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

THE FINNEY COMPANY, a partnership, Plaintiff, v. 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)

LEWIS H. FINNEBURGH, JR., being duly sworn, deposes and says that:

1. He is president of The Finney Company, Bedford, Ohio, and was the founding partner of its predecessor of the same name, a partnership founded in 1950, both companies having at all times been primarily engaged in the manufacture of radio and television antennas;

2. He developed and patented the antennas constituting the sole products of The Finney Company at its inception in 1950, and developed or participated in the development of most of its antenna products since that time;

PX-G

3. For about 10 years prior to 1950, except for a period of about four years during World War II, he was Chief Engineer of Ward Products Corporation, a manufacturer of antennas, and for the Ward Products Division of Gabriel Corporation after acquisition of the former by the latter about 1949;

4. During about four years of the period of World War II, he was the Chief Electronics Engineer of Winters & Crampton which, during that period, was heavily engaged in the manufacture for the war effort of antennas, oscillators, frequency multipliers, radio frequency power amplifiers, and variable air capacitors;

5. After completing his academic training about 1936, and up to the time he entered the employ of Ward Products Corporation about 1939, he was engaged in electronic and electrical development and research for Clark Controller Company, a manufacturer of electronic and electrical control equipment;

6. His academic training was both in the fields of mechanical engineering and electrical engineering, and he received bachelors degrees in both and a masters degree in electrical engineering from Massachusetts Institute of Technology; and

7. For over thirty years, his work has been entirely in the field of electrical and electronic equipment sales and development engineering and manufacturing, with the great bulk of that work for at least twenty-three of those years being in the field of radio and television antennas. Fifteen patents on antennas have been granted in his name as a sole or a joint inventor.

The following facts believed by him to be of interest and, possibly, helpful to the Court in connection with the above-entitled suit are known to him as a result of his training and experience in the electrical and electronics industry and, particularly, in the radio and television antenna industry:

8. For many years, and particularly since the advent of commercial television, much development work has been done in an effort to provide radio frequency antennas for a variety of radio and television purposes that are capable of operating effectively over more than a limited range of frequencies. Such antennas have been commonly referred to as "broad band antennas," the term being loosely used and commonly applied where the band of frequencies to be covered by a single antenna involved maximum to minimum frequencies ratios up to about two-to-one.

9. Particularly since the advent of commercial television, a great deal of work has also been done to provide antennas that would be effective over each of two or more moderate frequency ranges which are separated in the frequency spectrum by intermediate frequencies over which reception is not desired. An example would be an antenna designed to operate over the low VHF television band (54-88 megacycles -- generally abbreviated mc) of Channels 2 to 6 and the high VHF television band (174 to 216 mc) of Channels 7 to 13.

10. At least since shortly after the advent of commercial television and long prior to 1959, antennas comprising one or more V-dipoles have been extensively used to cover a plurality of spaced frequency bands such as the low VHF and high VHF television bands. For such purposes, the V-dipoles were dimensioned to be approximately a half wavelength long from tip to tip, measured along the arms of the V-shaped dipoles, for a frequency near the middle of the low VHF frequency range. When so dimensioned, the same V-shaped dipoles were approximately 3/2 wavelengths long at a frequency near the middle of the high VHF frequency range. In the low VHF frequency range, such V-dipoles operated approximately the same as simple, straight dipoles, so as to effectively receive over that range, although with diminishing effectiveness above and below the frequency for which the dipoles were approximately one-half wavelength long. Such operation was commonly termed "operation in the one-half wavelength mode." In the high VHF frequency range, the same V-dipoles, by virtue of their V-shaped configurations, operated effectively over that range with diminishing effectiveness above and below the frequency at which the V-dipoles were approximately 3/2 wavelengths long. Such operation in the high VHF range was commonly termed "operation in the 3/2 wavelengths mode." Such V-dipoles were well known to operate similarly over still higher frequency ranges at which the V-dipoles were approximately 5/2, 7/2, 9/2, etc. wavelengths long, and such operation at higher frequencies was commonly termed operation in the 5/2 wavelengths mode, 7/2

wavelengths mode, 9/2 wavelengths mode," etc.

