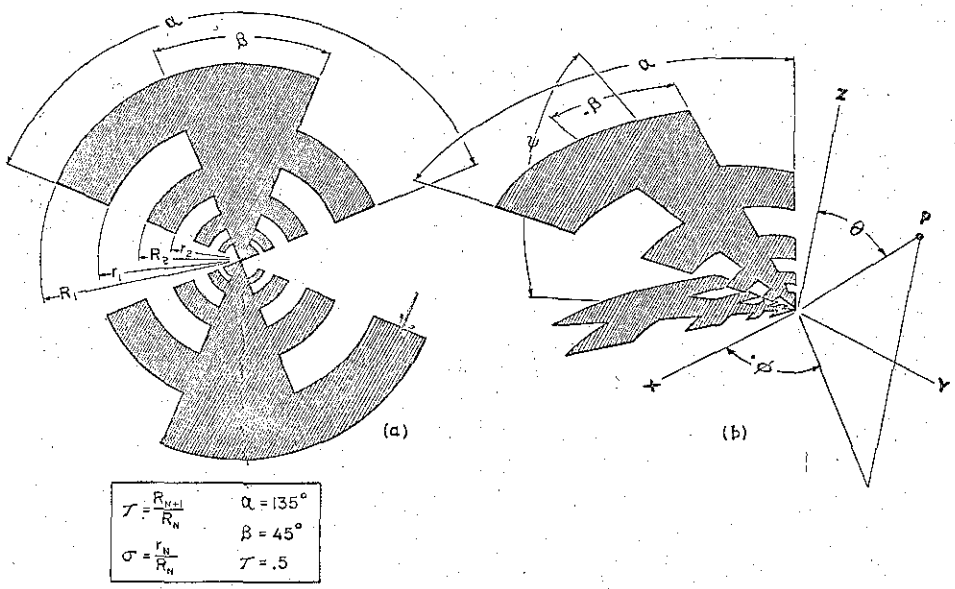


Figure 1. Parameters and Coordinate System for Circular Tooth Structures

plane beamwidths over a frequency band of 10 to 1 or more and has a constant input impedance of approximately 170 ohms. The axes of the lobes are perpendicular to the plane of the structure. It was originally believed that it was necessary to make these structures identical to their complement in order to obtain a frequency independent input impedance. However, the results reported in this paper demonstrate that this equi-complementary condition is sufficient but not always necessary. Several frequency independent antennas will be introduced where the deviation from the equi-complementary condition is quite severe.

The fact that the electrical characteristics of logarithmically periodic structures repeat every period greatly simplifies the experimental investigation of them because it is only necessary to measure these characteristics over a half or single period in most cases. The operation over other periods may be readily predicted provided the end effect is negligible and that all dimensions are made proportional to their distance from the vertex.

As illustrated in figure 1b, D. E. Isbell[4] found that by bending the curved tooth structure about a horizontal axis, a unidirectional pattern pointing in the direction of the positive y axis could be obtained. Some control of the principal plane beamwidths and front-to-back ratio was obtained by varying the parameters α, β, ψ, and τ. Typical E-plane and H-plane beamwidths of 60° and 90° and a front-to-back ratio on the order of 10 to 15 db were obtained. It was found that the characteristic impedance of the structure decreased as the angle ψ was decreased, but that the VSWR referred to this characteristic impedance increased rather rapidly to 3.5:1 for $\psi = 30°$.

A great number of logarithmically periodic antenna configurations are possible. The investigation reported in this paper was conducted to study impedance, pattern, and polarization characteristics of a variety of structures. Another objective of the investigation was to devise practical forms of this type of antenna. Since large, circular tooth structures would be difficult to construct, the possibility of simplifying this basic structure by straightening the teeth and by making wire approximations of the teeth was investigated and is reported in the following sections.

Trapezoidal Tooth Sheet Structures

Figure 2 shows a sketch of a general trapezoidal tooth structure and gives a definition of the coordinate system and various parameters that will be used throughout this paper to describe the various structures. Figure 3 is a photograph of a printed circuit board form of this type of structure which was used for the experimental investigation. By comparing a structure cut from sheet metal in a conventional way to an identical structure etched on teflon dielectric printed circuit

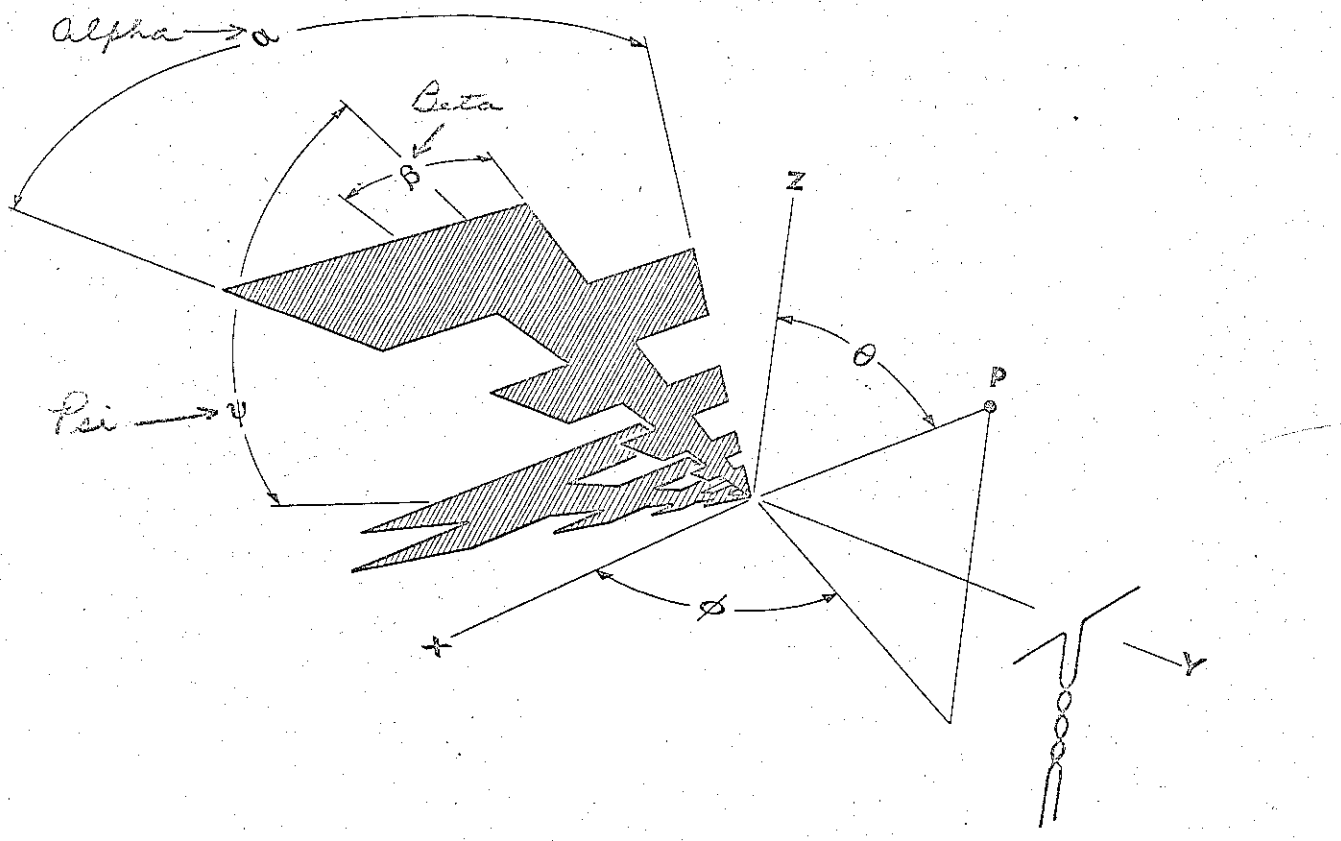


Figure 2. Parameter and Coordinate System for Trapezoidal Tooth Structures

Figure 3. A Printed, Nonplanar, Trapezoidal Tooth Structure Bent About the X Axis

board, it was found that the printed circuit board models could be used up to about 3000 mc without the presence of the dielectric becoming too objectionable. As a point of interest, the undesired metal can be removed either by an etching process or by cutting around the outline of the structure with a sharp instrument and then peeling the metal away. Two models of planar structures (with $\psi = 180°$) were constructed with the following parameters: $\alpha = 90°$, $\beta = 30°$ for one and

