

Sept. 22, 1970

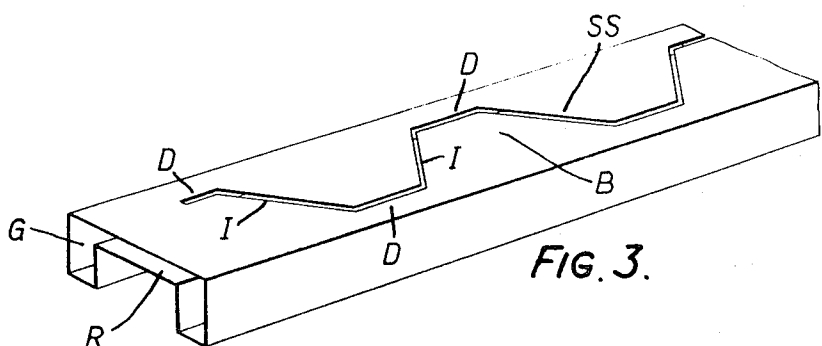
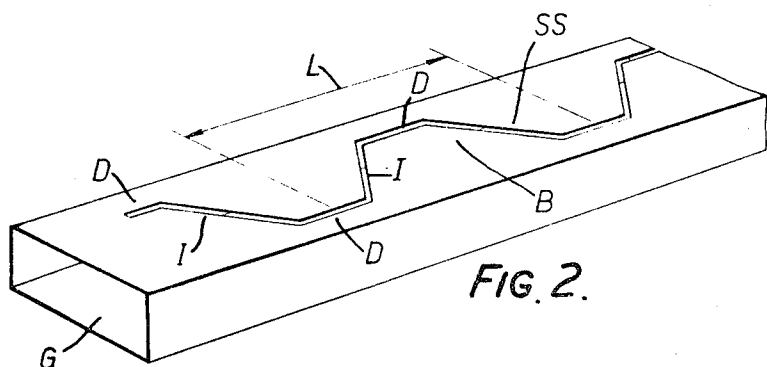
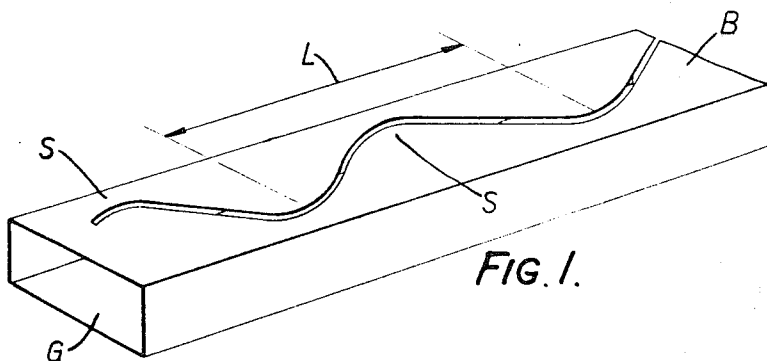
R. A. WALDRON