11. For various communication purposes and other specialized radio frequency operations, it became important to provide antennas whose operation would be essentially uniform over very broad frequency bands involving frequency ratios far in excess of two-to-one. The principal characteristics of an antenna having uniform response over any given frequency range were uniform "radiation patterns" and uniform "impedance" or "input impedance" over that range. Antennas having such uniform characteristics were generally referred to as being "frequency independent" over that range, and the problem of designing frequency independent antennas increased in difficulty and complexity as the frequency range to be covered for various purposes increased.

12. Frequency independent operation of antennas 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.

13. The type of frequency independent antennas to which the three patents in suit relate involves certainly 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." Isbell U. S. patent No. 3,210,767, and Mayes et al. patent No. Re. 25,740 involved in the above-entitled suit are directed to log periodic antennas which are essentially "unidirectional," i.e., when used as transmitting antennas, they transmit energy as a narrow, 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.

14. The above-mentioned Isbell patent makes use of a series of simple, straight dipoles 10, 11, 12, etc. of progressively diminishing lengths L_1, L_2, L_3, etc., with dipoles spacings that similarly diminish in the same direction. The dipole lengths and spacings are related by a constant scale factor or multiplier stated

in both patents to be "less than 1". Thus, the length of each successive smaller dipole is equal to the length of the adjacent larger one multiplied by the decimal fraction constituting the common scale factor, and each successive smaller space between dipoles is equal to the adjacent larger space multiplied by the same decimal fraction.

15. The above-mentioned Mayes et al. reissue patent is directed to antennas differing from the antennas of the Isbell patent only by substituting V-dipoles for the simple, straight dipoles of the antennas of the Isbell patent, for the purpose of rendering the antenna effective over higher frequency ranges than the one-half wavelengths mode, such as the 3/2 wavelengths mode, 5/2 wavelengths mode, 7/2 wavelengths mode, 9/2 wavelengths mode, etc. Whenever V-dipoles were used prior to 1959 as described in paragraph 10 above, herein, the included angle between the diverging arms or elements of each V-dipole was customarily determined by the particular mode of operation desired according to data that had long been available in standard handbooks for radio engineers, one of these handbooks being "Radio Engineers' Handbook" by Frederick Emmons Terman, 1943 (stipulation, PX-C), pp. 806-807 and the graph referred to therein and appearing at p. 788).

16. Referring particularly to page 807 of the Terman handbook cited in the preceding paragraph, the mode of operation of a V-dipole on higher modes than the half wavelength mode is

described so as to explain the need for selecting the proper V-angle according to the higher mode of operation desired. How to calculate the V-angle for a particular mode of operation is disclosed with reference to Fig. 19 of the handbook, appearing at p. 788 in the form of a graph of angles relative to the lengths of the dipole arms in terms of wavelengths (which lengths determine which of the higher modes of operation is to be used). Following the instructions so given by Terman and using the graph in Fig. 19 as directed, one would arrive at an included angle between the arms of a V-dipole of approximately 120° for 3/2 wavelengths mode operation and approximately 70° for 9/2 wavelengths mode operation. As explained in footnote 2 on p. 807, other practical considerations require some reduction of the included angle in practice, so that the calculated values of 120° and 70°, above, would be reduced and closely approximate the corresponding figures of 114° and 62° given in the Mayes et al. reissue patent, col. 3, lines 24-27. Thus, as early as 1943, any competent antenna engineer considering the use of a V-dipole for operation above the half wave mode would have understood that the included angle between the arms of the V-dipole would be determined by the desired higher mode of operation and would range from an angle of close to 114° for 3/2 wavelengths mode operation to an angle close to 62° for 9/2 wavelengths mode operation

