Sept. 5, 1950 W. E. KOCK 2,521,524

DIRECTIONAL ANTENNA SYSTEM

Filed April 27, 1945 2 Sheets-Sheet 1

FIG. 1

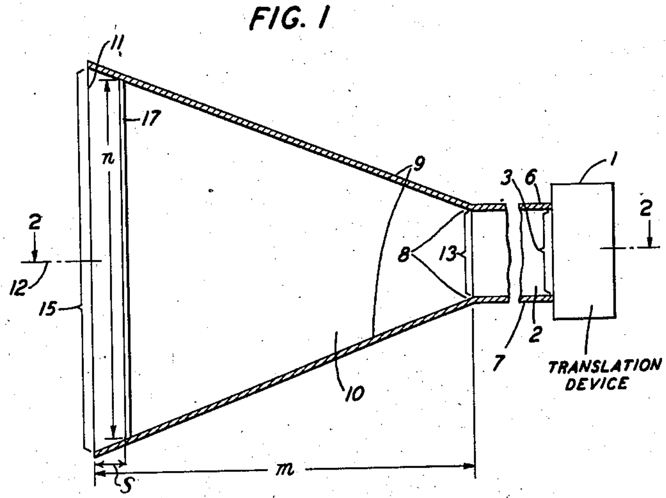


FIG. 3

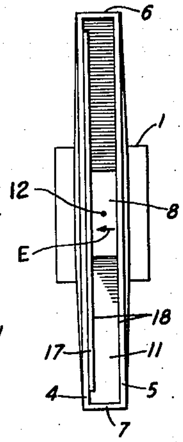


FIG. 2

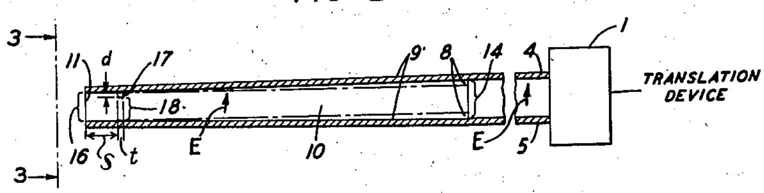
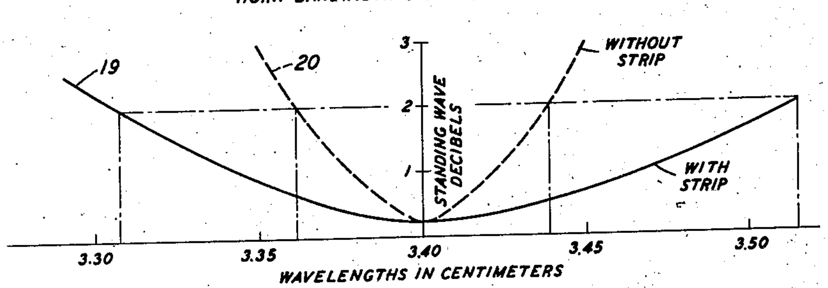


