

Jan. 21, 1969

P. FOLDES

3,423,756

SCANNING ANTENNA FEED

Filed Sept. 10, 1964

Sheet 1 of 4

Fig. 1.

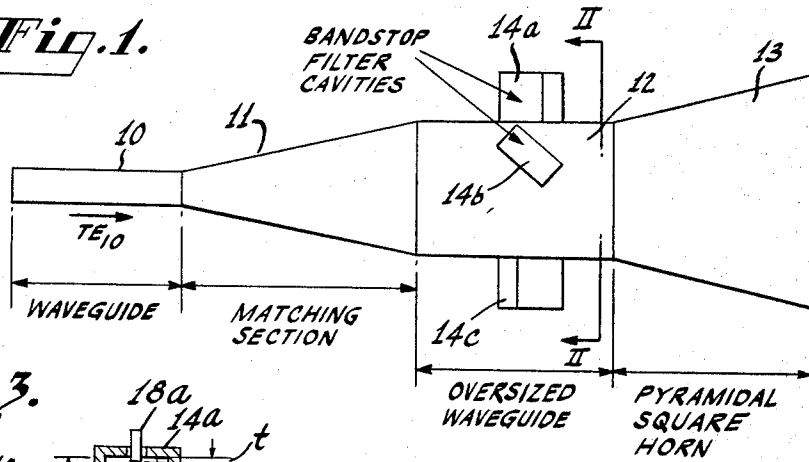


Fig. 3.

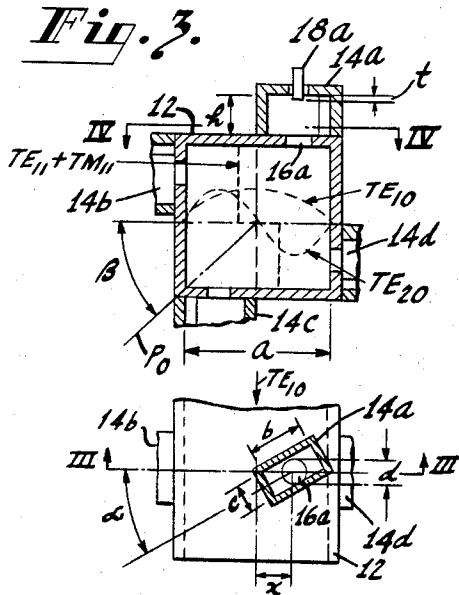


Fig. 4.

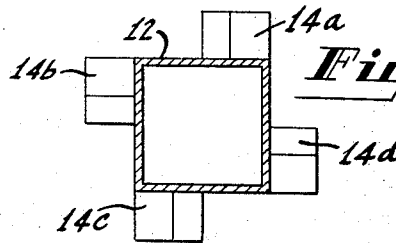
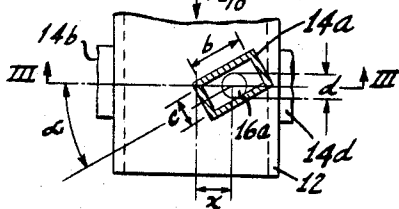


Fig. 2.

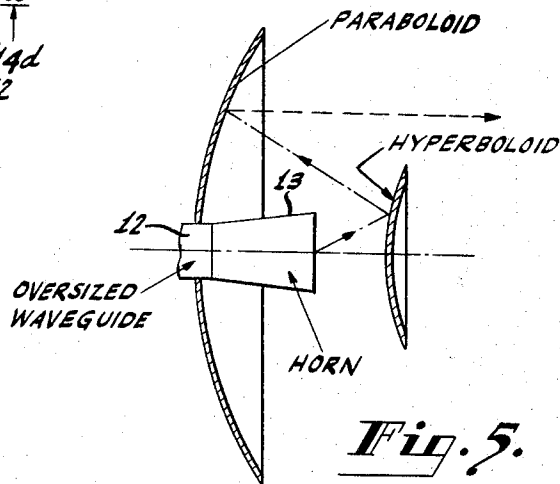


Fig. 5.

INVENTOR,

PETER FOLDES

BY

Floyd M. Harris

Attorney

Jan. 21, 1969

P. FOLDES

3,423,756

SCANNING ANTENNA FEED

Filed Sept. 10, 1964

Sheet 2 of 4

Fig. 6.

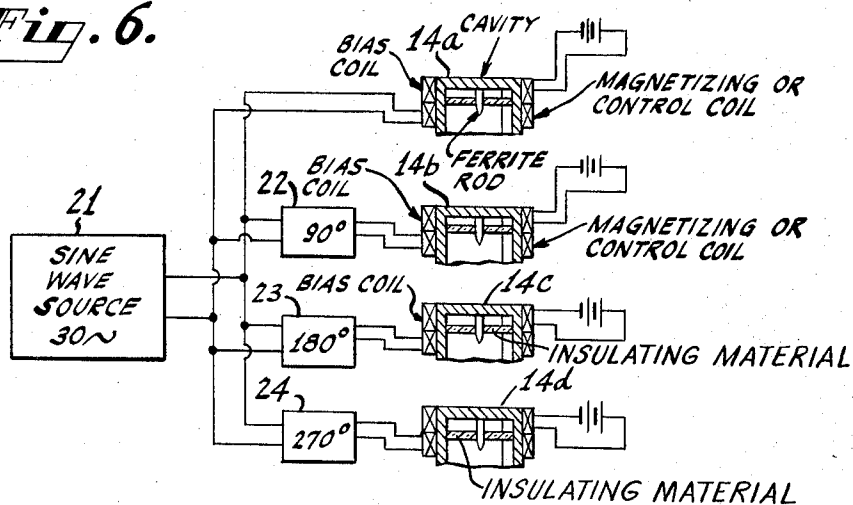


Fig. 7.