17. The radiation patterns of antennas of the type to which the above-mentioned Isbell and Mayes et al. patents are directed are essentially "unidirectional" to the left ("forward

direction") as viewed in Fig. 1 of both of those patents, typical radiation patterns for the antennas of the Isbell patent, for example, being shown in Fig. 3 and Fig. 4 thereof. The scale of those patterns shown in Fig. 3 and Fig. 4 of the Isbell patent is such that only the radiation in a generally forward direction is shown. To some degree, one or more much smaller radiation lobes in another direction or in several other directions would appear in Fig. 3 and Fig. 4 if drawn to a larger scale or, for example, if drawn on a variable scale commonly called a "logarithmic scale." This is indicated by the reference at col. 2, lines 49-50 of the Isbell patent by the reference to a "front-to-back ratio" of "17db," which is an expression used to indicate the relative intensity of radiation in the forward direction compared to the backward direction.

Further affiant saith not.

____
Lewis H. Finneburgh, Jr.

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

____
Notary Public

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

THE FINNEY COMPANY, a partnership, Plaintiff, v. 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)

LEWIS H. FINNEBURGH, JR., being duly sworn, deposes and says that:

1. He is president of The Finney Company, Bedford, Ohio, and was the founding partner of its predecessor of the same name, a partnership founded in 1950, both companies having at all times been primarily engaged in the manufacture of radio and television antennas;

2. He developed and patented the antennas constituting the sole products of The Finney Company at its inception in 1950, and developed or participated in the development of most of its antenna products since that time;

3. For about 10 years prior to 1950, except for a period of about four years during World War II, he was Chief Engineer of Ward Products Corporation, a manufacturer of antennas, and for the Ward Products Division of Gabriel Corporation after acquisition of the former by the latter about 1949;

4. During about four years of the period of World War II, he was the Chief Electronics Engineer of Winters & Crampton which, during that period, was heavily engaged in the manufacture for the war effort of antennas, oscillators, frequency multipliers, radio frequency power amplifiers, and variable air capacitors;

5. After completing his academic training about 1936, and up to the time he entered the employ of Ward Products Corporation about 1939, he was engaged in electronic and electrical development and research for Clark Controller Company, a manufacturer of electronic and electrical control equipment;

6. His academic training was both in the fields of mechanical engineering and electrical engineering, and he received bachelors degrees in both and a masters degree in electrical engineering from Massachusetts Institute of Technology; and

7. For over thirty years, his work has been entirely in the field of electrical and electronic equipment sales and development engineering and manufacturing, with the great bulk of that work for at least twenty-three of those years being in the field of radio and television antennas. Fifteen patents on antennas have been granted in his name as a sole or a joint inventor.

The following facts believed by him to be of interest and, possibly, helpful to the Court in connection with the above-entitled suit are known to him as a result of his training and experience in the electrical and electronics industry and, particularly, in the radio and television antenna industry:

8. For many years, and particularly since the advent of commercial television, much development work has been done in an effort to provide radio frequency antennas for a variety of radio and television purposes that are capable of operating effectively over more than a limited range of frequencies. Such antennas have been commonly referred to as "broad band antennas," the term being loosely used and commonly applied where the band of frequencies to be covered by a single antenna involved maximum to minimum frequencies ratios up to about two-to-one.

9. Particularly since the advent of commercial television, a great deal of work has also been done to provide antennas that would be effective over each of two or more moderate frequency ranges which are separated in the frequency spectrum by intermediate frequencies over which reception is not desired. An example would be an antenna designed to operate over the low VHF television band (54-88 megacycles -- generally abbreviated mc) of Channels 2 to 6 and the high VHF television band (174 to 216 mc) of Channels 7 to 13.

