Feb. 8, 1966 J. BARTHOLOMÄ ETAL 3,234,559

MULTIPLE HORN FEED FOR PARABOLIC REFLECTOR WITH PHASE AND POWER ADJUSTMENTS

Filed April 27, 1961 4 Sheets-Sheet 1

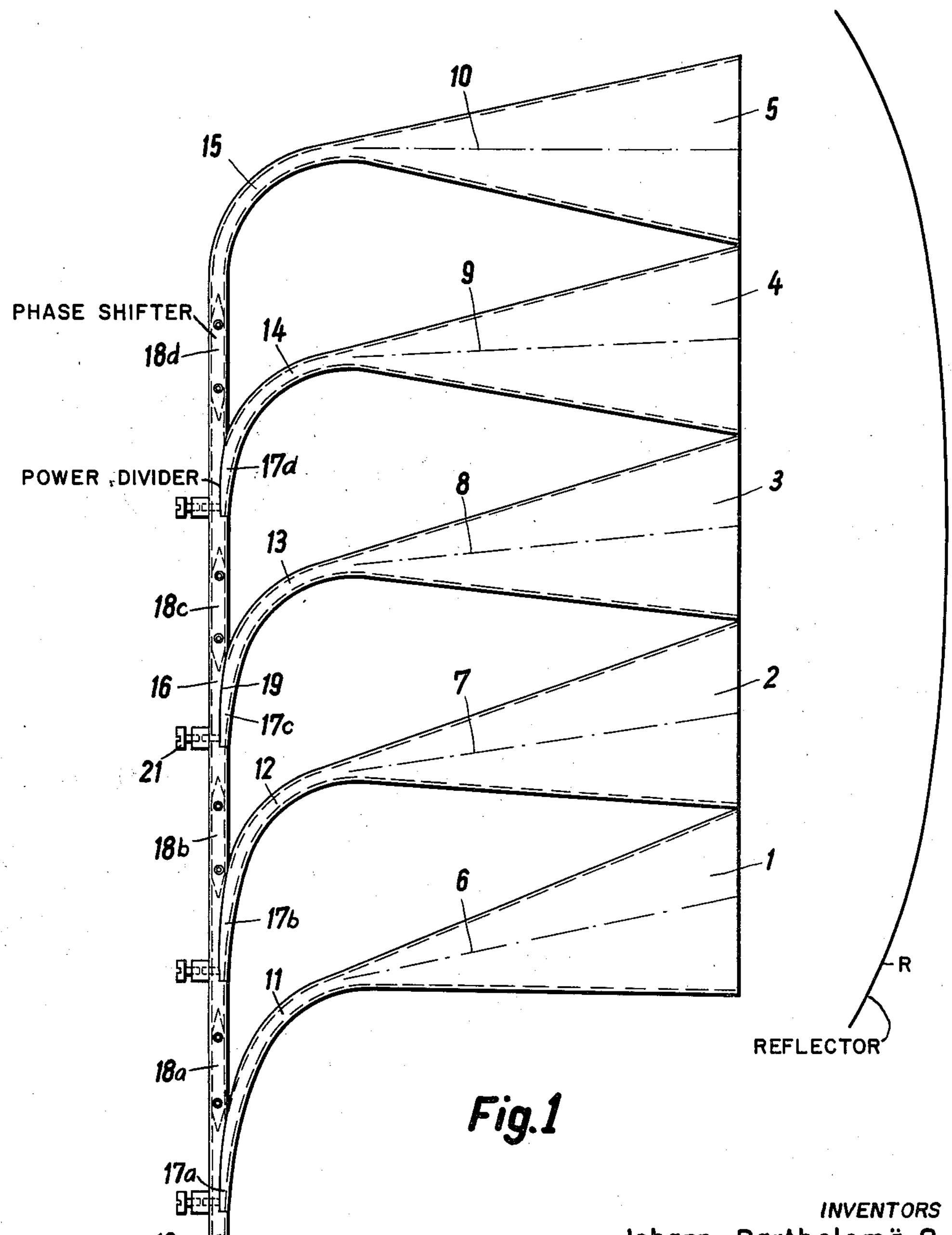


Fig.1

INVENTORS
Johann Bartholomä &
Heinz Brunner