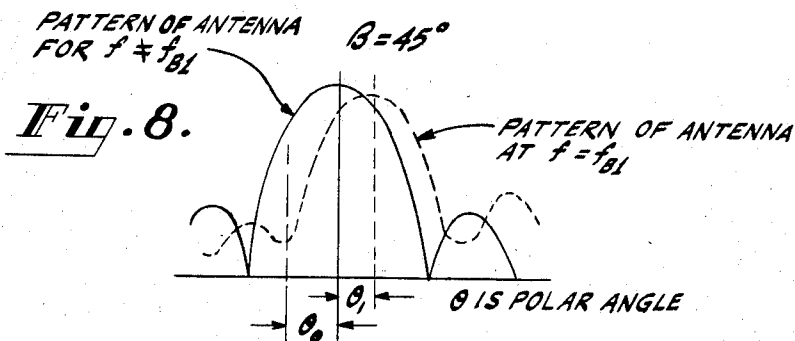
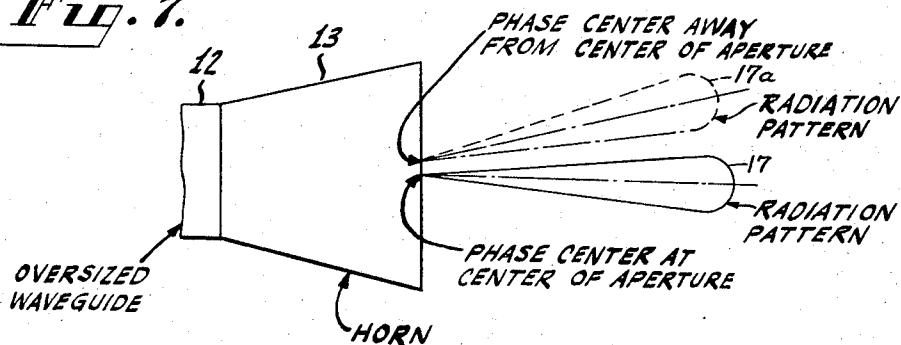


Fig. 8.

INVENTOR.
PETER FOLDES
 BY *Floyd M. Harris*
 Attorney

Jan. 21, 1969

P. FOLDES

3,423,756

SCANNING ANTENNA FEED

Filed Sept. 10, 1964

Sheet 3 of 4

Fig. 9.

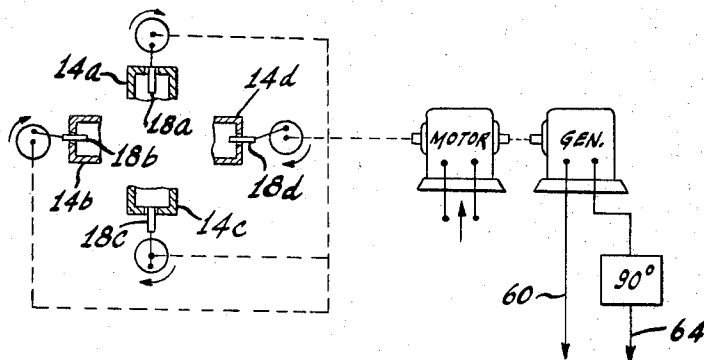


Fig. 10.

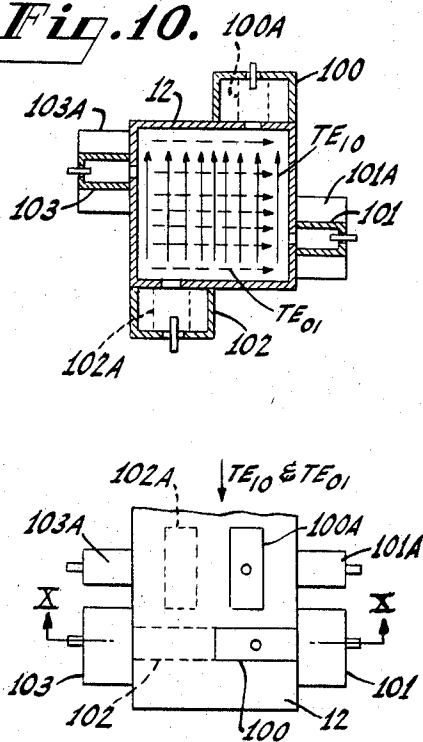
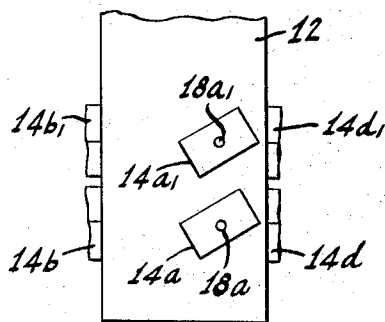


Fig. 11.

Fig. 13.