FIG. 4

HORN BANDWIDTH CHARACTERISTIC



INVENTOR
W. E. KOCK
BY
A. J. Zerbarini
ATTORNEY

Sept. 5, 1950 W. E. KOCK 2,521,524

DIRECTIONAL ANTENNA SYSTEM

Filed April 27, 1945 2 Sheets-Sheet 2

FIG. 5

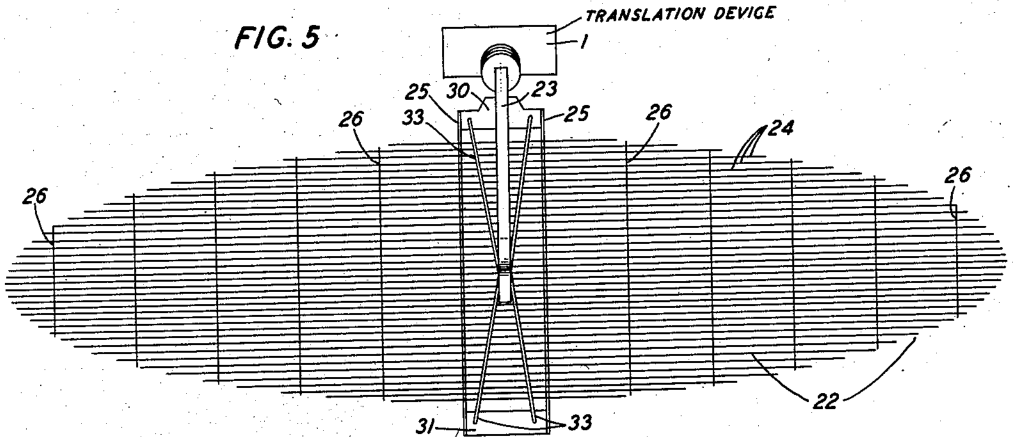


FIG. 6

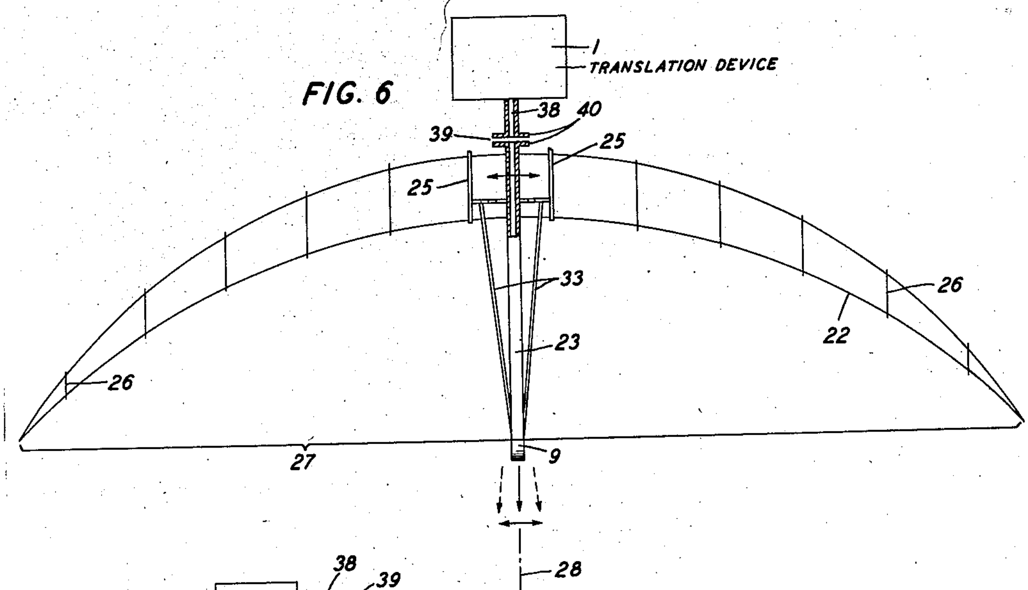
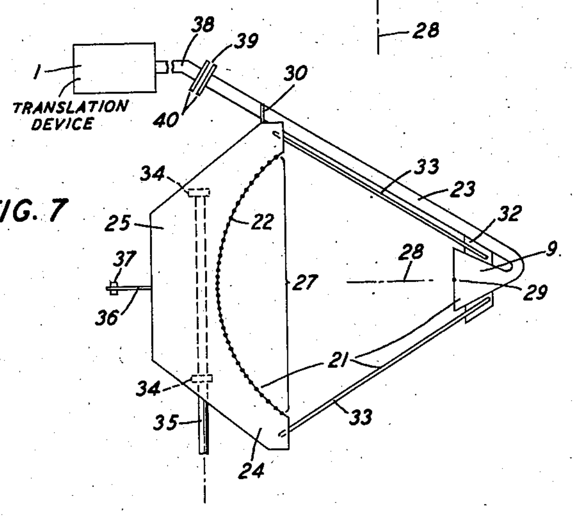


FIG. 7



INVENTOR
W. E. KOCK
BY A. J. Zerbarini
ATTORNEY

Patented Sept. 5, 1950 2,521,524

UNITED STATES PATENT OFFICE

2,521,524

DIRECTIONAL ANTENNA SYSTEM

Winston E. Kock, Middletown, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 27, 1945, Serial No. 590,562

5 Claims. (Cl. 250—33.65)

1

This invention relates to antenna systems and particularly to microwave and ultra-short wave directive antenna systems.