BY George H. Spencer
ATTORNEY

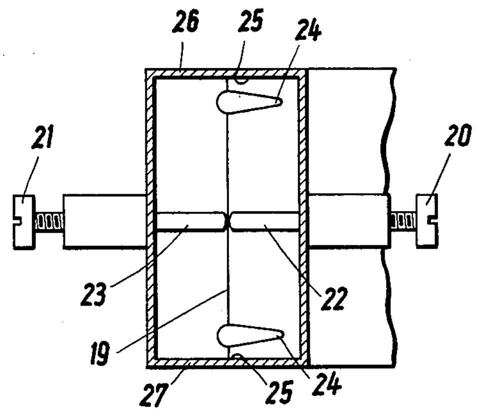


Fig.3

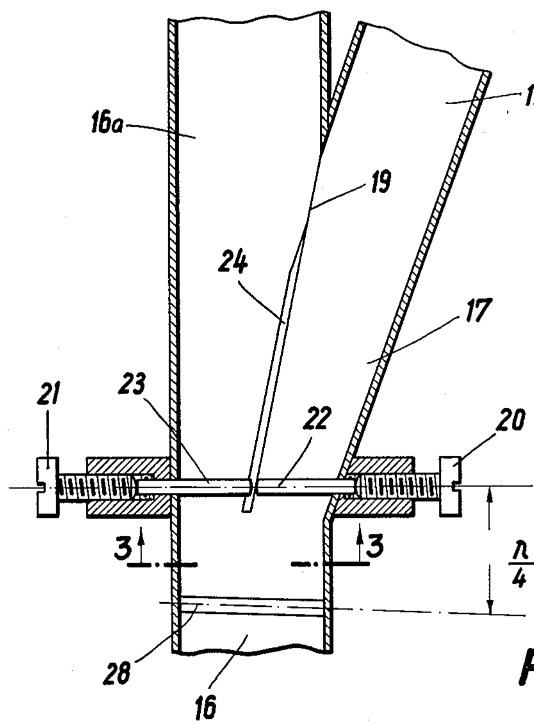


Fig.2

INVENTORS
Johann Bartholomä &
Heinz Brunner
BY George H. Spencer
ATTORNEY

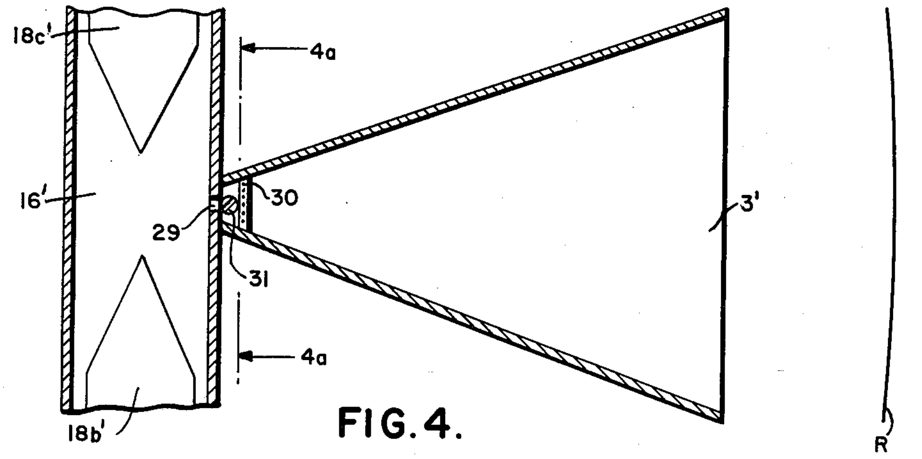


FIG. 4.