INVENTOR.
PETER FOLDES
BY *Floyd M. Harris*
Attorney

Jan. 21, 1969

P. FOLDES

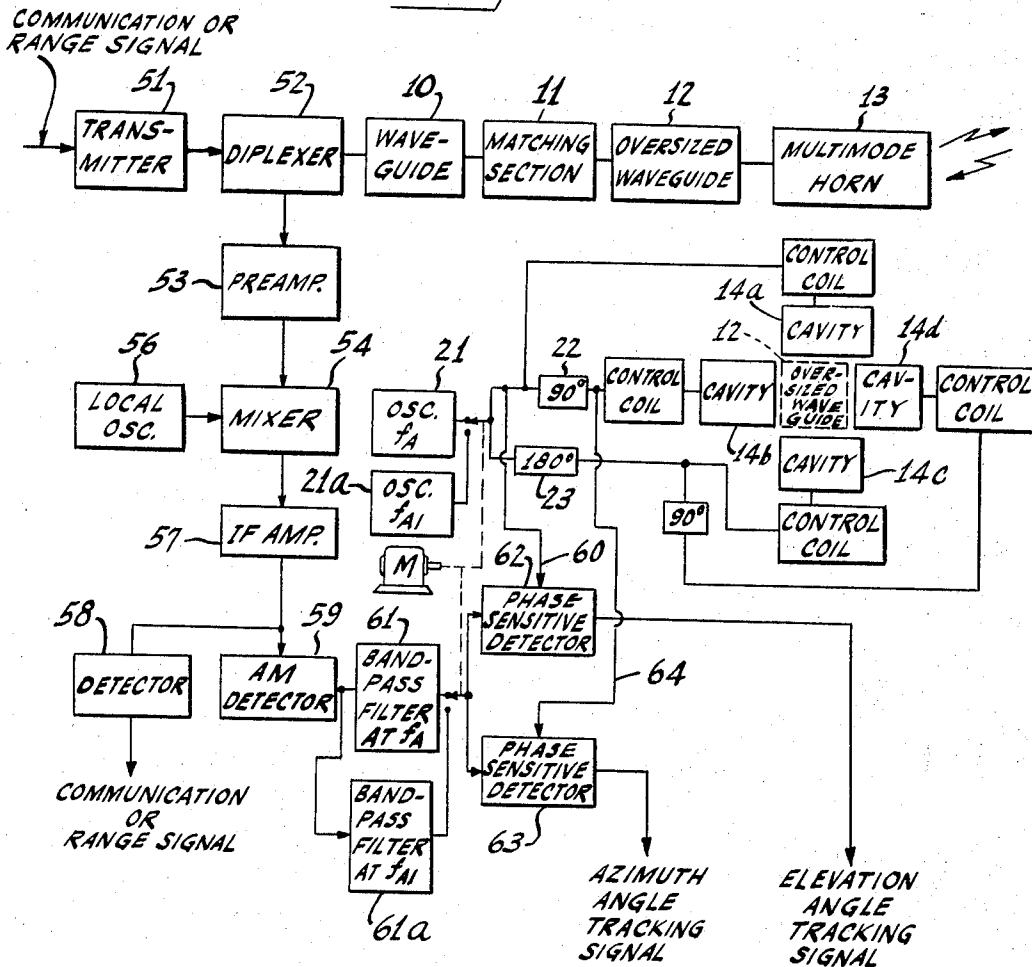
3,423,756

SCANNING ANTENNA FEED

Filed Sept. 10, 1964

Sheet 4 of 4

Fig. 12.



INVENTOR.

PETER FOLDES

BY

Floyd M. Harris

Attorney

1

3,423,756

SCANNING ANTENNA FEED

Peter Foldes, Montreal, Quebec, Canada, assignor to
Radio Corporation of America, a corporation of
Delaware

Filed Sept. 10, 1964, Ser. No. 395,401
U.S. Cl. 343—775 11 Claims
Int. Cl. H01q 19/14

ABSTRACT OF THE DISCLOSURE

An electronically controlled conical scanning antenna feed is provided by an oversized waveguide having four tuned cavities mounted about the waveguide and coupled to it. The signal of the frequency to which these cavities are tuned is split into higher order modes thus resulting in the movement of the radiation phase center from the center of the antenna aperture. By tuning the four cavities in sequence to the frequency of this signal, it is conically scanned. Signals at other frequencies if sufficiently separated from the frequency to which the cavities are tuned continue to propagate through the waveguide without any disturbance within the waveguide.

My invention relates to antennas and particularly to an improved feed system for deflecting the antenna pattern. In a preferred embodiment of the invention the pattern is deflected so as to conically scan without the utilization of mechanical movement of any large component, or even without any mechanical movement.

The invention will be described with particular reference to an antenna designed for use as a ground station antenna for a communications satellite system. Such an antenna should transmit and receive communication signals lying within a wide frequency band, and it should also transmit a signal having a radiation pattern or patterns having a characteristic such that when directed to a target such as a satellite an error signal is provided which may be utilized to make the antenna automatically track the target. Thus, the communication signal pattern is always directed toward the satellite.

The desired antenna tracking may be obtained, for example, by employing a monopulse antenna or by employing a conical scanning antenna. The latter has certain advantages; for example, it requires only one receiver.

The present invention, as applied to a communications satellite system, is an improved conical scanning antenna. Stated more specifically, it is an improved antenna feed which, in the example to be described, feeds a Cassegrainian antenna. The conical scanning is obtained without mechanically moving either the antenna reflectors or the feed. Also, if desired, only a narrow frequency band signal in the vicinity of a frequency f_B is conically scanned; the communication signals at a different frequency f_C which are transmitted or received by the antenna not being affected by the conical scan. Thus, in this case, there is provided an optimum gain characteristic for the communication signals.

An object of the invention is to provide an improved feed system for an antenna.

A further object of the invention is to provide an improved conical scanning radiating system.

A further object of the invention is to provide an improved means for deflecting an antenna radiation pattern.

A still further object of the invention is to provide an improved means for deflecting a radiation pattern without the mechanical movement of any large component.

A still further object of the invention is to provide an improved feed or radiating system that will radiate energy over a wide band of frequencies within a certain radiation

2

pattern and that will deflect only the radiation pattern of a narrow band of frequencies within said wide band.

In practicing one embodiment of the invention, the antenna feed comprises an oversized waveguide to which the signals are fed from a waveguide dimensioned to propagate the signals in the TE_{10} mode, for example. The signals propagate through the oversized waveguide in this same mode only so long as no asymmetry or discontinuity is introduced in the oversized waveguide.