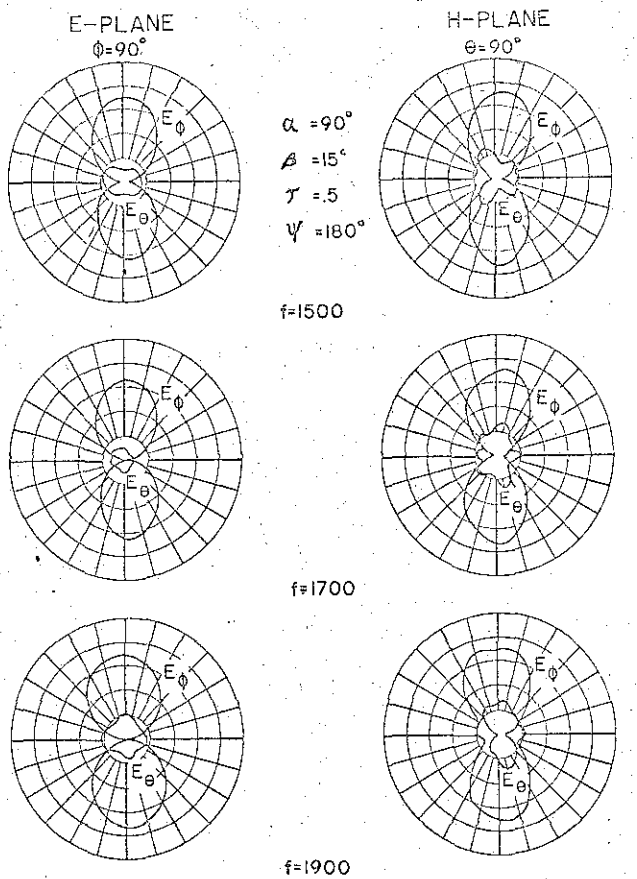


Figure 4. Patterns for Planar Trapezoidal Tooth Structure

$\beta = 15°$ for the other, $\tau = 0.5$, and R_1, the perpendicular distance from the vertex of one-half the structure to the longest element, is 12.75 cm. Patterns were taken over about a two to one frequency range (900 to 2100 mc). Figure 4 shows typical patterns for this type of structure. In general, both structures gave essentially frequency independent, linearly polarized, bidirectional patterns. Over the frequency range stated above, the E-plane (pattern in the xy plane of figure 1b) half-power beamwidth varied from 65° to 80° with an average beamwidth of 71°, and the H-plane (pattern in the yz plane of figure 1b) half-power beamwidth varied from 60° to 69° with an average beamwidth of 62°. Of the two antennas tested, the one having the narrower center section ($\beta = 15°$) demonstrated slightly less variation of beamwidth with frequency.

Patterns were taken for a nonplanar structure with $\psi = 60°$ over a 5:1 frequency range. Typical patterns are shown in figure 5. The E-plane patterns were unidirectional with beamwidths that varied from 60° to 75° with an average beamwidth of 65° and the H-plane patterns had beamwidths that varied from 80° to 110° with an average beamwidth of 85°. The front-to-back ratio, due to the cross polarization E_θ, had an average value of about 9 db; the front-to-back ratio, due to the major polarization E_ϕ, had an average value of about 13 db.

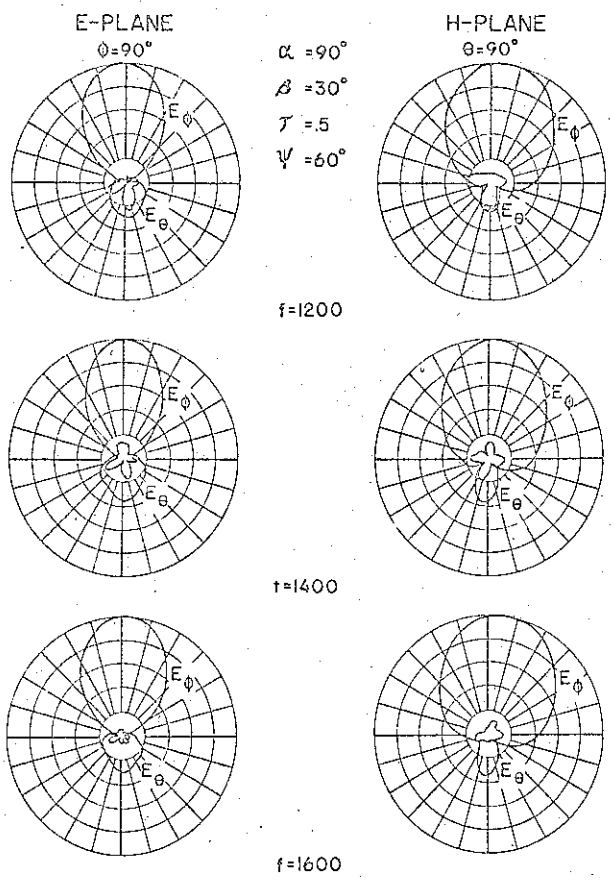


Figure 5. Patterns for Nonplanar (Bent About Horizontal Axis) Trapezoidal Tooth Structure

TABLE 1: VARIATION OF Z_0 AND VSWR WITH Ψ ANGLE FOR A PRINTED, TRAPEZOIDAL TOOTH STRUCTURE

Ψ Angle	Z_0	VSWR (Referred to Z_0)
180	170	1.4
60	105	1.6

Table 1 shows how the impedance of this particular structure compared with the corresponding planar structure. The input impedance Z_0 was reduced from 170 ohms to about 105 ohms and the VSWR's referred to their respective input impedances were about the same. Thus, the impedance characteristic of a nonplanar trapezoidal tooth structure is considerably better than that of a curved tooth structure.

Another possible nonplanar structure is where the original planar structure is bent about its vertical axis to an included acute angle χ. A structure of this type is shown in figure 6. Patterns and impedance were measured for a variation in χ from 180° to 60° in 30° steps. It was found that the E-plane patterns showed a definite tendency toward varying from bidirectional at $\chi = 180°$ to omnidirectional at $\chi = 60°$; the H-plane patterns remained bidirectional over the same range.

Figure 6. A Printed Nonplanar, Trapezoidal Tooth Structure Bent About the Z Axis

Typical patterns for $\chi = 90°$ are shown in figure 7. In general, the patterns varied considerably with frequency.