3,530,479

SLOTTED WAVE GUIDE AERIALS

Original Filed March 31, 1967

3 Sheets-Sheet 1



INVENTOR

Richard Arthur Waldron

By *Baldwin Wight Miller & Brown* ATTORNEYS

Sept. 22, 1970

R. A. WALDRON

3,530,479

SLOTTED WAVE GUIDE AERIALS

Original Filed March 31, 1967

3 Sheets-Sheet 2

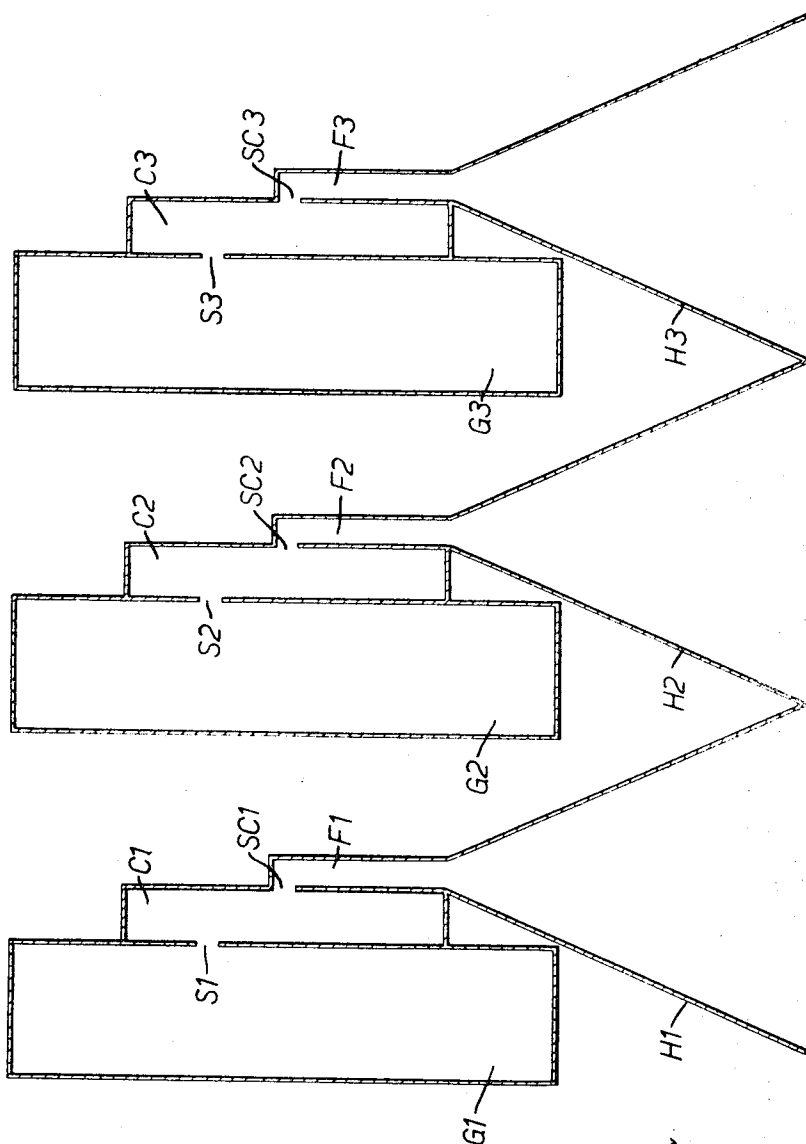


FIG. 4.