As is known, dielectric horn antennas have been suggested for use in point-to-point communication systems and in radio detecting and ranging systems employing microwaves or ultra-short waves. While, in general, these antennas have been successfully used at a single operating frequency, their bandwidth or frequency-standing wave amplitude characteristic is such that completely satisfactory operation over a given operating or design band has not always been achieved. More particularly the bandwidth-standing wave curve is peaked or sharp, rather than flat, and detrimental standing waves are established in the horn antenna at frequencies other than the mean or design frequency. Accordingly, it now appears desirable to obtain, for use in the above-mentioned systems, a horn antenna having a relatively flat bandwidth characteristic.

It is one object of this invention to obtain a horn antenna having a wide bandwidth.

It is another object of this invention to obtain a simple, easily constructed, fan beam horn antenna.

It is another object of this invention to obtain a simple primary antenna for illuminating or energizing an asymmetrical elongated parabolic reflector in an optimum manner.

It is a further object of this invention to obtain a mechanically steerable, or rockable, microwave scanning antenna of simple lightweight construction.

It is another object of this invention to produce the oscillatory or rocking action, in a rockable microwave scanning antenna system comprising a parabolic reflector, a primary horn antenna and a dielectric feed guide, all combined in a unitary structure, without utilizing rotary joints of the dielectric guide type.

As used herein the term "wave guide" generically applies to conductive guides, such as a conventional two-wire line or a coaxial line, and to dielectric guides such as a bare solid dielectric rod, an air-filled metallic tube or a hollow conductive member containing a gaseous, solid or liquid dielectric substance. The term "radar" connotes a radio detecting and ranging system.

2

In accordance with one embodiment of the invention, the wide parallel metallic walls, and the narrow parallel metallic walls of a non-equilateral rectangular dielectric auxiliary guide, converge and diverge, respectively, at one end of the guide so as to form a dielectric horn having a long narrow rectangular mouth aperture. In other words, the short and long dimensions of the horn mouth are smaller and greater, respectively, than the short and long dimensions of the horn throat. A thin linear metallic strip is attached to the inside surface of one of the wide horn walls so as to extend parallel to the long dimension of the mouth aperture. The strip is spaced about a quarter wavelength from the mouth aperture and projects into the dielectric channel or bell of the horn a small fraction of a wavelength. The rectangular aperture, formed by the linear strip and the horn walls opposite and adjacent thereto, constitutes a capacitive iris. The dielectric horn is positioned at the focus of a paraboloidal reflector having an unsymmetrical or elongated opening; and the associated auxiliary guide is attached to the periphery of the reflector, so that the horn, the auxiliary guide and the reflector form a unitary structure. The auxiliary guide is coupled to a stationary main dilectric guide through a flexible or wobble joint, and means are provided for rocking the unitary structure.

The horn antenna has a fan beam extending perpendicular to the fan beam of the reflector and critically tapered or shaped so as to effect, in transmission, optimum illumination or energization of the reflector. In reception, the converse operation obtains and optimum collection of the wavelets impinging upon, and reflected by, the reflector is obtained at the horn antenna. By reason of the capacitive iris in the bell of the horn a relatively flat bandwidth characteristic for the horn, and therefore for the complete antenna system, is obtained whereby highly satisfactory operation at any frequency in a wide band of microwaves may be secured. Considered mechanically, the inclusion of the auxiliary guide, horn and reflector in a rockable unitary antenna structure permits the use of a simple wobble dielectric guide joint, instead of a complicated dielectric guide rotary joint, for coupling the antenna to a stationary main guide.

Hence, from a manufacturing and maintenance standpoint, the antenna system of the invention possesses distinct advantages over prior art sector scanning antennas which ordinarily include a dielectric guide rotary joint.

The invention will be more fully understood from a perusal of the following specification taken in conjunction with the drawing on which like reference characters denote elements of similar function and on which:

Figs. 1, 2 and 3 are respectively, a side sectional view, a top sectional view and a front view of the horn antenna of the invention;

Fig. 4 illustrates the bandwidth characteristic of the horn antenna of the invention; and

Figs. 5, 6 and 7 are respectively front, top and side views of a complete unitary antenna system comprising a paraboloidal reflector and the horn antenna of Figs. 1, 2 and 3.