A signal at any preselected frequency passing through the antenna feed may be made to radiate in a radiation pattern (beam) that conically scans by utilizing four bandstop filter cavities that are mounted around the oversized waveguide, each cavity mounted asymmetrically with respect to a symmetry plane of the waveguide, and each cavity coupled to the waveguide when the cavity is tuned to resonate at the said preselected frequency. Such coupling introduces an asymmetrical discontinuity in the oversized waveguide so that the mode TE_{10} , in the instant example, is split into the additional modes TE_{20} and TE_{11} and TM_{11} . This results in deflection of the beam radiated or propagated from the oversized guide. By properly tuning the four cavities in time succession to resonate at the selected frequency, the signal at this frequency has its radiation pattern deflected so that it scans on a circular cone surface.

The present invention is particularly useful for ground stations of a communications satellite system because communication signals at widely spaced frequencies can be passed through the antenna feed without being deflected, while a signal at a different frequency may at the same time be passed through the feed and its pattern made to conically scan so as to provide error signals which may be employed to make the antenna automatically track the communications satellite. The communication signals being transmitted to or received from the satellite by the antenna are not affected by the conical scanning.

The invention will be described in detail with reference to the accompanying drawing, in which:

FIG. 1 is a side view of an antenna feed or radiating system constructed in accordance with one embodiment of the invention;

FIG. 2 is a view taken on the line II—II of FIG. 1 looking in the direction of the arrows;

FIG. 3 is a cross-sectional view of the oversized waveguide and the bandstop filter cavities shown in FIG. 1, this view being taken on the line III—III of FIG. 4 looking in the direction of the arrows;

FIG. 4 is a view taken on the line IV—IV of FIG. 3 looking in the direction of the arrows;

FIG. 5 is a view illustrating a Cassegrainian antenna that is fed by an antenna feed embodying the present invention;

FIG. 6 is a schematic diagram illustrating one way of so varying the resonant frequency of the bandstop filter cavities of FIG. 1 as to provide conical scanning;

FIG. 7 is a view showing a portion of the feed system of FIG. 1 together with an illustration of radiation patterns that are referred to in explaining the invention;

FIG. 8 is a pair of graphs representing radiation patterns which are referred to in explaining the invention;

FIG. 9 is a schematic diagram illustrating another way of so varying the resonant frequency of the bandstop filter cavities of FIG. 1 as to provide conical scanning;

FIG. 10 is a cross-sectional view of the oversized waveguide with bandstop filter cavities mounted thereon in accordance with another embodiment of the invention, this view being taken on the line X—X of FIG. 11 looking in the direction of the arrows;

FIG. 11 is a top view of the waveguide and cavities shown in FIG. 10;

FIG. 12 is a block diagram of a transmitter-receiver in which the present invention is incorporated; and

FIG. 13 is a top view of the oversized waveguide with bandstop filter cavities mounted thereon in accordance with another embodiment of the invention.

In the several figures, like parts are indicated by similar reference characters.

FIGS. 1 and 2 illustrate an embodiment of the invention designed to provide conical scanning. More specifically, it is designed to pass signals within a wide frequency band such as desired at the ground station of a communication satellite system, and is designed to conically scan the radiation pattern of a narrow band of energy within said wide frequency band. For example, the antenna feed of FIG. 1 will pass any communication signal from 5000 megacycles per second to 7500 megacycles per second; and within this frequency band a signal in the vicinity of 6000 megacycles per second may have its radiation pattern conically scanned.

The following description will be with reference to transmission or radiation from the feed system. However, on the basis of reciprocity theorem this is also a description of the operation when the feed system is receiving signal, as from a satellite. In the case of reception of signals, the signal that is conically scanned (the above-mentioned signal in the vicinity of 6000 mc., for example) may be the beacon signal from a satellite which is acted upon by conical scanning in the feed system to produce an error signal which may be utilized to make the antenna track the satellite.

In the embodiment shown in FIGS. 1 and 2, the signal is passed through a transmission line 10 which preferably is either a square or a rectangular waveguide. In the present example it is a square waveguide. The largest side dimension of the waveguide 10 is greater than one-half λ and is less than λ where λ is the wavelength of the lowest practical frequency to be passed. The signal is propagated down the line 10 in the TE_{10} mode, and is passed in that mode through an impedance matching or transition section 11 to a square oversized waveguide 12. The length of the transition section 11 preferably is from three to five times λ so that reflection from the transition remains negligible. The waveguide 12 preferably feeds into a pyramidal square horn 13 which, in the preferred embodiment, radiates the signal to the hyperboloid of a Cassegrainian antenna (see FIG. 5). The horn 13 may also be described as an oversized waveguide which is flared. If desired, the oversized waveguide 12 and the horn 13 may be circular. They should have two orthogonal symmetry planes. With reference to FIG. 5, it is not drawn to scale. Actual typical values are: Diameter of paraboloid=300 wavelengths; diameter of hyperboloid=30 wavelengths; aperture size of horn =3 wavelengths.

In order to provide conical scanning, four bandstop filter cavities 14a, 14b, 14c, and 14d are mounted on the four sides of the oversized waveguide. If preferred, these cavities may be mounted at the throat cross-section of the horn or on the horn itself. These cavities and their mounting are shown in more detail in FIGS. 3 and 4 which show that there is a coupling hole for coupling each cavity to the oversized waveguide. This coupling is effective, however, only for signal at substantially the frequency at which the cavities are resonant. Thus, signals at frequencies not close to the frequency at which the cavities are resonant are propagated down the oversized waveguide in the TE_{10} mode and are radiated in a radiation pattern which is not deflected.