INVENTOR

Richard Arthur Waldron

By Baldwin Wright Viller & Brown ATTORNEYS

Sept. 22, 1970

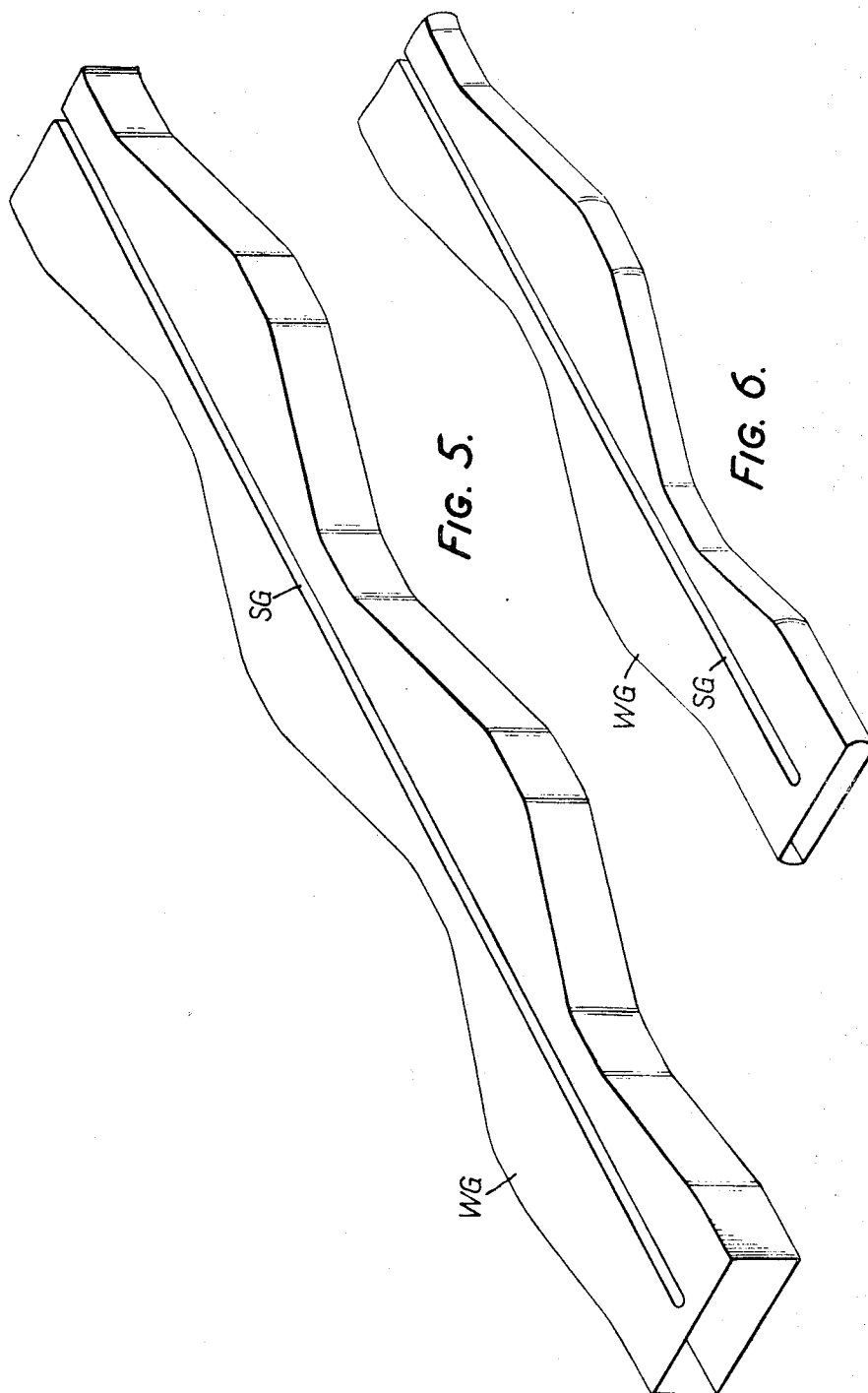
R. A. WALDRON

3,530,479

SLOTTED WAVE GUIDE AERIALS

Original Filed March 31, 1967

3 Sheets-Sheet 3



INVENTOR

Richard Arthur Waldron

By *Baldwin Wright Diller & Brown* ATTORNEYS

1

3,530,479

SLOTTED WAVE GUIDE AERIALS

Richard Arthur Waldron, Chelmsford, England, assignor to The Marconi Company Limited, London, England, a British company

Original application Mar. 31, 1967, Ser. No. 627,554.

Divided and this application Apr. 29, 1968, Ser. No. 724,873

Claims priority, application Great Britain, Mar. 31, 1966, 14,248/66

Int. Cl. H01q 13/10

U.S. Cl. 343—771

10 Claims

ABSTRACT OF THE DISCLOSURE

The disclosure herein relates to slotted waveguide aerials, i.e. a waveguide having one or more slots in it through which radiation takes place, and discusses known aerials of this type and points out that their bandwidth is undesirably low—about 12% at the most. Aerial arrays of the directional coupler type are disclosed to give a bandwidth of about 15% and bandwidths substantially larger than this are obtainable from leaky waveguide arrays—the latter are difficult and costly to construct and have a low efficiency. The invention disclosed herein provides aerials and aerial arrays which are simple and efficient and have a bandwidth of about 30%. The invention employs a waveguide having a parallel-sided slot in one wall, the distance of the slot from the edges of the wall varying at least approximately sinusoidally along the length of the slot. The sinusoidal variation may be achieved by making the slot straight and the edges of the wall sinusoidal. Aerial arrays incorporating slotted waveguide aerials in accordance with the invention are also disclosed.

This application is a division of application Ser. No. 627,554, filed Mar. 31, 1967, now abandoned, originally in the names of Matthew Frederick Radford and Richard Arthur Waldron, for Slotted Wave Guide Aerials.

This invention relates to slotted waveguide aerials, i.e. to aerials of the kind constituted by a waveguide having one or more slots cut in a wall thereof, radiation taking place through the slot or slots when the waveguide is fed with microwave energy. The object of the invention is to provide improved slotted waveguide aerials which, though simple and relatively easy to manufacture, shall be relatively wide band.