Referring to Figs. 1, 2 and 3, reference numeral **1** denotes a translation device, such as a radar transceiver, and numeral **2** denotes a rectangular air-filled dielectric guide connected at its near end **3** to device **1** and having two wide parallel metallic walls **4**, **5** and two narrow parallel metallic walls **6**, **7**. At the far end **8** of the guide **2** the wide walls **4**, **5** diverge, and the narrow walls **6**, **7** converge, to form a dielectric horn antenna **9** having a bell portion **10**, a long narrow rectangular mouth aperture **11**, a rectangular throat aperture identical with the open far end **8** of guide **2**, and a longitudinal axis **12**. Numerals **13** and **14** designate the long and short dimensions of the throat aperture **8**, and numerals **15** and **16** denote the long and short dimensions of the mouth aperture **11**. As is apparent from the drawing, the long dimension **15** of the mouth aperture **11** is greater than the long dimension **13** of the throat aperture **8** and the short dimension **16** of the mouth aperture **11** is smaller than the short dimension **14** of the throat aperture **8**. Reference letter *m* denotes the length of horn **9** as measured along the longitudinal axis **12** of the horn. Reference letter E designates the electric polarization of the wave supplied to, or received from, the device **1**, the polarization being perpendicular to the wide walls **4**, **5** of the guide **2** and horn **9**.

Reference numeral **17** denotes a thin linear metallic strip attached to the inside surface of the wide horn wall **4** at a distance *s* from the mouth aperture **11** and extending parallel to the long dimension **15** of the mouth aperture **12**, that is, perpendicular to the longitudinal axis **12** of horn **9** and to the polarization E of the wave. The strip **17** has a width or thickness *t* and a length *n*, and projects into the air dielectric bounded by the bell portion **10** a distance or depth *d*. As shown on the drawing, the strip **17** touches the opposite narrow walls **6**, **7** of the horn and its length *n* is slightly smaller than the long dimension **15** of the mouth aperture **11**. The strip **17**, the wide horn wall **5** opposite thereto and the narrow horn walls **6**, **7** form a rectangular capacitive iris **18**.

In operation, assuming device **1** is a pulse type radar transceiver, microwave pulses supplied by the transmitter or magnetron in device **1** are conveyed over dielectric guide **2** to the horn antenna and thence radiated. In reception, the converse operation obtains, that is, the echo waves collected at the mouth aperture are conveyed over guide **2** to the receiver in device **1**. The half power width of the directional pattern of the maximum lobe of the horn **9**, taken in the plane of the short mouth dimension **16**, is wider than the half power width of the lobe pattern taken in the plane of the long dimesion **15**, and a fan beam is secured. As explained in connection with Figs. 5, 6, and 7 the fan beam is tapered or shaped so as to produce optimum illumination of a paraboloidal reflector having an elongated opening.

While pulse type radars normally utilize a single operating frequency, the operating frequency may fluctuate as a result of magnetron pulling or other causes, and may change considerably when the magnetron becomes defective and is replaced by another. Assuming for the moment that strip **17** is omitted, the horn **9** has a fairly sharp band width characteristic centered on the mean frequency of the band. According to one theory, the impedance of the horn mouth aperture varies with frequency and, while the horn mouth impedance at the mean frequency may be such as to prevent undesired reflection and the consequent establishment of standing waves in the horn **9** and guide **2** at this frequency, pronounced standing waves are produced at the other frequencies in the band. The capacitive iris **18**, utilized in accordance with the invention, functions in a sense as a wide band impedance matching transformer and in effect transforms, at substantially all frequencies in the band, the mouth impedance to an impedance at which standing waves are not produced in the horn **9** or guide **2**, substantially whereby a relatively flat band width characteristic is obtained.