The action of the bandstop filter cavities will now be described with particular reference to FIGS. 3 and 4. The oversized waveguide 12 is dimensioned so as to support the four waveguide modes TE_{10} , TE_{20} , and TE_{11} and TM_{11} . These modes can be propagated for either vertical polarization or horizontal polarization or both. The inside width "a" (and also height since the waveguide is square) is greater than λ and less than 1.5λ where λ is the longest

operational wavelength. By "longest operational wavelength" is meant the wavelength of the signal of the lowest practical frequency to be propagated by the feed system. In the example being described, this frequency is 5000 megacycles per second. The longest practical wavelength is usually limited by losses in the waveguide. By the use of a ridge-loaded waveguide this wavelength can be made greater.

The four bandstop filter cavities and their coupling to the oversized waveguide are alike. Referring to the cavity 14a as shown in FIGS. 3 and 4, it is on the top of the waveguide 12 and is coupled to the waveguide 12 through a circular hole 16a. The cavity 14a and its coupling hole are mounted off-center with respect to the center axis of the top of the waveguide 12 (with respect to the vertical symmetry plane) so that the cavity 14a is coupled asymmetri- cally to the wave guide 12.

If the bandstop filter cavity 14a is tuned to a frequency in the vicinity of a frequency f_B which is not close to the operational frequency f_C , the cavity has practically no effect on the propagation of frequency f_C signal in the waveguide 12. As an example, if the cavity is tuned to a frequency of 6005 mc. and the operational frequency f_C is a 6010 mc. carrier wave carrying voice channels, the 6010 mc. carrier wave is substantially unaffected by the cavity. In this case the incoming 6010 mc. signal being propagated in the TE_{10} mode travels through the waveguide 10 (FIG. 1), the matching section 11, the waveguide 12 and the horn 13 without any disturbance, and the horn 13 radiates a symmetrical pencil beam 17 (radiation pattern) as illustrated in FIGS. 7 and 8 in solid line. Thus, any conical scanning of the radiation pattern of a signal at a frequency in the vicinity of f_B (f_B being 6000 mc. in this example) that is produced by the action of the cavities 14a, 14b, 14c and 14d does not deflect or otherwise affect the signal at frequency f_C (6010 mc. in this example). The minimum separation between f_B and f_C which provides unaffected operation for f_C depends upon the geometry of the bandstop cavities.

Now consider the case where conical scan is desired so that an error signal is obtained which may be employed to make the antenna automatically track a target such as a satellite. The four cavities 14a, etc., are tunable through a frequency range from f_{B1} to f_{B2} where the center frequency is f_B , which in this example is 6000 mc. In this example it will be assumed that $f_{B1}=6005$ mc. and that $f_{B2}=5995$ mc. A signal of frequency f_{B1} , for example, is propagated down the antenna feed (FIG. 1) in the TE_{10} mode to the oversized waveguide 12. Now the signal at frequency f_{B1} as it passes through the waveguide 12 is affected by one or more of the cavities 14a, etc., since they are tuned successively to the frequency f_{B1} and are, therefore, successively coupled to waveguide 12 at this frequency. Since the coupling is asymmetrical with respect to waveguide 12, the incoming TE_{10} mode splits into the above-mentioned four modes, namely, TE_{10} , TE_{20} , and TE_{11} and TM_{11} . These four modes are represented by graphs in FIG. 3. The TE_{10} and TE_{20} graphs represent the voltage read from a probe that is moved horizontally through the waveguide. The $TE_{11}+TM_{11}$ graph is for the sum of these two modes and represents the voltage read from a probe that is moved vertically through the waveguide. The presence of these modes results in an asymmetrical field distribution in the antenna feed from the cavity coupling to the output aperture of the horn 13.

Referring for the moment only to the effect of the one cavity 14a when it is resonant at frequency f_{B1} and the signal frequency is f_{B1} , the asymmetry can be characterized by an amplitude and phase asymmetry, and furthermore by a movement of the radiation phase center from the center of the aperture. This shift in the position of the phase center is illustrated in FIG. 7 where the radiation pattern 17a in broken lines represents the pattern of the f_{B1} frequency signal that is being deflected by the

cavity 14a. Also, it will be noted that the radiation pattern 17a is tilted off axis.

The frequency f_{B1} at which the cavity is resonant, and at which the radiation pattern of a signal is tilted, can be adjusted by selecting the geometrical dimensions b , c and h of the cavity (see FIGS. 3 and 4), and by selecting the amount t that a tuning pin 18a extends into the cavity.

The amount of angular tilt θ of the radiation pattern can be controlled by the diameter d of the coupling hole 16a and by the distance x that the center of the coupling hole is away from the center line of the top of the oversized waveguide 12.

If the input signal to waveguide 12 is dual or circularly polarized then one arrangement that is possible to obtain coupling to both the TE_{10} and TE_{01} modes is one that uses four cavities with the one cavity on each side being rotated as shown in FIGURE 1. Still referring only to the effect of a single cavity, the tilt of the radiation pattern occurs in a plane indicated in FIG. 3 as P_0 . The angle that the plane P_0 makes with a horizontal plane passing through the center of the waveguide 12 is identified as the angle β . This angle β of the plane in which the tilt occurs can be controlled by the angle α shown in FIG. 4. It will be seen that the angle α is the angle at which the wide side of the cavity is tilted with respect to a plane drawn perpendicular to the longitudinal axis of the oversized waveguide 12.

In the example illustrated, the angle α is adjusted so that the angle β of the plane in which the tilt occurs is 45 degrees. In this example the angle α is 12.5 degrees. Therefore the radiation pattern or beam is tilted in the same plane regardless of whether the exciting wave in the waveguide 12 is the TE_{10} mode or the TE_{01} mode. In this case the antenna feed may be used for either linear or circular polarizations. If linear polarization is used, the desired conical scanning at the frequency f_{B1} may be obtained regardless of the particular value of the angle α and, therefore, of the angle β .