10. At least since shortly after the advent of commercial television and long prior to 1959, antennas comprising one or more V-dipoles have been extensively used to cover a plurality of spaced frequency bands such as the low VHF and high VHF television bands. For such purposes, the V-dipoles were dimensioned to be approximately a half wavelength long from tip to tip, measured along the arms of the V-shaped dipoles, for a frequency near the middle of the low VHF frequency range. When so dimensioned, the same V-shaped dipoles were approximately 3/2 wavelengths long at a frequency near the middle of the high VHF frequency range. In the low VHF frequency range, such V-dipoles operated approximately the same as simple, straight dipoles, so as to effectively receive over that range, although with diminishing effectiveness above and below the frequency for which the dipoles were approximately one-half wavelength long. Such operation was commonly termed "operation in the one-half wavelength mode." In the high VHF frequency range, the same V-dipoles, by virtue of their V-shaped configurations, operated effectively over that range with diminishing effectiveness above and below the frequency at which the V-dipoles were approximately 3/2 wavelengths long. Such operation in the high VHF range was commonly termed "operation in the 3/2 wavelengths mode." Such V-dipoles were well known to operate similarly over still higher frequency ranges at which the V-dipoles were approximately 5/2, 7/2, 9/2, etc. wavelengths long, and such operation at higher frequencies was commonly termed operation in the 5/2 wavelengths mode, 7/2

wavelengths mode, 9/2 wavelengths mode," etc.

11. For various communication purposes and other specialized radio frequency operations, it became important to provide antennas whose operation would be essentially uniform over very broad frequency bands involving frequency ratios far in excess of two-to-one. The principal characteristics of an antenna having uniform response over any given frequency range were uniform "radiation patterns" and uniform "impedance" or "input impedance" over that range. Antennas having such uniform characteristics were generally referred to as being "frequency independent" over that range, and the problem of designing frequency independent antennas increased in difficulty and complexity as the frequency range to be covered for various purposes increased.

12. Frequency independent operation of antennas 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.

13. The type of frequency independent antennas to which the three patents in suit relate involves certainly 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." Isbell U. S. patent No. 3,210,767, and Mayes et al. patent No. Re. 25,740 involved in the above-entitled suit are directed to log periodic antennas which are essentially "unidirectional," i.e., when used as transmitting antennas, they transmit energy as a narrow, 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.

14. The above-mentioned Isbell patent makes use of a series of simple, straight dipoles 10, 11, 12, etc. of progressively diminishing lengths L_1, L_2, L_3, etc., with dipoles spacings that similarly diminish in the same direction. The dipole lengths and spacings are related by a constant scale factor or multiplier stated

in both patents to be "less than 1". Thus, the length of each successive smaller dipole is equal to the length of the adjacent larger one multiplied by the decimal fraction constituting the common scale factor, and each successive smaller space between dipoles is equal to the adjacent larger space multiplied by the same decimal fraction.

15. The above-mentioned Mayes et al. reissue patent is directed to antennas differing from the antennas of the Isbell patent only by substituting V-dipoles for the simple, straight dipoles of the antennas of the Isbell patent, for the purpose of rendering the antenna effective over higher frequency ranges than the one-half wavelengths mode, such as the 3/2 wavelengths mode, 5/2 wavelengths mode, 7/2 wavelengths mode, 9/2 wavelengths mode, etc. Whenever V-dipoles were used prior to 1959 as described in paragraph 10 above, herein, the included angle between the diverging arms or elements of each V-dipole was customarily determined by the particular mode of operation desired according to data that had long been available in standard handbooks for radio engineers, one of these handbooks being "Radio Engineers' Handbook" by Frederick Emmons Terman, 1943 (stipulation, PX-C), pp. 806-807 and the graph referred to therein and appearing at p. 788).

16. Referring particularly to page 807 of the Terman handbook cited in the preceding paragraph, the mode of operation of a V-dipole on higher modes than the half wavelength mode is

described so as to explain the need for selecting the proper V-angle according to the higher mode of operation desired. How to calculate the V-angle for a particular mode of operation is disclosed with reference to Fig. 19 of the handbook, appearing at p. 788 in the form of a graph of angles relative to the lengths of the dipole arms in terms of wavelengths (which lengths determine which of the higher modes of operation is to be used). Following the instructions so given by Terman and using the graph in Fig. 19 as directed, one would arrive at an included angle between the arms of a V-dipole of approximately 120° for 3/2 wavelengths mode operation and approximately 70° for 9/2 wavelengths mode operation. As explained in footnote 2 on p. 807, other practical considerations require some reduction of the included angle in practice, so that the calculated values of 120° and 70°, above, would be reduced and closely approximate the corresponding figures of 114° and 62° given in the Mayes et al. reissue patent, col. 3, lines 24-27. Thus, as early as 1943, any competent antenna engineer considering the use of a V-dipole for operation above the half wave mode would have understood that the included angle between the arms of the V-dipole would be determined by the desired higher mode of operation and would range from an angle of close to 114° for 3/2 wavelengths mode operation to an angle close to 62° for 9/2 wavelengths mode operation