Referring to Fig. 4, the full line curve **19** represents the measured band width characteristic of a horn antenna which was actually constructed and tested and which was equipped with the strip **17** and capacitive iris **18**, as shown in Figs. 1, 2 and 3. In this tested system, the horn throat dimensions **13** and **14** were 0.672λ and 0.299λ, respectively; the horn mouth dimensions **15** and **16** were 2.98λ and 0.224λ, respectively; the horn length *m* was 2.98λ; the strip dimensions *t* and *d* were 0.023λ and 0.112λ; the spacing *s* was 0.256λ, and the mean or design wavelength, λ, was 3.4 centimeters. Also, in this tested system, the electric polarization of the transceived waves was parallel to the short dimension of the horn aperture. The estimated band width characteristic for the same horn, with the strip **17** and iris **18** omitted, is represented by the dash-dash curve **20**. As is apparent from Fig. 4, the band width characteristic of the horn **9** with the iris **20** in position, is relatively flat as compared to that of the same horn with the strip **17** omitted. In other words, the effective or operating wavelength band for the horn with the strip **17** is considerably broader than the band of the horn without the strip **17**. To illustrate, assuming standing waves greater than 2 decibels cannot be tolerated, the operative band for the horn **9** equipped with the iris **18** is approximately 3.305–3.510 centimeters, whereas it is only about 3.360–3.435 centimeters for the horn without the iris **18**.

Referring to Figs. 5, 6 and 7, reference numeral **21** denotes an antenna structure comprising a paraboloidal reflector **22** of the dielectric grille type, a dielectric auxiliary guide **23** and a primary horn antenna **9** at the far end of the auxiliary guide **23**. The reflector **22** comprises a large number, say 39, of metallic light weight tubes **24** having different lengths and spaced apart less than a half mean wavelength. The tubes **24** are supported by the two central transverse members

25 and the side transverse members 26. As shown in Fig. 5, the projection of the periphery of the opening 27, Figs. 6 and 7, of reflector 22 on a plane perpendicular to the reflector axis 28, that is, on the latus rectum plane, is an ellipse. The elongated paraboloidal reflector is disclosed and claimed in the copending application of C. C. Cutler, Serial No. 546,687, filed July 26, 1944, now Patent No. 2,483,575, granted October 4, 1949; and an elongated grille reflector is described in the copending application of A. C. Beck, Serial No. 574,335, filed January 24, 1945, now Patent No. 2,495,219, granted January 24, 1950.

The auxiliary guide 23 extends across a portion of the reflector 22 and the horn 9 faces reflector 22, the center point of the horn mouth aperture and the focal point 29 of reflector 22 being coincident. As shown on the drawing, the long and short dimensions of the horn mouth aperture are parallel to the minor axis and major axis, respectively, of the ellipse mentioned above. Numerals 30, 31 denote brace members extending between the central transverse members 25 and numeral 32 denotes a brace member attached to horn 9 and auxiliary guide 23. The auxiliary guide 23 is attached to brace member 31 and the converging struts 33 extend between the brace member 32 and the brace members 30, 31, at an acute angle to the axis 28 of the reflector. Hence, the auxiliary dielectric guide 23 is connected to, and supported by, the upper peripheral portion of reflector 22; and the horn 9, auxiliary guide 23 and paraboloidal reflector 22 are rigidly connected together so as to form a unitary antenna structure. Numerals 34, Fig. 7, denote bearing plates which extend between the central transverse members 25 and support a vertical shaft 35. Numeral 36 denotes a triangular plate member attached to the transverse members 25; and numeral 37 designates a reciprocating connecting rod extending perpendicular to the plane of the drawing and connected to plate 36. While the mechanism for oscillating the antenna structure 21 may be of a prior art type (see Patent 1,934,078 to W. Ludenia), preferably the mechanism disclosed and claimed in my copending application Serial No. 638,349 filed December 29, 1945, is employed.

Reference numeral 38 denotes a stationary main dielectric guide connected to the translation device 1 and coupled, through wave trap wobble joint 39 to the movable auxiliary dielectric guide 23. The joint 39 comprises the flanges 40, each a half wavelength long, and is of a type well known in the art. The flanges in effect constitute an open-circuited half wave line having a zero input impedance, whereby the guided waves flow or pass from one to the other of the physically separated guides 23, 38 without loss.