In order that conical scanning may be provided, rather than deflection in one plane, four cavities are mounted around the oversized waveguide 12, one cavity on each side of the cavity as shown in FIGS. 1 to 4. The four cavities indicated at 14a, 14b, 14c and 14d are mounted symmetrically around the waveguide 12, but with each cavity mounted asymmetrically with respect to the symmetry plane. Each cavity is a duplicate of the other, and each cavity is mounted on and coupled to the waveguide the same as described in connection with the cavity 14a.

Assume a signal at frequency f_{B1} is propagated down the antenna feed and is to be conically scanned. As shown in FIGS. 3 and 9, in order to provide conical scanning, movable tuning pins 18a, 18b, 18c and 18d are provided for the cavities 14a, 14b, 14c and 14d, respectively. Each pin is mounted so that it may be slid in and out of its cavity. The pins are slid in and out sinusoidally with a 90 degree or one quarter time period delay in the motion of the pin in consecutive cavities. There are F_A complete periods per second, F_A preferably being an audio frequency. One suitable drive to provide such motion for the tuning pins is illustrated in FIG. 9. As shown in FIG. 9, each tuning pin is driven by a crank, and the cranks are phased so that when pin 18a is fully in the cavity (and the cavity resonant at frequency f_{B1}), the pin 18b is one-half way in, the pin 18c is completely out (180 degrees out of phase with pin 18a), and the pin 18d is one-half way in. At this position of the tuning pins the cavity 14a is producing the entire deflection of the signal f_{B1} radiation pattern, the cavity 14c is producing no deflection since it is not resonant to the signal at frequency f_{B1} , and the cavities 14b and 14d are each producing less than maximum deflection but in equal amounts and in opposite directions so that their deflections cancel.

In the example being described, each cavity is resonant at frequency f_{B2} (5995 mc. in this example) when its tuning pin is completely out. Therefore a signal at fre-

quency f_{B2} propagated down the antenna feed will be conically scanned as previously described by driving the tuning pins as shown in FIG. 9.

A signal at the center frequency f_B , the frequency at which a cavity is resonant with its tuning pin half way in, will not be deflected by driving the tuning pins. However, a signal at any frequency between f_B and f_{B1} or between f_B and f_{B2} may be conically scanned by driving the tuning pins, although the cone will not be a circular one. In practice this deviation of the cone from the circular has no importance because it only makes the horizontal and vertical error signals slightly different, and it causes a slight reduction in the error voltage because the audio filter in the detector circuit for this voltage removes the higher harmonics of the error signal which result from a noncircular cone scanning. At frequencies f_{B1} and f_{B2} the cone of scanning is practically circular.

The communication frequency band of this antenna system when used for communication ideally is

$$f_C \leq f_{B2} - f_1 \text{ or } f_C \geq f_{B1} + f_1$$

where f_1 is the 3 db bandwidth of a cavity and is

$$f_1 = \frac{1}{2} (f_{B1} - f_{B2})$$

With f_C so located, a signal at either f_{B1} or f_{B2} , or at a frequency between f_{B1} and f_{B2} , may be conically scanned without deflecting (conically scanning) the communication signal.

By tolerating a small amount of conical scanning loss, the communication frequency band f_C can be in the frequency band of scanning; for example, f_C might be somewhere between f_{B1} and f_{B2} . In general, this is not a preferred arrangement, but it is a useable one for communication.

FIG. 6 illustrates an arrangement for obtaining conical scanning without even a minor mechanical motion. Instead of tuning pins, each cavity is provided with a ferrite rod and a magnetizing or control coil for changing the permeability of the ferrite rod. In this case the cavities should be of a non-magnetic material such as brass. Each ferrite rod may be held in place by a sheet of insulating material, such as Teflon, frictionally supported in the cavity.

The magnetizing coils have a sine wave current flowing through them which is supplied from a source 21. The current in the magnetizing coils is displaced 90 degrees in consecutive coils by means of the phase shifters 22, 23 and 24. Each cavity is also provided with a bias coil carrying a steady direct current supplied from a D-C source such as a battery. The magnetic field of the bias coil causes the ferrite rod to have a permeability intermediate its maximum and minimum permeabilities produced by the sine wave current flowing through the magnetizing coil. The conical scanning action is the same as that described in connection with FIG. 9. Specifically, taking the instant when maximum positive polarity is flowing through the magnetizing coil of cavity 14a, the ferrite rod of 14a has maximum permeability (the fields of the magnetizing and bias coils adding) and cavity 14a is tuned to resonance at frequency f_{B1} . At the same time, maximum current of negative polarity is flowing through the control coil of 14c and the ferrite rod of cavity 14c has minimum permeability (since the sine wave field cancels the bias field) so that cavity 14c is not resonant at frequency f_{B1} . No current is flowing through the magnetizing or control coils of cavities 14b and 14d at this instant so that the ferrite rods in these cavities have the same permeability, which is a value intermediate the maximum and minimum permeabilities. Thus, the deflection effects of cavities 14b and 14d cancel out at this instant. All deflection of the radiation pattern at this instant is caused by the cavity 14a.

In the foregoing examples, the coupling hole or aperture between each bandstop cavity and the oversized waveguide has been described and illustrated as a circular

hole. However, it may have other shapes. For maximum coupling, the coupling hole should be a slot having a length about equal to a half free space wavelength of the signal to be conically scanned, and the length to width ratio of the slot should be about ten. Also, the largest coupling is obtained if the coupling hole is about half-way between the symmetry plane and the side wall of the cavity. The coupling is most frequency sensitive when adjusted for maximum coupling as described above. Considerable frequency sensitivity may be desirable so that the existence of the TE_{20} and TE_{11} and TM_{11} modes can be restricted to a narrower frequency band.