TABLE 2: VARIATION OF Z_0 AND VSWR WITH VARIOUS χ ANGLES FOR A PRINTED, TRAPEZOIDAL TOOTH STRUCTURE

χ Angle	Z_0	VSWR (Referred to Z_0)
180	170	1.4
120	180	1.35
90	200	1.4
60	210	1.9

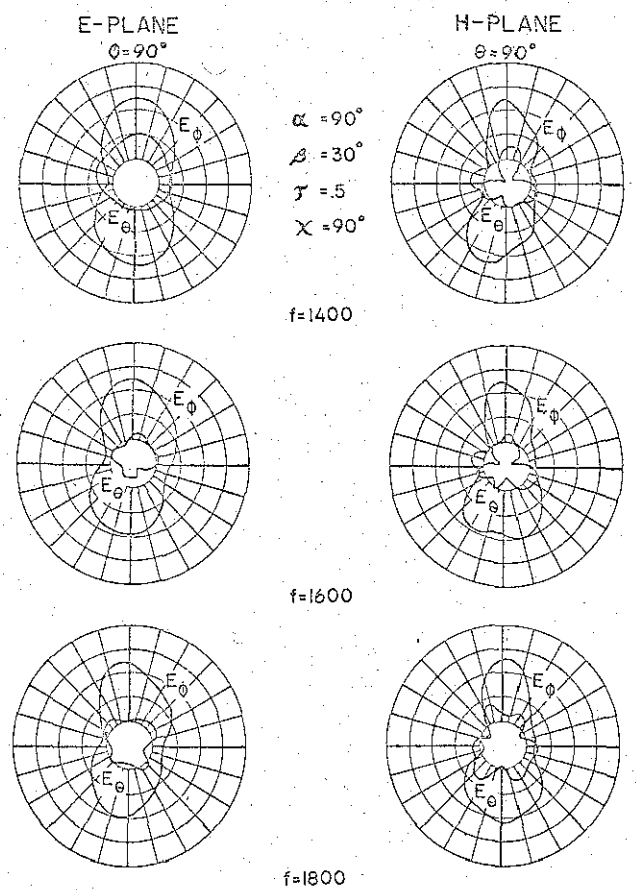


Figure 7. Patterns for Nonplanar (Bent About Vertical Axis) Trapezoidal Tooth Structure

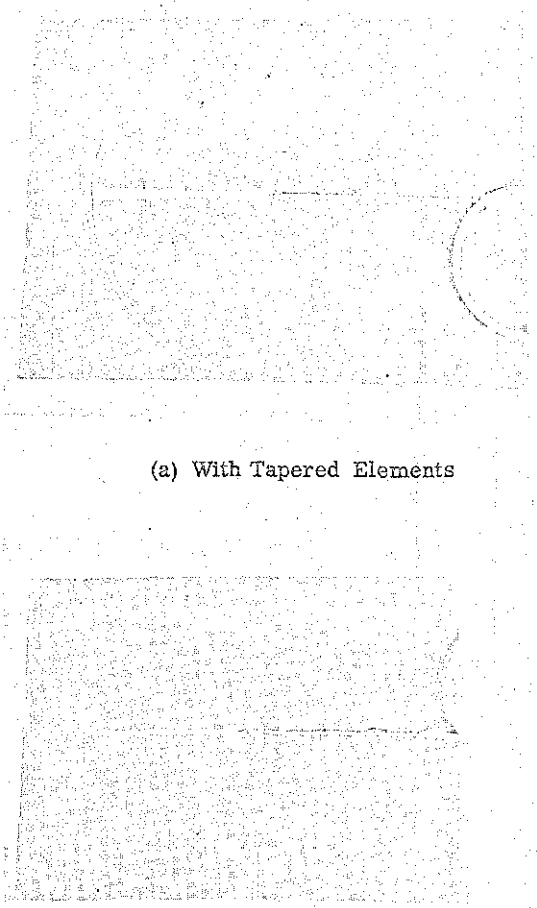
The variation of impedance with the angle χ was rather interesting, as can be seen in table 2. The average input impedance Z_0 increased as the χ angle was decreased. This was just the reverse of the effect that the reduction in ψ produced.

Wire Structures

Wire, Curved Tooth, Planar Structure

The approximation of sheet structures with wire structures was first investigated for a circular tooth structure. Two different approximations are shown in figure 8 and as can be seen, all the metal was removed except for narrow strips outlining the teeth. A still closer observation will indicate that the horizontal metal strips in figure 8a vary in width proportional to the distance from the center of the structure and the vertical members are triangular in shape. This is necessary in order to make the structure logarithmically periodic. Figure 8b is a structure identical to that of figure 8a, except that all members are of uniform width.

The average input impedance of the structure in figure 8b was slightly lower than that in figure 8a,



(a) With Tapered Elements

(b) With Uniform Elements

Figure 8. Planar, Printed, Wire Like, Circular Tooth Structure

110 ohms for figure 8b as compared to 150 ohms for figure 8a. As an interesting comparison, the impedance of a similar basic circular tooth structure was about 150 ohms.

In general, the patterns for the two cases were very similar. In both cases, the patterns were essentially independent of frequency, with the structure having tapered elements being slightly less frequency sensitive. The beamwidths in both the above cases were slightly wider than the beamwidth of the corresponding basic circular tooth structure.

Nonplanar, Wire, Trapezoidal Tooth Structure

Since the circular tooth structures with only the outline of the teeth being made of metal performed almost as well as the basic circular tooth structure, this technique was used in constructing the trapezoidal tooth structures. In figures 9a and 9b are two typical types of wire, nonplanar, trapezoidal tooth structures. The only difference is that in figure 9a, the β angle has

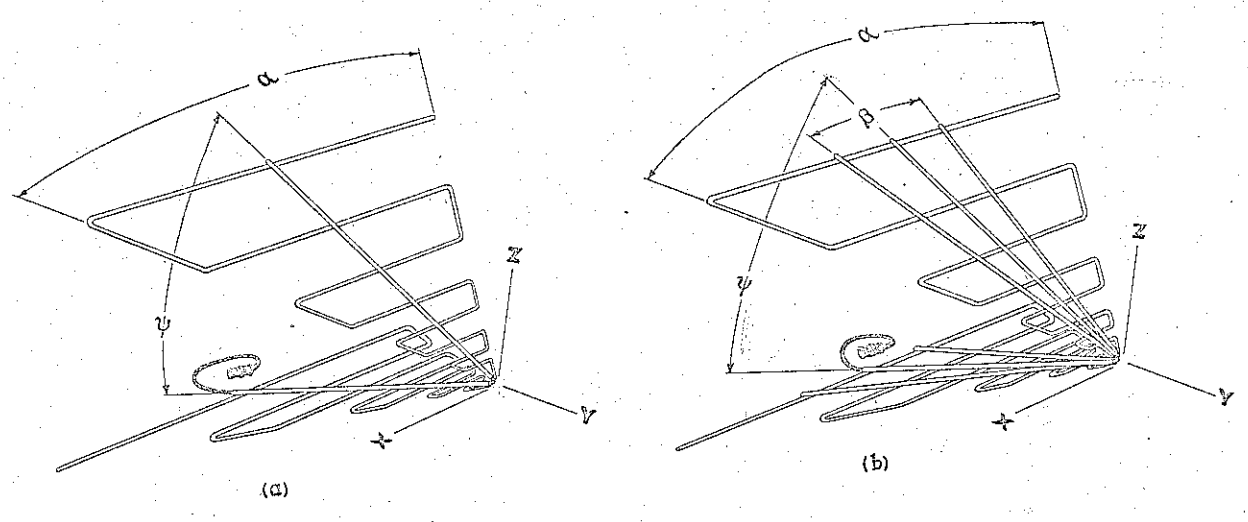


Figure 9. Types of Nonplanar, Wire, Trapezoidal Tooth Structures

been decreased to zero. Figure 10 is a photograph of a typical model used in the investigation of this type of structure. (In the photograph, the dielectric rod between the halves of the antenna was used for support only and is not part of the antenna.)

A considerable number of models of this type of structure with various values of the parameters α, ψ, and τ were constructed and tested. In general, the patterns of these structures were quite independent of frequency, especially those with the larger values of τ. Variations of the beamwidth of only several percent over a period of operation were common.

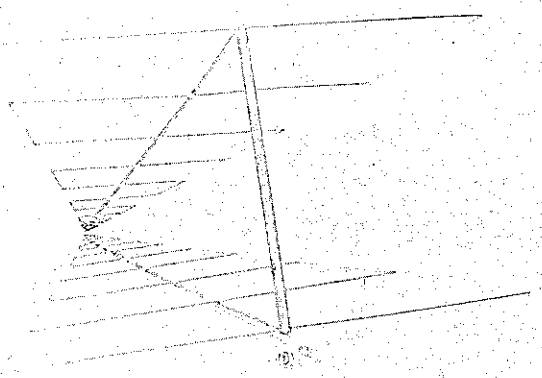


Figure 10. A Typical, Wire, Nonplanar, Trapezoidal Tooth Structure

Figure 11 shows the patterns over a half-period for the antenna shown in figure 10. This particular antenna had an average E-plane beamwidth of 67°, an average H-plane beamwidth of 106° and an average front-to-back ratio of 15 db.