In operation, the unitary antenna structure 22, 23 and 9 is oscillated or rocked, by means of the reciprocating rod 37, about the shaft 35, whereby the antenna beam sweeps back and forth over a predetermined angular scanning sector. The simple light weight unitary construction of the antenna 22, 23 and 9 permits the use of the dielectric wobble joint 39; and the wobble joint 39 in turn permits an exceedingly high sector scanning rate, for example, five double scans or oscillations per second, to be used in the mechanically-steerable sector-scanning antenna system. The scanning rate obtainable with the system of Figs. 5, 6 and 7 is considerably greater than that ordinarily achieved in prior art sector scanning systems utilizing conventional dielectric rotary joints.

As previously indicated, the fan beams of the horn 9 and of the reflector 22 are perpendicular to each other. As disclosed in the above-mentioned application of C. C. Cutler, optimum energization of the elongated reflector 22 is obtained when the intensity of the reflector illumination is graded from a maximum at the reflector center or vertex to a value, at the periphery of the reflector, of about eleven decibels below maximum. In accordance with the invention, assuming the ratio of the major to minor axis of the projected ellipse of the reflector is about 4, the ratio of the long to the short dimension of the single mouth aperture of horn 9 is about 13.3, whereby optimum energization of an elongated paraboloidal reflector is obtained by means of a single-apertured horn antenna. Also, as previously indicated, the ratio 13.3, and therefore the selected critical taper for the fan beam of the horn antenna 9, are secured by utilizing a rectangular horn antenna having a pair of converging walls and a pair of diverging walls, as viewed from the horn throat aperture.

In the test mentioned above it was found that the minor lobes in the directive pattern taken in the plane of polarization, were reduced or rendered negligible by tilting the struts 33 at an acute angle to the reflector axis 28. On the other hand, with the struts vertical, that is, perpendicular to the axis 28 and to the plane of polarization, pronounced minor lobes were obtained.

Although the invention has been explained in connection with a specific embodiment, it is to be understood that it is not to be limited to the embodiment described inasmuch as other apparatus may be employed in successfully practicing the invention.

What is claimed is:

1. In combination, an air-filled rectangular horn antenna for transceiving waves included in a given wavelength band, said horn comprising two wide walls and two narrow walls, a linear metallic member attached to the inner surface of one of said wide walls and extending perpendicular to the axis of said horn, said member projecting into said horn approximately 0.112 of the mean wavelength in said band.

2. A combination in accordance with claim 1, said member being spaced approximately 0.256 of the mean wavelength from the mouth or output aperture of said horn.

3. A combination in accordance with claim 1, said member having a width as measured in a direction parallel to the horn axis of approximately 0.023 of the mean wavelength.

4. In combination, a paraboloidal reflector, the projection of the periphery of the opening of said reflector on the latus rectum plane being an ellipse, a horn antenna facing said reflector and having rectangular throat and mouth apertures, the dimensions of the adjacent sides of each aperture being unequal and the short dimension of the mouth aperture being smaller than the short dimension of the throat aperture.

5. In combination, a paraboloidal reflector, the projection of the periphery of the opening of said reflector on the latus rectum plane being an ellipse, a horn primary antenna facing said reflector and having a rectangular aperture centered on the focus of said reflector, the dimensions of the adjacent sides of said aperture being unequal, the ratio of the long to the short dimen-

sion of said aperture being at least twice as large as the ratio of the major to the minor axis of said ellipse, and a translation device connected to said primary antenna.

WINSTON E. KOCK.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,049,070	Mathieu	July 28, 1936
2,173,897	Clavier	Sept. 26, 1939
2,216,707	George	Oct. 1, 1940
2,255,042	Barrow	Sept. 9, 1941
2,257,320	Williams	Sept. 30, 1941
2,283,935	King	May 26, 1942
2,298,272	Barrow	Oct. 13, 1942
2,396,044	Fox	Mar. 5, 1946
2,405,242	Southworth	Aug. 6, 1946
2,412,446	De Walt	Dec. 10, 1946
2,409,183	Beck	Oct. 15, 1946
2,415,680	Hoyt	Feb. 11, 1947
2,415,807	Barrow et al.	Feb. 18, 1947
2,427,005	King	Sept. 9, 1947
2,436,380	Cutler	Feb. 24, 1948

FOREIGN PATENTS

Number	Country	Date
495,977	Great Britain	Nov. 23, 1938