17. The radiation patterns of antennas of the type to which the above-mentioned Isbell and Mayes et al. patents are directed are essentially "unidirectional" to the left ("forward

direction") as viewed in Fig. 1 of both of those patents, typical radiation patterns for the antennas of the Isbell patent, for example, being shown in Fig. 3 and Fig. 4 thereof. The scale of those patterns shown in Fig. 3 and Fig. 4 of the Isbell patent is such that only the radiation in a generally forward direction is shown. To some degree, one or more much smaller radiation lobes in another direction or in several other directions would appear in Fig. 3 and Fig. 4 if drawn to a larger scale or, for example, if drawn on a variable scale commonly called a "logarithmic scale." This is indicated by the reference at col. 2, lines 49-50 of the Isbell patent by the reference to a "front-to-back ratio" of "17db," which is an expression used to indicate the relative intensity of radiation in the forward direction compared to the backward direction.

Further affiant saith not.

____
Lewis H. Finneburgh, Jr.

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

____
Notary Public

AF 33(616)-6079

Distribution Total 132 T

5338

LOCAL LIST

	Technical	Progress
P. Mayes	9	9
Dr. E. C. Jordan, E. E. Bldg.	1	1
~~Dean Wendell Miller, 145 E. E. Bldg.~~	~~1~~	~~1~~
Engineering Library, 106 Civil Eng. Hall	2	2
Local Library, E.E.R.L.	1	1
C. H. Tang (box)	1	1
Raj Mittra, E.E. College box	1	1

PX-35

RADIO ENGINEERS' HANDBOOK

BY

FREDERICK EMMONS TERMAN, Sc.D.
Professor of Electrical Engineering and Executive Head, Electrical Engineering Department, Stanford University (absent on leave); Director, Radio Research Laboratory, Harvard University; Past President, the Institute of Radio Engineers

FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK AND LONDON
1943

PX-34

I = current, amp., at a current loop.
L = length of antenna, meters.
λ = wave length, meters.
θ = angle of elevation measured with respect to wire axis.

The field distribution is a figure of revolution about an axis coinciding with the antenna wire, is symmetrical about a plane perpendicular to the center of the wire, and has the character illustrated in Fig. 19. The relative magnitude and position of the various lobes in the directional pattern can be quickly obtained with the aid of Figs. 19 and 20.

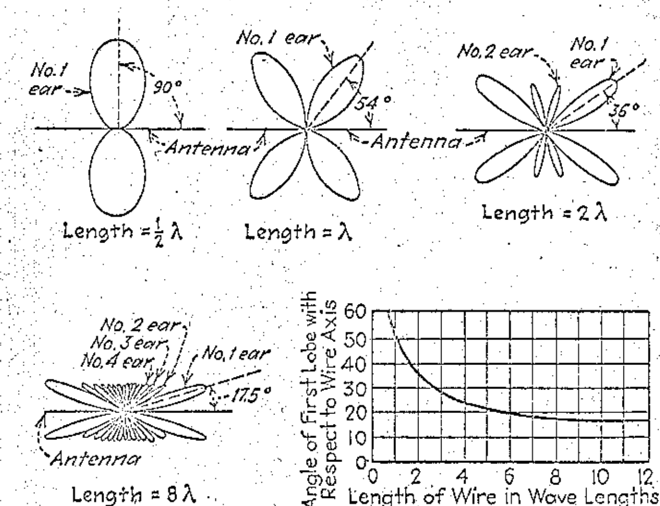

Fig. 19.—Polar diagram showing strength of field radiated in various directions from an antenna consisting of a wire remote from the ground. These diagrams can be considered as cross sections of a figure of revolution in which the axis is the antenna.