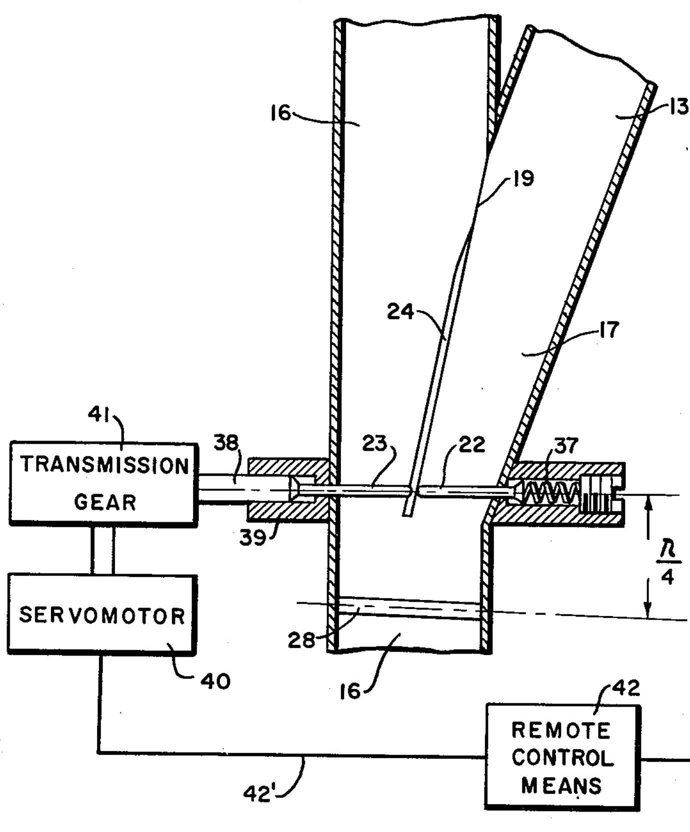


FIG. 6.

INVENTOR
Johann Bartholomä &
Heinz Brunner

BY George H. Spencer
ATTORNEY

FIG. 4a

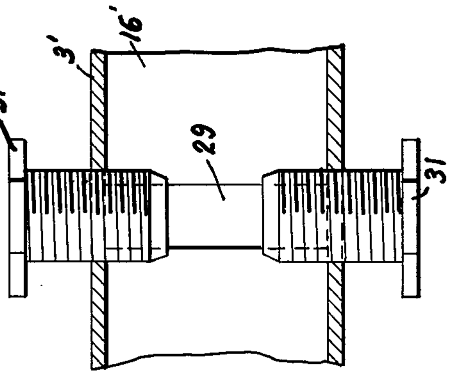
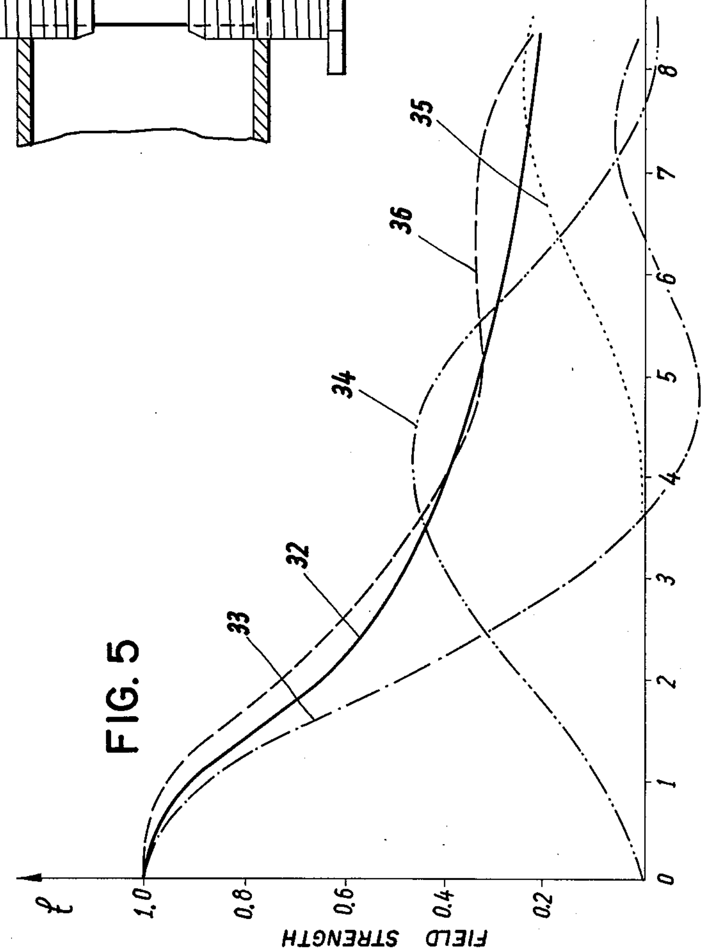


FIG. 5



INVENTORS
Johann Bartholomä &
Heinz Brunner
BY George H. Spencer
ATTORNEY

3,234,559
Patented Feb. 8, 1966

3,234,559

MULTIPLE HORN FEED FOR PARABOLIC REFLECTOR WITH PHASE AND POWER ADJUSTMENTS

Johann Bartholomä, Ulm (Danube), and Heinz Brunner, Gunzburg (Danube), Germany, assignors to Telefunken Patentverwertungs-G.m.b.H., Ulm (Danube), Germany

Filed Apr. 27, 1961, Ser. No. 105,985
Claims priority, application Germany, May 7, 1960, T 18,346
11 Claims. (Cl. 343—779)

The present invention relates to a radiator including several horn exciters and reflector means for producing an adjustable directional pattern, and in particular, one having a cosec^2 shape.