Slotted waveguide aerials are, of course, well known, but such aerials as at present known and used in practice are undesirably limited as to their bandwidths. In general they have bandwidths of between 6% and 12% (depending upon their designs and type), and, so far as the present applicant is aware, a bandwidth of 12% is about the largest figure attainable with known slotted waveguide aerials as now in use. Known aerial arrays of the directional coupler type can be designed to give slightly better bandwidths—up to about 15%—but the bandwidth improvement over slotted waveguide aerials is not very great and they are expensive and difficult to construct. When substantially larger bandwidths are required, it is usual, at the present time, to resort to what are commonly called leaky waveguide arrays—i.e. waveguides in which one of the two narrower walls is replaced by a grid of wires running perpendicularly to the length of the guide. This type of aerial is quite costly and difficult to construct and has the serious defect of being of low efficiency because the beam emerges obliquely. The present invention provides aerials of relatively simple and satisfactory construction mechanically which are of good efficiency and capable of being designed to have bandwidths in the neighborhood of 30%—a very substantially

2

larger bandwidth than is attainable with known slotted waveguide aerials.

According to the invention disclosed in said application Ser. No. 627,554, a wide band slotted waveguide aerial comprises a waveguide which is of such cross section that it will propagate microwave energy in only the principal mode at which the guide cut-off frequency is lowest and which has at least one flat or approximately flat wall and, in said wall, a substantially parallel sided slot the distance of which forms an adjacent longitudinal extremity of said wall varies at least approximately sinusoidally along the length of said slot.

The expression "approximately sinusoidal" and similar expressions are herein employed to include not only sinusoidal shapes but also shapes consisting of a succession of straight line portions which together approximate to the sinusoidal. In the latter case the "corners" where the straight line portions meet may be smoothed or rounded off.

The waveguide may be of any of a variety of different cross sectional shapes, e.g. the said shape may be simple rectangular or it may approximate to a flattened ellipse or a so-called ridged waveguide may be used, the slot being, in all cases, in one broad wall.

According to the present invention, the approximately sinusoidal variation of distance of the slot in a slotted wall of the guide from an adjacent longitudinal extremity of said wall can be obtained by making said extremity approximately sinusoidal and said slot straight.

The slot width is not critical. A practical range for slot width is from $g/50$ to $g/10$ where g is the length of the wave in the guide. Very good results are obtainable with a slot width of $g/20$.

Slotted waveguide aerials in accordance with this invention are intended to be end fed, i.e. a radio transmitting and/or receiving system in accordance with the invention would comprise a slotted waveguide aerial according to the said invention and radio transmitting and/or receiving apparatus coupled to one end of the guide.

All parts of the approximately sinusoidal slot of an aerial in accordance with this invention contribute to the radiation, the portions which are or can be regarded as approximately inclined to the axis of the guide doing so because they are at a small angle to the longitudinal currents in the guide and the other portions, which are or can be regarded as mutually displaced portions approximately parallel to the axis of the guide doing so because by virtue of the displacement they couple with the lateral currents in the guide.

The amount of power radiated depends upon the amplitude of the approximate sinusoid and can be controlled in design between widely spaced limits by suitably choosing this amplitude.

If the period of the sinusoid is equal to the wavelength in the guide the direction of maximum radiation is at right angles to the guide axis, i.e. the aerial is a broadside one. If the wavelength in the guide is changed from this value the direction of maximum radiation will be swung so as to incline to the broadside direction. Accordingly, by suitably changing the frequency in the guide, the direction of maximum radiation may be varied over a usefully wide angle extending on both sides of the broadside direction.

Aerials in accordance with this invention may be stacked to form aerial arrays either with their broad walls (containing the slots) coplanar or spaced apart and parallel to one another and perpendicular to a certain plane. In the latter case, sideways extending feeder guides are used to convey the microwave energy from the slots in a direction parallel to the broad walls of the waveguides and perpendicular to the principal axes of the guides so as to deliver the energy to horns with their smaller ends

situated in said certain plane. If this is done, however, the path lengths from the slots to the smaller ends will be variable with a spatial periodicity equal to the spatial periodicity of the slots, thus causing the same spatial periodicity in the phase of the radiated waves which may produce an undesired radiation pattern. A more desirable radiation pattern can be obtained by interposing cavities between the waveguides and the feeder guides and so arranging matters that the path length from the waveguide slot to the cavity slot and thence to the smaller end of the horn has a periodicity twice that of the waveguide slots. This results in a more desirable radiation pattern over bandwidths up to about 30%. If, however, such an arrangement is used with a bandwidth exceeding about 30%, undesirable effects are liable to occur due to coupling into a new undesired mode of propagation arising in the structure. This difficulty can be overcome by using a waveguide which is sinusoidal or approximately so and has a straight slot in it as hereinbefore described. The need for the cavity is then eliminated since the path length from the slot to the smaller end of the horn is constant.