Radiation Resistance and Gain.—The radiation resistance of an isolated wire is

$$\left.\begin{matrix}\text{Radiation}\\ \text{resistance}\end{matrix}\right\} = 30\left[0.5772 + \log_e\left(4\pi\frac{l}{\lambda}\right) - Ci\left(4\pi\frac{l}{\lambda}\right)\right] \qquad (14)$$

where the resistance is in ohms, l/λ is the antenna length in wave lengths, and $Ci(x)$ is

$$Ci(x) = \int_{\infty}^{x} \frac{\cos x}{x}\,dx \qquad (15)$$

Values of $Ci(x)$ can be obtained from the tabulated values of $S_1(x)$ given in Table 15 Sec. 1. When $\frac{l}{\lambda} > 1$, the radiation resistance is approximately

$$\left.\begin{matrix}\text{Radiation}\\ \text{resistance}\end{matrix}\right\} = 17.32 + 30\log_e\left(4\pi\frac{l}{\lambda}\right) \qquad (16)$$

The relation between radiation resistance and length is given in Fig. 21, which also gives the gain of an isolated long-wire antenna as compared with an antenna a half wave length long. The power gain of the latter as compared with a doublet is 1.0

Effect of a Perfect Ground on Characteristics of a Resonant Wire.—The effect of a perfect earth on the directional characteristics of a resonant wire antenna is determined by the method of images discussed in Par. 4. For horizontal antennas, and al

The power gain of a rhombic antenna array depends upon the length of the legs measured in wave lengths, and upon the other proportions of antenna. With leg lengths ranging from two to four wave lengths, the power gain is commonly of the order of 20 to 40 in typical cases. The higher gains tend to go with the longer lengths, since then the concentration of energy in the desired direction is greater, and furthermore the amount of energy radiated is greater in proportion to that dissipated in the terminating resistance.

The radiation resistance of a rhombic can be defined as that quantity which when multiplied by the square of the average current in the wire will equal the radiated power. When the length and breadth are both considerably greater than λ, this resistance R in ohms is[1]

$$R = 240\left[\log_\epsilon\left(4\pi\frac{l}{\lambda}\cos^2\phi\right) + 0.577\right] \tag{35}$$

In considering its effect on current distribution, this resistance can be considered as being uniformly distributed along the wire.

The terminating resistance of a rhombic antenna must dissipate a considerable amount of power when the antenna is used for transmitting. This may in typical

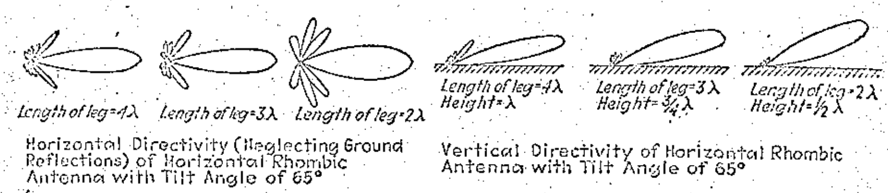

FIG. 41.—Polar diagram showing directional characteristics of the same horizontal rhombic antenna for three different frequencies.

cases be of the order of a quarter to a half of the total power supplied to the antenna, with the exact value depending upon the antenna design. When high-powered transmitters are involved, a convenient way of obtaining a terminating resistance of the required power-handling capacity is to use a two-wire transmission line having a characteristic impedance equal to the desired terminating resistance and employing iron wire to give high loss. This transmission line can be run back from the terminating apex toward the input apex, and after being made sufficiently long to dissipate all except a negligible proportion of the power, can be terminated in a low-wattage resistance, or even left unterminated.

It is possible to modify the minor lobes in the rear of the directional pattern, and in particular to obtain a null in any desired backward direction, merely by modifying the magnitude or phase angle, or both, of the terminating resistance.