For the purpose of producing asymmetrical directional antenna propagation patterns employing reflectors excited by horns, it is known in the prior art to give the reflector an asymmetrical design and to use horn exciters, arranged in a line in front of a parabolic reflector, and to produce the desired pattern by delivering different power outputs to the exciters in the required mutual phase relationship. Each individual horn of this line may be considered substantially as a point source having as a consequence its own sharply beamed primary directional pattern contributing to the secondary directional propagation pattern. The angular spread of the individual-horn primary directional patterns—giving by superposition the resulting composite secondary pattern—from the main axis of the parabolic reflector is a function of the amounts of offset of the position of the individual horns from this main axis. The power division and the corresponding phase adjustments of these known horns are established by their construction once and for all, for example, by projecting separator sheets into the main waveguide or by the selection of the lengths of the individual coupling waveguides supplying the individual horns.

The invention is addressed to the purpose of providing a directional antenna having a selectively and easily adjustable complex directional propagation pattern especially one having a cosec^2 shape.

The invention comprises for this purpose a device for producing a complex directional pattern including several exciters, preferably horns, arranged in a line and directed into a common reflector, the individual exciters being coupled to a feeder line through adjustable power dividers and phase shifters, which can be adjusted to provide a uniform phase front directed into the reflector by said horns.

Such an antenna may be used to particular advantage, for example, as an elevation searching antenna in so-called precision aircraft-approach radar installations since its directional pattern, having preferably a cosec^2 shape, is particularly suited to such purpose by installation of the antenna next to the landing strip. The easy adjustability of the directional pattern of the antenna according to the invention makes it possible to adapt it to the ambient local conditions by producing such a directional pattern as to discriminate against obstructions, for example, structures standing near the landing strip, which ability is of advantage especially in the case of mobile radar stations.

Additional objects and advantages of the present invention will become apparent upon consideration of the following description when taken in conjunction with the accompanying drawings in which:

FIGURE 1 schematically illustrates an exciter for a parabolic reflector comprising five horns arranged in a line and coupled to supply lines in accordance with the invention.

FIGURE 2 shows in cross section an enlarged adjustable power divider of the type used in FIGURE 1.

FIGURE 3 is a cross-sectional view of the power divider according to FIGURE 2 taken along the line 3—3.

FIGURE 4 is a sectional view through a modified embodiment according to the invention.

FIGURE 4*a* is a sectional view taken on line 4*a*—4*a* of FIGURE 4.

FIGURE 5 is a graphical representation of the pattern obtained by means of the exciter according to FIGURE 1 for producing a cosec^2-shaped characteristic from which the elementary directional patterns of the individual horns and their resulting directional patterns may be read off.

FIGURE 6 schematically illustrates part of a further embodiment according to the invention comprising remote-control means.

Referring now to FIGURE 1, the horn exciter according to the invention consists of five individual horns **1** to **5**, arranged in a line side-by-side, and the axes **6**, **7**, **8**, **9**, and **10** of these horns are arranged in such a way that they meet at a common point on the mirror surface of a parabolic reflector R placed in front of these horns, the distance between the horns and the reflector being shown disproportionately small, to permit illustration. The horns are connected to a common supply waveguide **16** through curved coupling waveguides **11**, **12**, **13**, **14**, and **15**. The desired adjustable power division between the individual horns is accomplished by power dividers **17*a***, **17*b***, **17*c***, and **17*d***. The variable adjustment of the phase of the energy supplied to the individual horns is accomplished by phase shifters **18*a***, **18*b***, **18*c***, and **18*d***.