If the input wave from waveguide 10 is dual or circularly polarized, the arrangement using four cavities at an angle α described in the foregoing example may be used where the angle α is adjusted so that the cavity has an equal amount of coupling to both the TE_{10} and the TE_{01} exciting modes, and the corresponding beam tilt occurs in the diagonal plane of the radiating horn 13.

A second arrangement using eight cavities as shown in FIGS. 10 and 11 may be used where the input wave is dual or circularly polarized. Each cavity is provided with a tuning pin as previously described. In this arrangement, for a signal to be deflected, the cavities 100, 101, 102 and 103 are coupled to the signal being propagated in the TE_{10} mode. The cavities 100 and 102 at the top and bottom of the waveguide 12, respectively, have their wide dimension perpendicular to the direction of propagation of the signal. The cavities 101 and 103 at the sides of the waveguide 12 have their wide dimensions parallel to the direction of propagation of the signal.

In the example now being described, the signal is also being propagated in the TE_{01} mode. The cavities 100A, 101A, 102A and 103A are coupled to the signal in this mode. As illustrated, the cavities 100A and 102A on the top and bottom of the waveguide 12, respectively, have their wide dimension parallel to the direction of propagation of the signal. The cavities 101A and 103A on the sides of the waveguide 12 have their wide dimension perpendicular to the direction of propagation of the signal.

In the case of either dual polarization (illustrated in FIG. 10) or circular polarization, the actuation of the tuning pins for producing conical scanning is the same as previously described. It may be noted that when the tuning pin of cavity 100 is extended into its cavity a maximum amount, the tuning pin of its adjacent cavity 100A is also extended into its cavity a maximum amount. The same is true with respect to the operation of the tuning pins of the other adjacent cavities.

FIG. 12 illustrates in block diagram a communication or radar system which incorporates an embodiment of the present invention. If employed as a radar system, it may be of the pulse-echo type for tracking a target and measuring its range.

The system comprises a radio transmitter 51 which feeds signal through a diplexer 52 to the waveguide 10, matching section 11, oversized waveguide 12 and multimode horn 13 previously described. The received signal passes through the horn 13, waveguide 12, matching section 11, and waveguide 10, and through the diplexer 52 to a preamplifier 53. The amplified signal is passed to a mixer 54 where it beats with signal from a local oscillator 56. The resulting IF signal is amplified in amplifier 57 and detected by detector 58 to supply the demodulated received signal.

The error signal of frequency f_A resulting from the conical scanning is detected by an amplitude modulation detector 59 and supplied to a bandpass filter 61 that passes the error signal and applies it to phase sensitive detectors 62 and 63. Each of the detectors 62 and 63 is sensitive to both the relative phase and the relative amplitudes of the signals applied to it. Each of these detectors preferably is phase locked in accordance with well-known practice.

The previously described arrangement for conical scan-

ning employing ferrite rods in the bandstop filter cavities is shown in block diagram form. Signal at frequency f_A from the oscillator 21 is applied without phase shift over a lead 60 to the phase detector 62 where it functions as a reference signal for the elevation error signal. The output of detector 62 is a signal that controls, by a servo system (not shown), the elevation tracking of the antenna being fed by the multimode horn. Also, signal at frequency f_A is applied with 90 degree phase shift over a lead 64 to the phase detector 63 where it functions as a reference signal for the azimuth error signal. The output of detector 63 is a signal that controls the azimuth tracking of the antenna by means of a servo system (not shown).

If the conical scanning is produced by means of tuning pins driven as shown in FIG. 9, the reference signals for the detectors 62 and 63 may be obtained from signal supplied from a generator coupled to the driving motor as illustrated.

As illustrated in FIG. 13, the conical scanning can be restricted to a narrower frequency band by locating more than one cavity along the direction of propagation of the signal. In the example illustrated, two cavities are located along this direction, these being 14a and 14a1 on the top of waveguide 12, 14b and 14b1 on one side, and 14d and 14d1 on the other side. The two cavities on the bottom of waveguide 12 are not shown. The tuning pins for the cavities 14a and 14a1 are indicated at 18a and 18a1, respectively. The two cavities in line are tuned to the same frequency. When a signal is being conically scanned, the tuning pins of the two cavities in line are moved together, the tuning pin 18a1 being completely out when the tuning pin 18a is completely out.

If, for some reason, the target tracking is to be achieved in a wide frequency band, then the cavities which are in line along the direction of signal propagation may be tuned to different and equally spaced frequencies with their frequency spectrums overlapping. There may be three or more such cavities rather than only the two in line cavities shown in FIG. 13.

It may be desirable to design the antenna feed so that the antenna is capable of tracking any one of several satellites or targets. Such satellites may each be radiating a beacon signal at a frequency different from the beacon frequencies of the other satellites. For such a design the cavities which are in line may be designed to be resonant at widely spaced frequencies located in the overall communication frequency band of the antenna.

The narrowness of the frequency band to which the conical scanning is restricted depends in large part upon how sharply resonant the cavities are. A cavity is resonant at a signal frequency if its electrical length is equal to one-half the signal wavelength. However, the cavity may be made more sharply resonant to this frequency if the cavity is given a length that is a multiple of this one-half wavelength.

The bandstop filter cavities have been described as being mounted on the oversized waveguide 12. Instead of being mounted on waveguide 12, they may be mounted at the throat of the horn 13 or on the multimode horn 13 itself. The conical scanning operation is the same whether the bandstop filter cavities are mounted on the waveguide 12 or on the horn 13. As previously mentioned, the horn 13 is a flared oversized waveguide. The phrase "oversized waveguide" in the claims refers to the horn 13 as well as to the waveguide 12.