Table 3 shows how the beamwidth, gain, and front-to-back ratio are functions of the parameters of the antenna for several structures. From the table, it can be seen that both E-plane and H-plane beamwidths decrease as the design ratio of τ is increased. For example, take $\psi = 45°$, $\alpha = 60°$; then as τ was varied from 0.4 to 0.707, the E-plane beamwidth decreased from 86° to 64°, and the H-plane beamwidth decreased from 112° to 79°. It can then be concluded that if high gain is required, a large design ratio is desirable. It was found that the spacing between two adjacent transverse elements should not be greater than 0.3 of the length of the longer element. Otherwise, the pattern starts breaking up. Also, from the table it can be seen that the H-plane beamwidth increased with a decrease in ψ angle for any one design ratio, while the E-plane pattern is essentially independent of the ψ angle. Also, the front-to-back ratio, in general, increased with a decrease in ψ angle. The α angle had a second-order effect on the beamwidth; with an increase in α, a decrease in E-plane beamwidth and an increase in H-plane beamwidth resulted.

In using the information in table 3 to design an antenna with relatively high gain, high front-to-back ratio, not too great complexity (the number of elements increases as the design ratio increases), one must make a compromise as to what parameters to choose. For example, antenna number 14 has $\alpha = 60°$, $\beta = 0$, $\psi = 45°$, and $\tau = 0.6$. The gain is 6.5 db over a dipole and the front-to-back ratio is 15.8 db.

These pattern characteristics compare very favorably with those of a three-element Yagi antenna. Admittedly, this type of structure is somewhat more complex to construct than a Yagi, insofar as the number of elements required is greater, and it is necessary to use either a tapered coax line or a balanced open wire transmission line transformer in order to match the impedance of the structure to conventional transmission lines. It has, however, the added advantage of having

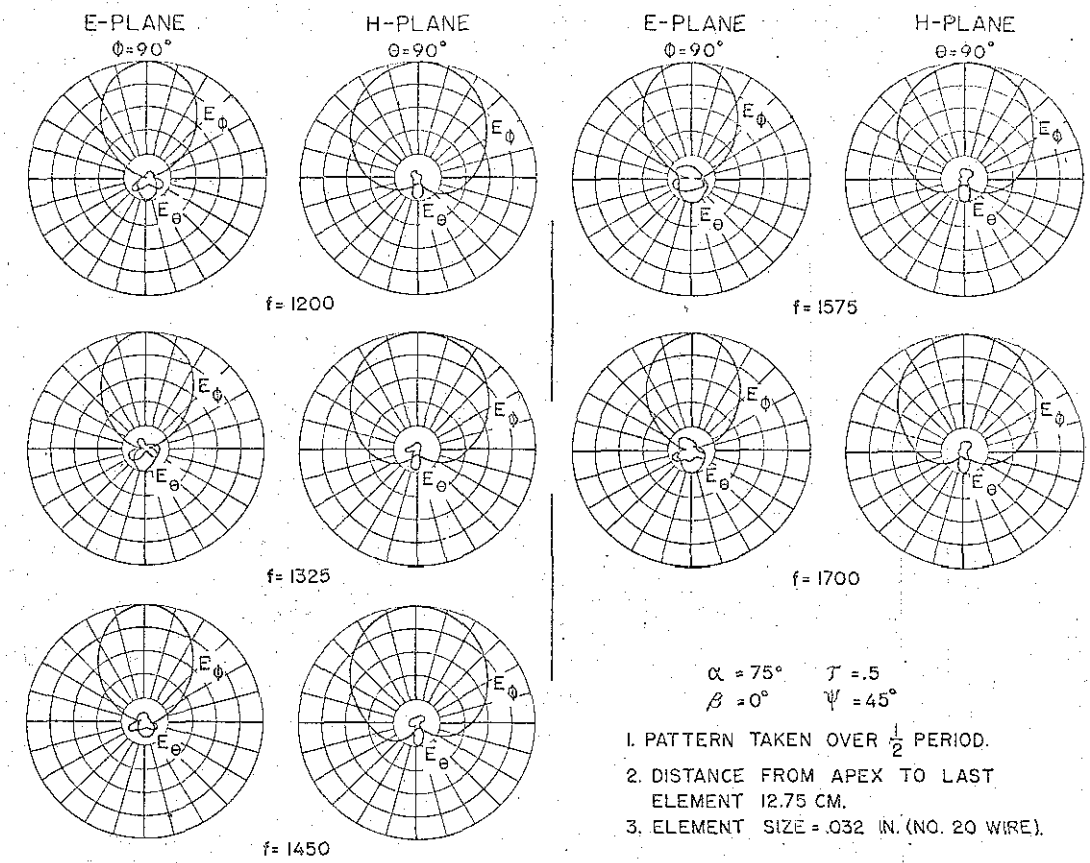


Figure 11. Patterns for a Typical Wire, Nonplanar, Trapezoidal Tooth Structure

TABLE 3. PATTERN CHARACTERISTICS FOR VARIOUS WIRE, TRAPEZOIDAL TOOTH STRUCTURES

ANT	PARAMETERS α	γ	ψ	AVE. HALF POWER BEAM WIDTHS IN DB E PLANE	H PLANE	APPROX. GAIN/DIPOLE IN DB	MAX. SIDE LOBE LEVELS IN DB
1	75	.4	30	74	155	3.5	12.4
2	75	.4	45	72	125	4.5	11.4
3	75	.4	60	73	103	5.3	8.6
4	60	.4	30	85	153	3.0	12.0
5	60	.4	45	86	112	4.2	8.6
6	60	.4	60	87	87	5.3	7.0
8	75	.5	30	66	126	4.9	17.0
9	75	.5	45	67	106	5.6	14.9
10	75	.5	60	68	93	6.1	12.75
11	60	.5	30	70	118	4.9	17.7
12	60	.5	45	71	95	5.8	14.0
13	60	.5	60	71	77	6.7	9.9
14	60	.6	45	67	85	6.5	15.8
15	60	.707	45	64	79	7.0	15.8
16	45	.707	45	66	66	7.7	12.3

essentially frequency independent impedance and pattern characteristics over a ten to one or more bandwidth.

The patterns of a larger antenna model, with the above design parameters (see figure 12) were measured over a ten to one frequency range (100 to 1000 mc). A slight increase in the beamwidths and a slight decrease in the front-to-back ratio was observed at about 300 mc. This effect was investigated by taking patterns of the structure and removing the elements one by one. It was found that the elements whose lengths were about 1.5 λ were responsible for these pattern changes. Thus, some end effect was noticeable for this structure at a frequency approximately three times the low frequency limit of the antenna.