FIGURE 2 shows a typical power divider **17*c*** according to FIGURE 1, on an enlarged scale. The curved coupling waveguide **13**, for example, is connected thereby to the supply waveguide **16**. A resilient bronze sheet **19**, about 0.2 mm. thick divides the tapped-off energy from the main part of the waveguide **16**, the remaining portion of which energy travels on to the upper part of this waveguide through the guide **16*a***, and the tapped-off portion goes to the curved coupling waveguide **13**. The power tapped off depends upon the position of the adjusting screws **20** and **21** which serve to move the bronze divider sheet **19** in the axial direction of the screws through insulator pins **22** and **23** which are of low-loss material, for example, glass fiber.

As may be seen from FIGURE 3, taken through the waveguide of FIGURE 2 along the line 3—3, the bronze sheet **19** is fixed along its edges **25** to the waveguide **16**, but is provided with corrugations **24** so as to permit elastic deformation thereof by the adjusting screws, in order to change the spatial position of the center of the sheet to obtain the power division desired, the edges **25** of the bronze sheet **19** being solidly connected with the narrow sides **26** and **27** of the supply waveguide **16**. It is thus apparent that the power dividers are infinitely, i.e., steplessly, variable.

The glass-fiber pins **22** and **23** have some tendency to disturb the electromagnetic fields, but these interference effects may be cancelled by compensation pins **28**, for example also comprising glass-fiber pins, arranged at a distance of $n{:}\lambda/4$, where $n=1, 3, 5, \ldots$ and λ is a propagation wavelength in the waveguide. Preferably, however, this spacing will be $\lambda/4$ from these points of interference.

The phase shifters **18** shown in FIGURE 1 are known per se. They comprise a dielectric material, for example a material known as "Polystyren," and take the form of disks mounted in pairs and having a width corresponding substantially to the internal dimensions of the narrower sides **26**, **27** of the supply waveguide **16**. These disks taper off at both ends in a wedge-shaped manner in order to reduce reflections of the electromagnetic waves reaching them. By adjusting means which are not shown in detail, such as screws and glass-fiber pins, these phase shifters are displaceable perpendicular to the plane of drawing of FIGURE 1 by moving the pairs of phase shifters towards one another in such a way, that any desired phase shift between 0° and 360° is possible at each individual phase shifter. Of course, any other suitable phase shifters may be used instead of the phase shifters **18** shown herein by way of example.

FIGURES 4 and 4*a* show a more compact embodiment of the invention wherein the horns **1** to **5** of FIGURE 1 do not have to be connected to the supply waveguide through curved coupling waveguides **11** to **15** but may be fixed directly at their tapered ends to the supply waveguide. This embodiment is illustrated in cross section through part of such a device. A horn **3'** is directly connected with a supply waveguide **16'**, containing also phase shifters **18*b'***, **18*c'*** similar to shifters **18** according to FIGURE 1. The coupling of power to the horn **3'** is by way of a slit **29** in the broad side of the supply waveguide **16'**, which slit does not have to extend over the entire width of the waveguide. In order to adjust the effective length of the slit, a cylindrical screw **31** is provided between a disk **30** of low-loss material, such as "Teflon," arranged in the horn and the slit **29** through the waveguide in such a way that, depending upon the position of the screw, it more or less covers the slit. As shown in FIGURE 4*a* such screws **31** may be provided in front of each slit, thus making possible any desired degree of covering of the slit **29**, which covering is always symmetrical and provides a definite power division.

FIGURE 5 graphically shows a directional pattern, in this case one having a cosec^2 shape, adjustable with the device according to the invention, for example as shown in FIGURE 1, plotting relative field strength E against the angle α made with the main axis of radiation. The solid curve **32** gives the desired pattern; curve **33** shows the characteristic curve of horn **3** according to FIGURE 1; curve **34** shows that of horn **2** according to FIGURE 1; curve **35** that of horn **1** according to FIGURE 1; and curve **36** shows the composite directional pattern resulting from the blending of the individual characteristics to produce an over-all characteristic. The measured deviations of the resulting directional pattern from the theoretical desired values lie in each case below 2 db, and usually even below 1 db. During the independent measuring of the individual horn characteristics for the purpose of plotting curves 33, 34, **35**, all horns except the one under consideration were covered with low-reflection power-absorbing material so that they did not contribute to the radiation. The composite characteristic, resulting from the superposition of the individual characteristics of the horns **3**, **4** and **5** of the device according to FIGURE 1, is not shown in FIGURE 5, since it is merely a mirror image of the curves shown for the horns **1**, **2** and **3**.