The invention is illustrated in the accompanying drawings which show several embodiments of the invention by way of example. In these drawings, FIGS. 1, 2, and 3 show waveguide aeri- als as disclosed in the parent application Ser. No. 627,554 and which may be used in accordance with the present invention, FIG. 4 shows an array of such waveguide aeri- als, and FIG. 5 and 6 show waveguide aeri- als according to the present invention.

Referring to FIG. 1, this shows an embodiment consisting of a simple rectangularly sectioned guide G of standard dimensions having a sinusoidal slot S cut in one broad wall B thereof. The dimension L is the period of the sinusoid. If this is equal to λ_g (the guided wavelength) the aerial will radiate broadside. A good value for the width of the slots S is $\lambda_g/20$.

FIG. 2 shows a modification differing from that of FIG. 1 only in that the slot, here referenced SS, is not a true sinusoid but only approximately sinusoidal. It consists of a succession of straight line portions which together approximate to the sinusoid. In the particular embodiment shown in FIG. 2, the portions comprise portions such as I which are inclined to the guide axis and portions such as D which are parallel to the guide axis and displaced with respect to one another.

FIG. 3 shows a modification differing from that of FIG. 2 only in that the rectangular guide G, instead of being of simple rectangular cross section, is ridged as known per se, having a ridge R so that it is of reduced height where the ridge occurs. Obviously, the guide of FIG. 1 could be ridged like the guide of FIG. 3.

FIG. 4 illustrates an aerial array comprising a number of slotted waveguide aeri- als, each having a cavity with a straight slotted cavity wall associated therewith, each aerial having a sinusoidal or approximately sinusoidal slot in a broad wall thereof. These aeri- als could be as illustrated in any of FIGS. 1-3. In FIG. 4, the guides are shown in end view and referenced G1, G2 and G3. There may be any number of such guides in the array, but it is sufficient, for the purpose of illustration, to show only three. Each guide has a sinusoidal or approximately sinusoidal slot S1, S2 or S3 which is covered by and opens into a cavity C1, C2 or C3 having a straight slot SC1, SC2 or SC3 in the wall thereof remote from the guide. These slots couple into sideways extending feeder guides F1, F2 or F3 which may terminate in horns or flares H1, H2 or H3 as shown. Such an array has the property that the path length from S1, S2 or S3 via SC1, SC2 or SC3 respectively to the end of F1, F2 or F3 respectively adjacent to H1, H2 or H3 respectively in the same whether S1, S2 or S3 are in the positions shown in FIG. 4 or are an equal distance from the centers of the broad walls in which they are situated but are on the opposite sides of the centers. The result is that the periodicity of the path lengths and thus of the phases at the ends of F1, F2, F3 is

twice that of the slots S1, S2, S3. This arrangement has the defect, above mentioned, that an unwanted mode can exist and be excited if operation over a bandwidth exceeding about 30% is required.

FIG. 5 shows in perspective a modification of an aerial as shown in FIG. 1. It consists of a rectangularly sectioned guide WG having a slot SG in one broad wall thereof, but, instead of the guide being straight and the slot sinusoidal, the slot is straight and the guide sinusoidal.

FIG. 6 shows a modification generally similar to that of FIG. 5, but differing therefrom only in that the guide section is not rectangular, but like a flattened ellipse, the broad walls of the guide being continued into and joined by outwardly curved narrow walls of arcuate or approximately arcuate shape. The sections of the guides shown in any of FIGS. 1-3 may similarly depart from the rectangular, e.g. they may similarly have outwardly curved narrow walls.