There is an advantage in making each conductor of a rhombic antenna consist of two or more spaced wires connected in parallel. This lowers the characteristic impedance of the rhombic antenna, thereby making the terminating impedance less critical and also causing a greater proportion of the total energy supplied to the rhombic to be radiated. There is a further advantage to be gained by arranging such a spaced-wire conductor so that the effective conductor diameter is greater at the two corners of the rhombic that are between the apexes than at the corners of the apexes. It is possible in this way to compensate for the fact that the varying spacing between the sides of the rhombic tends to cause the characteristic impedance of the antenna to be different at different places.

[1] Lewin, *loc. cit.*, or Rhombic Transmitting Aerial Efficiency, *Wireless Eng.*, Vol. 18, p. 180, May, 1941. This latter article also contains additional useful information on the performance of rhombic antennas.

16. The Resonant V Antenna.[1]—This antenna consists of two long resonant wires arranged to form a V and excited so as to carry equal currents that are in phase opposition. The apex angle of the V is made twice the angle that the first lobe in the field pattern of a long resonant wire makes with the wire (see Fig. 19).[2] This gives a strong concentration of radiation in the plane of the V, with the major lobe of the directional pattern in the direction of the line bisecting the V as shown in Fig. 42.

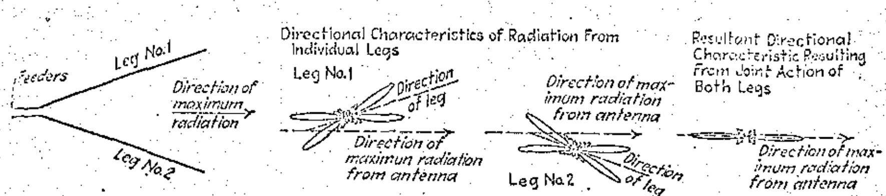

Fig. 42.—V antenna, showing how the radiation from the two legs combine to give a well-defined beam.

The radiation pattern from a V antenna, if it is assumed that the antenna is remote from earth and that each leg is an even multiple of a half wave length long, is[3]

$$\text{Field strength in plane of V} = \sqrt{E_a^2 + E_b^2 - 2E_aE_b \cos\left(2\pi \frac{l}{\lambda} \sin\alpha \sin\phi\right)} \qquad (36a)$$

Radiation in vertical plane passing through bisector of apex angle

$$\epsilon = \frac{120I}{d}\left[\frac{\sin\left(\frac{n\pi}{2}\cos\alpha\cos\theta\right)\sin\alpha}{1 - \cos^2\theta\cos^2\alpha}\right] \qquad (36b)$$

where E_a and E_b = radiation in desired direction from individual legs of antenna as given by Eq. (13).
l = length of leg.
λ = length corresponding to one wave length.
α = half of angle at apex.
ϕ = bearing angle with respect to bisector of apex.
ϵ = field strength, volts per meter.
n = number of half wave lengths in each leg of antenna.
θ = angle of elevation with respect to plane of antenna.
I = current at current loop.
d = distance to antenna, meters.

Increased directivity can be obtained by means of an array, each element of which is a V antenna. Thus the directivity in a vertical plane can be improved by stacking two or more V's one above the other, as illustrated in Fig. 43a. Similarly, a unidirectional pattern can be developed by the use of a second system of V antennas spaced an odd number of quarter wave lengths behind the original system and excited

[1] For further information see P. S. Carter, C. W. Hansell, and N. E. Lindenblad, Development of Directive Transmitting Antennas by RCA Communications, Inc., *Proc. I.R.E.*, Vol. 19, p. 1773, October, 1931; P. S. Carter, Circuit Relations in Radiating Systems, *Proc. I.R.E.*, Vol. 20, p. 1004, June, 1932.

[2] When the sides of the V are short, for example, one wave length or less, the apex angle at which the power gain of the antenna is maximum is less. Thus, for legs one wave length long, maximum gain is obtained with an apex angle of 90° rather than the 105° corresponding to exact superposition of the major lobes. When the antenna is near the earth, the optimum angle is also slightly less than when the V is isolated.

[3] See Carter, Hansell, and Lindenblad, *loc. cit.*