FIGURE 6 schematically illustrates a part of a further embodiment according to the invention. As indicated by the same numbers of the parts the power divider according to FIGURE 6 is similar to that shown in FIGURE 2. Instead of the adjusting screw **20**, however, there is provided a spring **37** which presses the glass-fiber pin **22** against the bronze sheet **19**. The adjusting screw **21** is substituted by the shaft **38** which is provided with a thread and driven in the socket **39** by the servo motor **40**, through a suitable gear **41**. The motor **40** is connected with its remote control means **42** by the cable **43**.

In order to adjust the bronze sheet **19** by the remote-control means **42** in pre-selected, fixed positions further means **43** known per se, for instance storage means or automatic switch means, are connected with the remote-control means **43**.

During practical measurements, the phase shifters have turned out to need adjustment only very rarely, normally only during the first adjustment of the device according to the invention. When producing a directional pattern of a different kind, it was found that normally only the power dividers had to be adjusted. If necessary, provision may be made for calibration of the adjusting means for the power dividers, or for grid devices corresponding with pre-selected special kinds of patterns, permitting especially fast and simple changes of pattern. Also means, known per se, may be provided for remote-control adjustments, especially of the power dividers.

It will be understood that the above description of the present invention is susceptible to various modifications, changes, and adaptations, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

What is claimed is:

1. A device for producing a complex directional secondary radiation pattern from a reflector, comprising in combination: a plurality of separate exciters arranged in a line and disposed to direct their primary radiations into said reflector; a feeder transmission line comprising a supply wave guide means for coupling said exciters to said line, said means including adjustable power dividers associated with respective ones of said exciters for adjusting the amount of power supplied to the particular exciter to which the power divider is connected, said power dividers being connected to said feeder transmission line to allow the power distribution to be varied at any time, including during operation of the device, to produce the particular radiation pattern desired, each adjustable power divider comprising a metal sheet projecting into the supply waveguide at at least one point of connection of a curved waveguide to the supply waveguide; and phase shifters associated with respective ones of said exciters for adjusting the phase of the particular exciter with which the phase shifter is associated, said phase shifters being variable independently of each other and of said power dividers for achieving a uniform phase front radiated by said exciters.

2. In a device as set forth in claim **1**, adjustment means extending through the waveguide and contacting said sheet for adjusting the position thereof in the waveguide from outside.

3. In a device as set forth in claim **2**, said adjustment means comprising remote-control means for adjusting the metal sheet.

4. In a device as set forth in claim **2**, said adjustment means including insulator pins extending into the waveguide, and said device including means for compensating for interference with the electromagnetic waves caused by the adjusting means and including other insulator pins extending across the waveguide in spaced relation with the first-mentioned pins.

5. In a device as set forth in claim **4**, said compensating means comprising pins disposed across the waveguide one quarter wave length ahead of the pins of said adjustment means.

6. In a device as set forth in claim **1**, said sheets being fixed to the sides of the waveguide and having corrugations permitting warping of the centers of the sheets into various positions in the waveguide.

7. In a device as set forth in claim **1**, said phase shifters comprising plates of low-loss dielectric material within the supply waveguide.

8. In a device as set forth in claim **7**, said phase shifter plates having at least at one end wedge-shaped tapers to reduce reflections therefrom.

9. In a device as set forth in claim **7**, said plates being mounted in the waveguide on adjustable means whereby their positions transversely of the waveguide may be adjusted.

10. In a device as set forth in claim **1**, said reflector comprising a parabolic mirror, and the axes of said exciters converging at the focus thereof.

11. A device as set forth in claim **1** wherein said power dividers are infinitely variable.

References Cited by the Examiner

UNITED STATES PATENTS

2,286,839	6/1942	Shelkunoff	343—853 X
2,464,276	3/1949	Varian	343—768 X
2,605,413	7/1952	Alvarez	343—854 X
2,898,593	8/1959	Ruze	343—854
2,976,535	3/1961	Cutler	343—779
3,016,531	1/1962	Tomiyasu et al.	343—17.1

FOREIGN PATENTS

895,737	4/1944	France.
1,021,643	12/1952	France.

HERMAN KARL SAALBACH, *Primary Examiner.*

GEORGE N. WESTBY, *Examiner.*