TABLE 4. VARIATION OF AVERAGE IMPEDANCE AND VSWR WITH ψ ANGLE FOR A TYPICAL, WIRE, TRAPEZOIDAL TOOTH STRUCTURE

ψ Angle	Z_o	VSWR (Referred to Z_o)
60	120	1.4
45	110	1.45
30	105	1.5
7	65	1.8

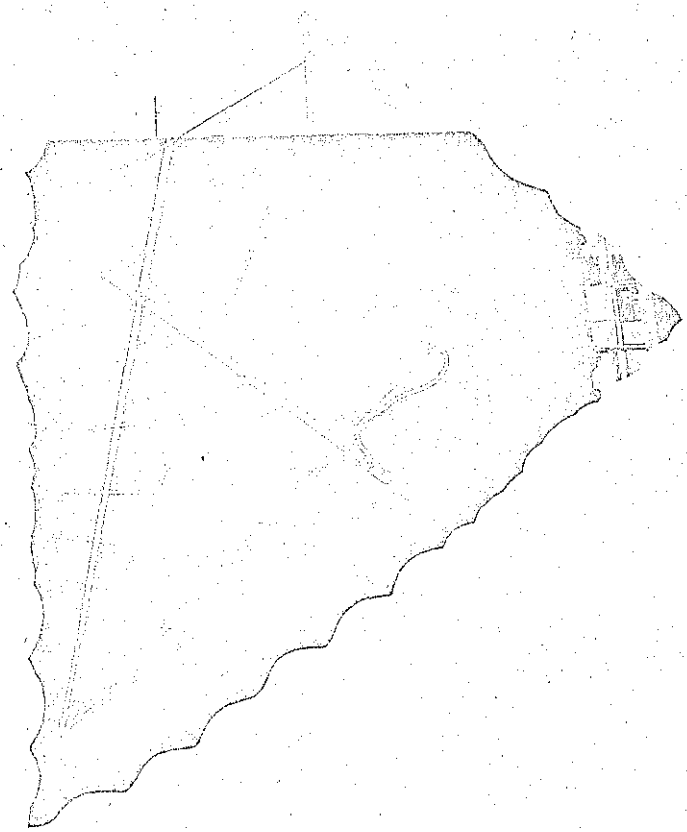


Figure 12. A Larger Model of a (Low Frequency Limit of About 100 Mc) Wire, Nonplanar, Trapezoidal Tooth Structure

Table 4 shows how the impedance varies with the ψ angle for a typical wire, trapezoidal tooth structure.

The impedance of the wire, trapezoidal tooth structure (shown in figure 10) having the following parameters: $\alpha = 75°$, $\beta = 0$, $\tau = 0.5$, $\psi = 45°$, and $R_1 = 12.75$ inches, was measured over a sixteen to one frequency band (250 to 4000 mc). The impedance was good from 350 mc to 4000 mc or an eleven to one frequency band. This closely agrees with the previous definition of the low frequency limit since the width of the structure at the last element was 19.5 inches or a half wavelength at 304 mc. The actual measurements showed that the input impedance Z_o decreased slowly and uniformly from about 150 ohms at 350 mc to about 75 ohms at the high end of the range of measurements. This change in input impedance is due to the modeling technique rather than a fault of the antenna. The elements of this particular model were of constant diameter (# 14 wire) and as the frequency was increased, the length-to-diameter ratio of the elements which were responsible for the radiation decreased. As further proof that modeling was partially responsible for this Z_o change, the impedance of another larger model, figure 12, where the elements had been slightly tapered, was measured over a ten to one frequency range. Although the Z_o of this structure also decreased as the frequency increased, the change was somewhat smaller. Thus, in order to obtain good frequency independence over a 10:1 bandwidth, it is necessary to model the structure accurately according to the design principles.

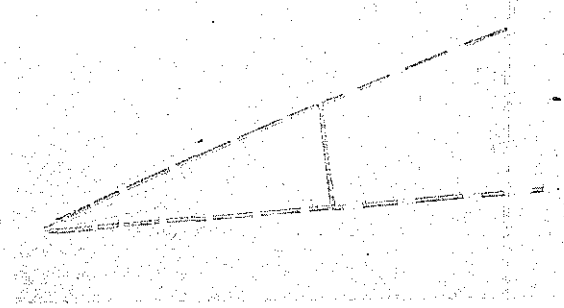


Figure 13. A Long (2 λ at 1000 Mc) Nonplanar, Wire, Trapezoidal Tooth Structure

From the observed trends indicated in table 3, an antenna with relatively high gain was designed. The model was constructed as shown in figure 13. The parameters for this particular model were $\alpha = 14.5°$, $\beta = 0$, $\tau = 0.85$, $\psi = 29°$ and $R_1 = 60$ cm. In order to make the vertical spacing between horizontal elements of the same length of the two half-structures about twice the length of the particular elements, ψ was set equal to 29°. R_1 was chosen equal to 60 cm in order to make the last element one half-wavelength long at 1000 mc. The patterns for this structure are shown in figure 14. The average E-plane beamwidth was 59°; the average H-plane beamwidth was 38°; and the front-to-back ratio was about 18 db. The resulting gain of this antenna then was slightly better than 10 db over a dipole, and the patterns were extremely frequency

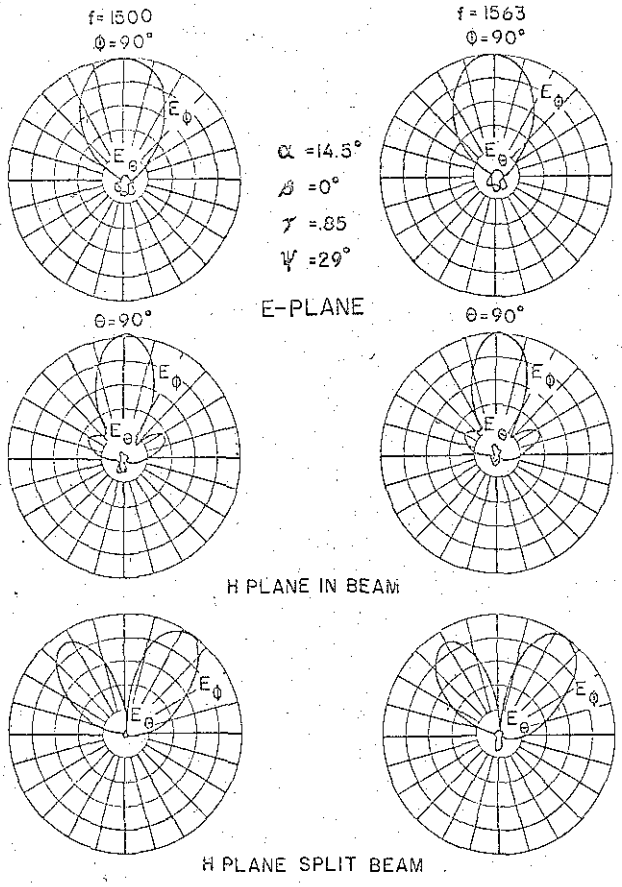


Figure 14. Patterns for a Long (2 λ at 1000 Mc) Nonplanar, Wire, Trapezoidal Tooth Structure

independent. The H-plane split beam patterns of figure 14 were the result of turning one of the half-structures over 180°, i. e., one half-structure is then the mere image of the other. The same effect could be had by placing one of the half-structures over a ground plane at an angle 1/2 ψ to the ground plane. It can be seen that the ground plane would divide the structure symmetrically. The double lobes appear at about $\pm$ 35° from this plane of symmetry.

On the shorter structures, where the spacing between the half-structure and the ground plane was small, that is, much less than a half-wavelength, the effect of the ground plane caused the impedance to rotate around the center of a Smith chart in a periodic manner, but at a VSWR of five to eight, which is very undesirable. However, this long structure had impedance characteristics very similar to a structure in free space, with the Z_o being only one-half the Z_o of an antenna in free space. The actual Z_o was 80 ohms with a VSWR of 1.1:1 over a period.