According to the present invention, aeri- als as shown in FIG. 2 or 3 may also be modified by substitution of a sinusoidal or approximately sinusoidal guide with a straight slot for a straight guide with a sinusoidal or approximately sinusoidal slot. In other words, the guide of FIG. 5 or 6, or a ridged 6, can be modified to have broad wall edges which are not sinusoidal but are composed of a series of straight lines producing an approximation to a sinusoid. The "corners" where such straight lines adjoin may be rounded or smoothed off to avoid undesired reflections from what would otherwise be sharp "corners." The illustrated arrangements with sinusoidal guides are, however, at present preferred. They are not unduly difficult to manufacture by machining from the solid. Aeri- als as exemplified by FIGS. 5 and 6 can be stacked to form an array. Because the distance from the slot to the smaller end of the horn is constant, there is no need for the cavity illustrated in FIG. 4 and difficulties caused by coupling into an unwanted mode are avoided. It will be seen that, when this is done, the defect of an array as shown in FIG. 4—namely undesired non-uniform phase distribution effects—is avoided since, the slot in each guide being straight and parallel to that in the associated cavity wall, there are no path length differences to cause such effects.

Although the invention may be carried into effect using waveguides of the at present standard rectangular cross sections, it is, as will already have been seen, not limited to the employment of such standard sized rectangular guides and other sectional shapes and sizes may be used. For example, very good results have been experimentally achieved using rectangular guides of reduced height (as compared to standard guides) the narrow dimension of the rectangular section being only about one-quarter of the broad dimension instead of the more usual one-half,

I claim:

1. A wide band slotted waveguide aerial comprising a waveguide which is of such cross section that it will propagate microwave energy in only the principal mode at which the guide cut-off frequency is lowest and which has at least one substantially flat wall and, in said wall, a substantially parallel sided slot the distance of which from longitudinal extremities of said wall varies at least approximately sinusoidally along the length of said slot, and in which said longitudinal extremities of said wall are substantially sinusoidal and said slot is substantially straight.

2. An aerial as claimed in claim 1, wherein the width of the slot is approximately one-twentieth of the guided wavelength.

3. A wide band slotted waveguide aerial as defined in claim 1 wherein the width of the slot is within a range from about one-fiftieth to about one-tenth of the guided wavelength.

4. A wide band slotted waveguide aerial as defined in claim 1 wherein the periods of the substantially sinu-

5

soidal longitudinal extremities are substantially equal the period of the guided wavelength.

5. A wide band slotted waveguide aerial as defined in claim 3 wherein the periods of the substantially sinusoidal longitudinal extremities are substantially equal to the period of the guided wavelength.

6. A wide band slotted waveguide aerial as defined in claim 2 wherein the periods of the substantially sinusoidal longitudinal extremities are substantially equal to the period of the guided wavelength.

7. An aerial array comprising a plurality of wide band slotted waveguide aerials, each of which comprises a waveguide which is of such cross section that it will propagate microwave energy in only the principal mode at which the guide cut-off frequency is lowest and which has at least one flat or approximately flat wall and, in said wall, a substantially parallel sided slot the distance of which from an adjacent longitudinal extremity of said wall varies at least approximately sinusoidally along the length of said slot, said aerials being stacked side-by-side and spaced apart, each guide having a slotted cavity structure fitted over the slot in said guide, the slot in the cavity structure providing coupling with a sideways extending guide, each pair of slotted guides having, in the space between them, the cavity structure and the sideways extending guide associated with one slotted guide of the pair, all said sideways extending guides being parallel with one another so that a beam-like polar radiation diagram is obtained.

6

8. An aerial array as claimed in claim 7 in which, in each aerial, the cross sectional shape of the guide is that of a flattened ellipse with the slot in one broad wall.

9. An aerial array as claimed in claim 7, wherein the slotted guides are sinusoidal or approximately so and the slots therein are straight.

10. An aerial array as claimed in claim 7, in which, in each aerial, the width of the slot is approximately one-twentieth of the guided wavelength.

References Cited

UNITED STATES PATENTS

2,676,257	4/1954	Hebenstreit	-----	343—771	X
2,681,990	6/1954	Purcell	-----	343—771	
3,039,097	6/1962	Strumwasser et al.	----	343—771	

FOREIGN PATENTS

580,377	9/1946	Great Britain.
983,033	2/1951	France.
1,006,104	1/1952	France.

HERMAN K. SAALBACH, Primary Examiner

S. CHATMON, JR., Assistant Examiner

U.S. Cl. X.R.

343—767