Wire Triangular Tooth Structures

Another step toward simplifying the construction of these logarithmically periodic structures was the triangular tooth or "Zig-Zag" structure illustrated in

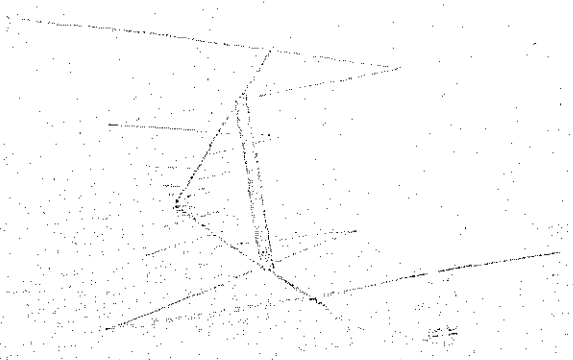


Figure 15. A Typical Wire, Nonplanar, Triangular Tooth Structure

figure 15. It has the same parameters as the trapezoidal tooth structure of figure 10. Figure 16 shows typical patterns for this triangular tooth structure. In general, the pattern characteristics are a slight improvement over those of the trapezoidal tooth structure. The average E-plane beamwidth was 70° as compared to 67°; the average H-plane beamwidth was 89° as compared to 106°; and the front-to-back ratio was 14.4 db as compared to 14.9 db for the trapezoidal tooth structure. The impedance for the triangular tooth structure was slightly lower (100 ohms with a VSWR of 1.5 over the frequency range compared) than that of the trapezoidal tooth structure.

Another model of the triangular tooth structure was constructed similar to antenna 14 in table 3 (α = 45°, β = 0, τ = 0.707 and ψ = 45°). As before, the H-plane beamwidth was slightly narrower, the E-plane beamwidth was about the same, and the front-to-back ratio was slightly greater than that of the similar trapezoidal tooth structure.

Phase Rotation Principle

The phase rotation phenomenon is a basic characteristic of these logarithmically periodic structures and has been verified experimentally. It can best be explained in the following manner: if one of these structures is fed, and if the phase of the electric field received at a distant dipole (see figure 2) is measured relative to the phase of current at the feed point of the structure, the phase of the received signal will advance 360° as the structure is shrunk through a period. Or,

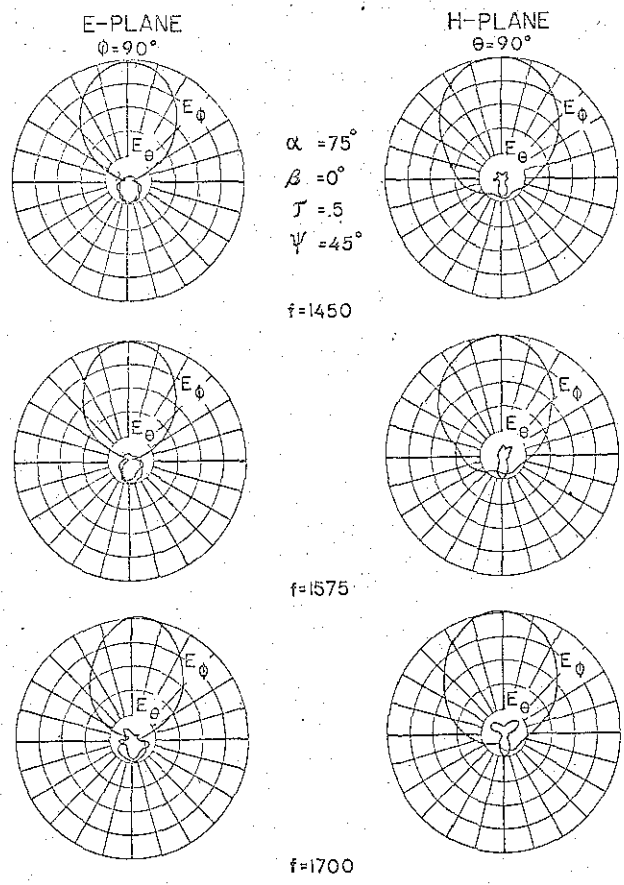


Figure 16. Patterns for Nonplanar, Wire, Triangular Tooth Structure

in other words, if the frequency of the exciting signal is increased by a period, and the phase is measured at the dipole while keeping the dipole at a constant electrical distance from the periodic structure, the phase will be delayed 360°, relative to the phase of the feed current. This characteristic is analagous to the pattern rotation principle[2] of angular structures.

This phenomenon is the factor which makes it possible to achieve the omnidirectional and circularly polarized logarithmically periodic structures discussed in the following sections.

Omnidirectional Structures

Often it is desirable to have a wide band antenna that gives omnidirectional patterns. The most common antenna to date that tends to meet such a requirement is the vertically polarized discone or biconical antenna. However, pattern breakup limits the bandwidth of these antennas to 2 or 3 to 1. The desirability of designing a logarithmically periodic structure with omnidirectional characteristics is readily apparent.

Since two dipoles arranged in a turnstile and fed ninety degrees out of phase give omnidirectional patterns, it was decided to arrange two planar, sheet metal structures (which have approximate dipole patterns) in a turnstile as shown in figure 17a. Since the planar sheets were actually soldered together where they crossed, it is obvious that the two sheet structures could not be identical or the same result would occur as when feeding two crossed dipoles in phase (a bidirectional pattern with maximum lobes occurring at an angle of 45°). Therefore, one of the structures was made $\tau^{1/N}$ times the size of the other (where N is the number of arms of the structure) in order to obtain the 90° phasing.

An easy way to visualize such a structure is to imagine two cones placed apex to apex on a common

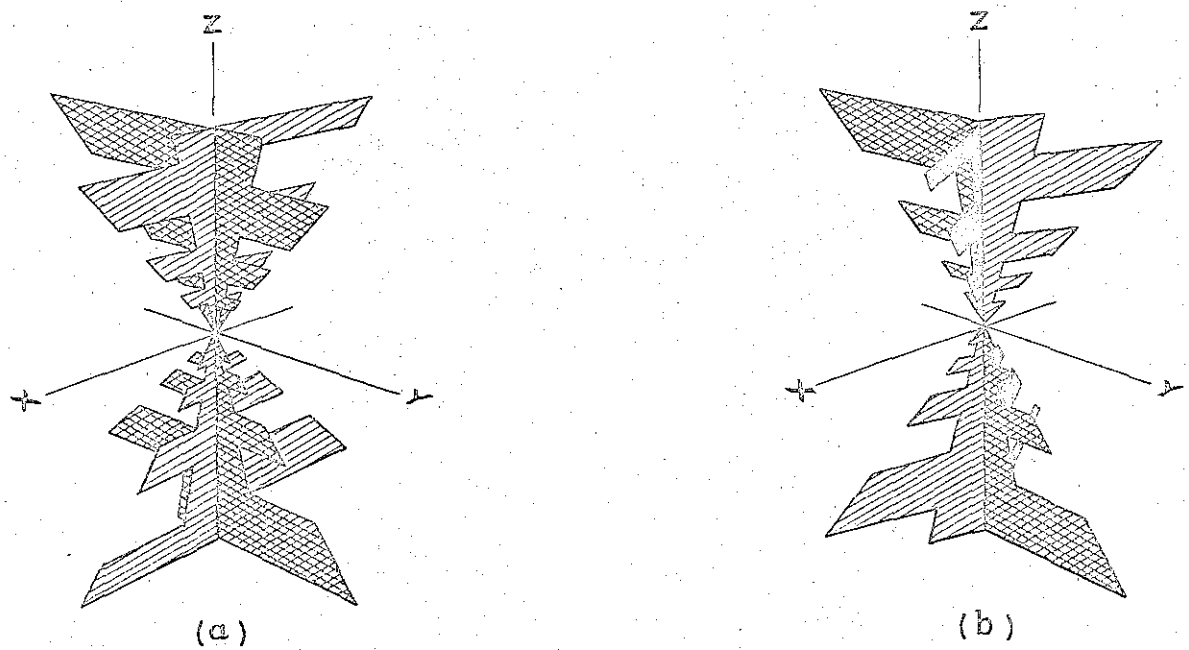


Figure 17. Types of Omnidirectional Structures

axis. Starting at the apex of each cone, an equiangular spiral is placed on the slant side of the cone with the axis of the spiral coinciding with the axis of the cone. The spiral on one cone is made to rotate clockwise; the spiral on the other cone is made to rotate counterclockwise as the two cones are viewed simultaneously from the point where their respective apexes meet. Actually, these spirals are the openings of grooves which become progressively wider and deeper as they spiral away from the apexes of the cones. The outlines of four arms of a four-arm structure would be the lines of intersection of the cones and two planes perpendicular to each other and intersecting on the axis of the cones. When the cone concept is used, it is possible to visualize a number of different structures. Figure 17b is an example of a structure with three arms.

Figure 18 is a photograph of a circular tooth structure constructed as stated above. The design ratio τ of this particular structure is 0.7. Of the various structures constructed and tested, it was found that the structure with a design ratio of 0.5 had the best pattern characteristics. Typical patterns of this structure are shown in figure 19. The $\theta = 90°$, ϕ variable patterns are omnidirectional within ±1.5 db over the frequency range of one period; the $\phi = 90°$, θ variable patterns are bidirectional and have an average beamwidth of about 65°. The characteristic impedance was 100 ohms with a normalized VSWR of 1.2 to 1.

Figure 18. A Typical, Four Armed, Sheet, Circular Tooth, Omnidirectional Structure

A limited investigation of the effect of varying the α angle while holding β fixed at 45° for a structure having a design ratio of 0.7 (figure 18) was made. As α was reduced from 135° to 115°, the E-plane patterns were unchanged while the H-plane beamwidth increased slightly from 68° to 75°. When α was reduced to 95°, the E-plane pattern was omnidirectional within ±3 db, and the H-plane pattern beamwidths were about 90°. The impedance did not change appreciably as α was reduced.

The trapezoidal tooth structure shown in figure 17a ($\alpha = 90°$, $\beta = 30°$, $\tau = 0.5$) did not have as uniform

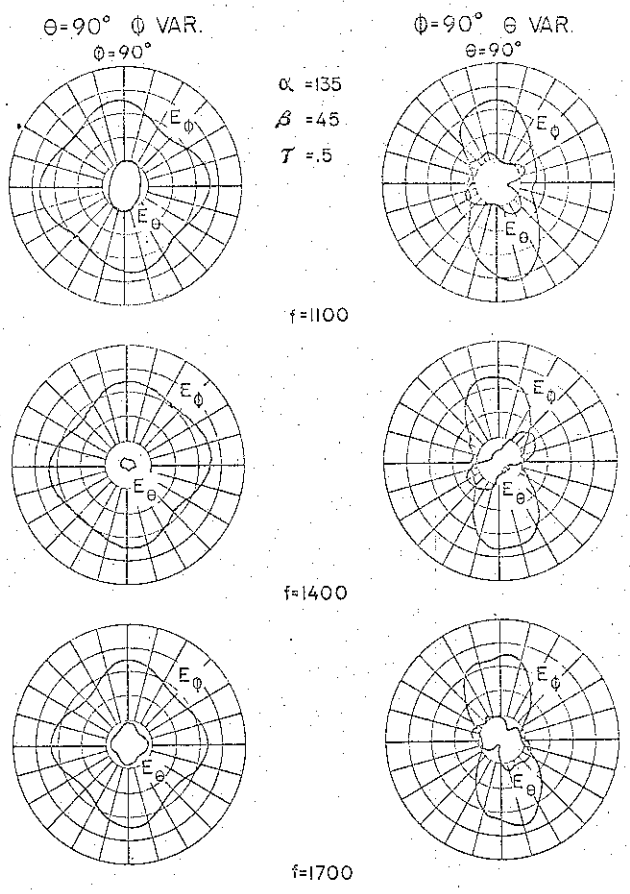


Figure 19. Patterns for Omnidirectional Curved Tooth Structure

or as frequency independent omnidirectional characteristics as did the similar circular tooth structure. As a comparison, the trapezoidal tooth structure was omnidirectional within ±2.1 db as compared to ±1.5 db for the circular tooth structure; and the H-plane, bidirectional patterns were on an average 55° as compared to 65°. The impedance was 140 ohms and 100 ohms for the trapezoidal and circular tooth structures, respectively. Both had a normalized VSWR of 1.2 to 1.

The only other type of sheet metal omnidirectional structure tested was a three-armed circular tooth structure (see figure 17b for a similar trapezoidal tooth structure). The structure was omnidirectional within ±3 db and the patterns were more frequency dependent than the structure having four arms. It appears that the more arms a structure has (within reason), the more omnidirectional it will be.

One wire, trapezoidal tooth, omnidirectional structure was constructed and tested (see figure 20). The E-plane patterns varied somewhat in their omnidirectional characteristics with frequency, but on an average, they were omnidirectional within ±2.1 db; the H-plane patterns were bidirectional with an average beamwidth of 60°. The input impedance was 135 ohms with a normalized VSWR of 1.3 to 1. In view of the relative simplicity, this structure could be used as an hf antenna. The wire structure could be easily strung up between four wooden poles.

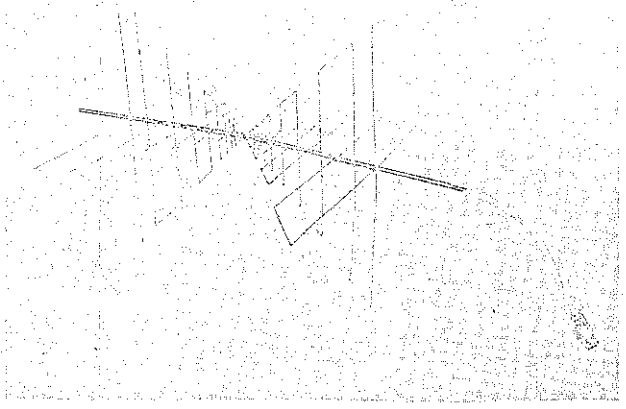


Figure 20. A Typical Four Armed, Wire, Trapezoidal Tooth, Omnidirectional Structure

Unfortunately, it is not possible to use one-half of any of the above structures over a ground plane (and fed against the ground plane) without having large variations of pattern and impedance over a period of frequency.

Circularly Polarized Antennas

A limited investigation of circularly polarized, unidirectional logarithmically periodic broadband structures was performed. The most successful of the various techniques tried was that of taking the planar structure shown in figure 21 and placing the quarter-structures, one on each slant side of a pyramid. The angle between opposite slant sides of the pyramid is the ψ angle of the structure.

As can be observed from the figure, one structure is $\tau^{1/4}$ the size of the other. A very well-defined circularly polarized beam (at $\phi = 90°$, $\theta = 90°$) is obtained. The enlarged view of the feed point shows that, in general, two adjacent quarter-structures are fed against the remaining two quarter-structures; two and three are being fed against four and one. The sense of the circular polarization can be reversed by simply switching the feed point, or by feeding three and four against one and two.

Four experimental patterns over approximately a half-period are shown in figure 22. As can be seen, the axial ratio r as measured on the beam axis varied from 1.05 to 2 over this range. Since the patterns for the linearly polarized components (E_θ and E_ϕ) are very similar, it is expected that good circular polarization is obtained over most of the beam.

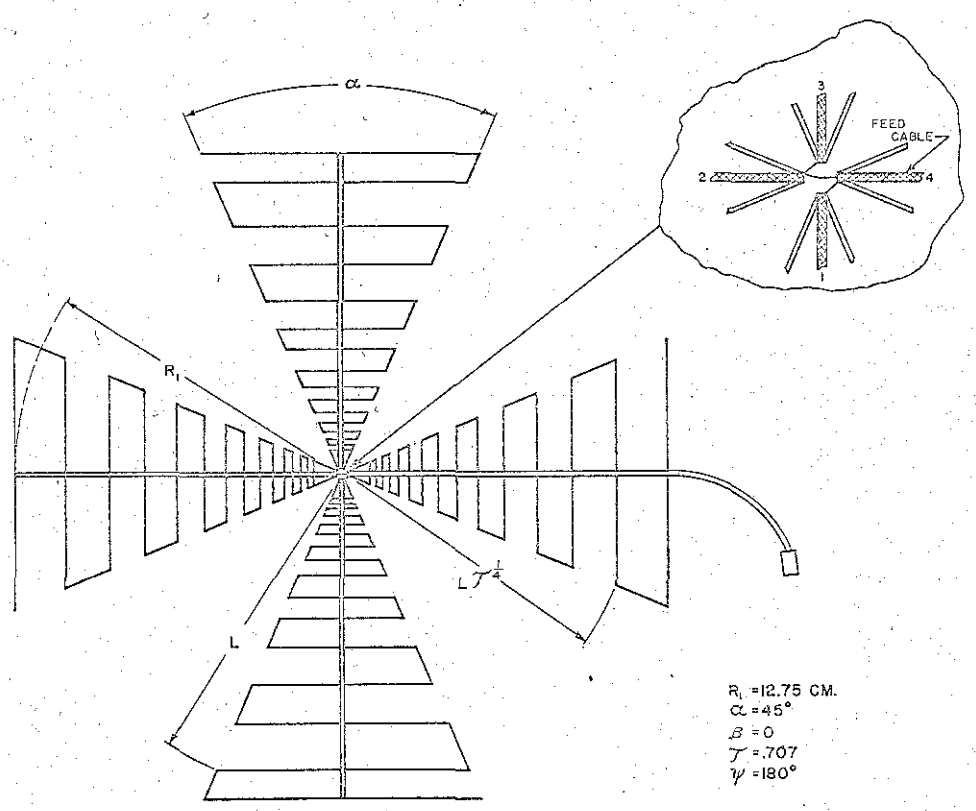


Figure 21. Wire, Trapezoidal Tooth, Circular Polarized Structure

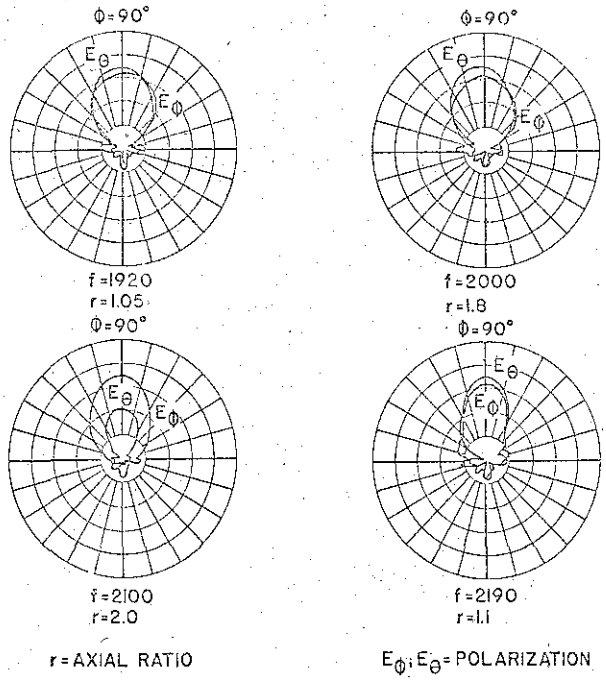


Figure 22. XY Plane Patterns of Circular Polarized Pyramidal Structure

Current Distribution Measurements

An attempt was made to measure the magnitude and phase of the currents flowing on the elements of a typical nonplanar, wire, trapezoidal tooth structure. The current distribution was very complex and the results were not too conclusive. However, it was observed that, as the magnitude of the currents was measured from the vertex out toward the longer transverse elements, a point of maximum current magnitude was reached. From this point, the magnitude of the current decreased to more than 30 db below its value at the maximum point. The transverse elements at this low current point were much longer than a half wavelength of the operating frequency. This tends to demonstrate that end effects are negligible on these structures, which must be the case for wide band operation. As would be expected, the point of maximum current magnitude shifted toward the vertex of the structure as the frequency was increased.

Conclusions

Many types of logarithmically periodic antenna structures have been built and tested. Most of those which gave essentially frequency independent operation have been reported here but there were many structures for which the pattern and/or impedance were quite frequency sensitive. Unfortunately, no theory has been established which even predicts the types of structures which will give frequency independent operation. The equicomplementary condition (for planar structures) is sufficient to insure frequency independent impedance but not patterns. All of the planar structures (even those that don't work) may be considered as cross sections of frequency independent three-dimensional angular structures so that this approach leads nowhere. Thus, it is felt that a theoretical investigation of this class of antennas would be most fruitful.

Nevertheless, a small amount of effort has led to the discovery of structures which give a wide variety of essentially frequency independent radiation characteristics over practically unlimited bandwidths. One of many possible applications is for flush-mounted microwave antennas. Here, unidirectional structures can be placed in cavities with the cavity having little influence on the electrical characteristics because of the unidirectional pattern.

Acknowledgment

Special thanks are due Dr. R. L. McCreary for his support and tolerance and to Forrest G. Arnold who constructed and tested many of the models.

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United States District Court
Northern District of Illinois
Eastern Division

THE FINNEY COMPANY
v.
JFD ELECTRONICS CORPORATION and THE UNIVERSITY OF ILLINOIS FOUNDATION

CIVIL ACTION
NO. 65 C 220
and
NO. 65 C 671
(Consolidated)

Plaintiff's Exhibit No. 12

May 1 1/7/67

RESEARCH PROJECT REPORT

ENGINEERING EXPERIMENT STATION · UNIVERSITY OF ILLINOIS

5336

Department of: Electrical Engineering Date: June 12, 1959

Title of Investigation: Research and Investigation on Antennas for High Speed Aircraft

Departmental Contract No.: 46-22-25-314 Sponsor's Contract No.: AF 33(616)-6079

Name, Division, Code No. of Sponsor's Technical Contract Monitor:
Wright Air Development Center
Air Research and Development Command
Attn: WCACE

Investigator in Charge: Georges Deschamps Annual Budget (Approx.): $100,000

Other Investigators:
P.E. Mayes, W. L. Weeks, J.D. Dyson
P.E. Mast, R. Mittra, Y.T. Lo
D.E. Isbell, C.R. Allen, R.H. MacPhie, C.H. Tang, K. G. Balmain

Est. Full Time Equiv. Persons Employed (including shop, student help, etc.): 11

Number graduate thesis investigations supported by this project: Ph.D. 3 M.S. 3

Summary of (a) objectives, (b) methods used, (c) achievements during year, and (d) present status.
Statement should be brief and suitable for publication.

The general objective of this research is to advance the knowledge of electromagnetic phenomena associated with controlled radiation which is used in a wide variety of communication systems. The products of this effort provide engineers with information useful in the design of antennas for many applications.

Achievements of immense practical import have been realized in obtaining antennas which operate satisfactorily over a much wider range of frequencies than heretofore possible. In the past year investigations in this area have produced two significant new designs: the conical equiangular spiral, which has a broad circularly polarized beam, and the logarithmically periodic dipole array which has a broad linearly polarized beam. These antennas were developed in experimental research and efforts toward their analysis are continuing.

Two projects completed during the past year have provided evaluations of the effect upon the radiation pattern of dielectric in the near field of an antenna. In one instance the dielectric was a coating on a spheroid; in the other case, a thin sheet of finite extent.

Other areas of investigation include the following: coupled waveguide radiators, zoned microwave reflectors, waveguide junctions, antennas with low noise output, antennas with integral distributed detecting action.

Publications published and theses completed during year (give full information — date, volume, page, etc.).
Use back of sheet if necessary. List separately technical and progress reports to sponsors.

P.E. Mayes, D.E. Isbell, R.L. Carrel "Antennas with Periodic and Pseudo Frequency Independent Performance," 1958 National Telemetering Conference, p. 279; June 2-4, 1958. Published by the Institute of Aeronautical Sciences. (This work was partially supported by Boeing Aircraft Co. under another contract.

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Signed

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