It may be noted that the conical scanning system can be optimized for the tracking signal. For example, assume the antenna feed of FIG. 1 is operated with the communication signal having a frequency far enough removed from the frequency of the signal being conically scanned so that the communication signal is unaffected by the conical scanning. Then the antenna pattern's angle of tilt θ_1 , shown in FIG. 8, preferably is made equal to $0.5 \theta_0$ where, as shown in FIG. 8, θ_0 is the half angle between the 3 db points of the pattern. On the other hand,

if the communication signal itself is being conically scanned, then the angle of tilt θ_1 preferably is given a value between $0.3 \theta_0$ and $0.4 \theta_0$.

There will now be described a way in which a system, such as that illustrated in FIG. 12, may be made less sensitive to error caused by amplitude modulation of the received signal due, for example, to fading, target scintillation or target rotation. Instead of rotating the antenna beam at one rate such as 30 cycles per second, it may be rotated alternately at two different rates such as 30 c.p.s. and 45 c.p.s. This may be done as illustrated in FIG. 12 by providing a second oscillator 21a and a second bandpass filter 61a. As an example, the oscillator 21 has a frequency of 30 c.p.s. and the oscillator 21a has a frequency of 45 c.p.s. Then the filters 61 and 61a are designed to pass 30 c.p.s. and 45 c.p.s., respectively. A motor M drives switches as illustrated to connect alternately the oscillator 21 and filter 61 to the circuit and the oscillator 21a and filter 61a to the circuit. This switching may be done, for example, at the rate of once per minute. Thus, an undesired amplitude modulation of a frequency of approximately 30 c.p.s. due to target scintillation, for example, will be less likely to prevent the antenna from tracking the target.

Instead of switching as described above, the oscillators 21 and 21a may be connected to feed simultaneously into the system so the antenna beam will scan at different rates, i.e., the beam will speed up and slow down in the course of making several rotations. With this arrangement the bandpass filters 61 and 61a are connected in parallel so that their outputs are connected at all times to the two phase sensitive detectors.

What is claimed is:

1. An antenna feed for providing angular deflection of signals within one frequency band while simultaneously passing undeflected signals within other frequency bands, said feed comprising:

a waveguide having two orthogonal symmetry planes, a transmission line connected to said waveguide for propagating to said waveguide said signals within said one frequency band and within said other frequency bands in a dominant mode,

said waveguide being dimensioned so as to support the propagation of said signals in additional modes, means for only splitting said dominant mode of said signals within said one frequency band into said additional modes causing deflection of said signals within said one frequency band and for simultaneously passing undeflected said signals within said other frequency bands.

2. An antenna feed for providing angular deflection of signals within one frequency band while simultaneously passing undeflected signals within other frequency bands comprising:

an oversized waveguide having two orthogonal symmetry planes,

a transmission line coupled to said waveguide, said line being dimensioned to propagate signals within said one frequency band and within said other frequency bands in at least one of two dominant TE modes, said waveguide being dimensioned so that it can propagate said signals in the additional modes TE_{20} , TE_{11} and TM_{11} ,

and means for introducing asymmetry into said waveguide only for said signals within said one frequency band and for simultaneously passing undeflected said signals within said other frequency bands whereby said dominant mode of said signals within said one frequency band is split into said additional TE_{20} , TE_{11} and TM_{11} modes and said signals within said one frequency band are deflected.

3. An antenna feed comprising an oversized waveguide having two orthogonal symmetry planes,

a transmission line coupled to said waveguide, said

line being dimensioned to propagate signals in a certain mode,

said waveguide being dimensioned so that it can propagate signals in the additional modes TE_{20} , TE_{11} and TM_{11} ,

means for introducing asymmetry into said waveguide whereby said certain mode is split into said additional TE_{20} , TE_{11} and TM_{11} modes, said last named means includes

a resonant cavity mounted on each side of said waveguide, each of said cavities being coupled asymmetrically to said waveguide for a propagated signal of a frequency to which the cavity is resonant, and means for tuning said cavities to resonance successively in the same order in which they are positioned around the waveguide whereby said propagated signal is conically scanned when radiated.

4. In an antenna feed for providing angular deflection of signals within one frequency band while simultaneously passing undeflected signals within other frequency bands, the combination comprising:

an oversized waveguide having two symmetry planes, a transmission line coupled to said waveguide, said line being dimensioned to propagate said signals in a dominant mode such as the TE_{10} mode or the TE_{01} mode,

said waveguide being dimensioned so that it can propagate said signals in the additional modes TE_{20} , TE_{11} and TM_{11} ,

a tunable cavity mounted on one side of said waveguide, means for only coupling said cavity to said waveguide when a signal having a frequency within said one frequency band propagated through said waveguide and for passing uncoupled and undeflected said signals within said other frequency bands,

said coupling means being located asymmetrically with respect to the longitudinal center axis of said one side of the waveguide whereby said dominant mode of only said signals within said one frequency band is split into said additional TE_{20} , TE_{11} and TM_{11} modes and only said signals within said one frequency band are deflected.

5. An antenna feed for providing conical scanning, said feed comprising

an oversized waveguide having two symmetry planes, a transmission line connected to said waveguide for propagating to it signal in a dominant mode,

said waveguide being dimensioned so as to support the propagation of said signal in higher-order modes,

a resonant cavity mounted on each side of said waveguide, each cavity having a coupling aperture extending into the waveguide,

each coupling aperture being located asymmetrically with respect to the longitudinal center axis of the waveguide side in which it is located, each cavity being coupled to said waveguide when the cavity is resonant to a signal passing through said waveguide whereby said signal is passed through said waveguide with said dominant mode of propagation split into said higher-order modes, and

means for tuning the successive cavities positioned around said waveguide successively to resonance in a sine wave cycle so that each cavity is resonated 90 degrees out of phase with the preceding cavity.

6. In an antenna feed for providing angular deflection of signals within one frequency band while simultaneously passing undeflected signals within other frequency bands, the combination comprising:

an oversized waveguide,

a transmission line coupled to said waveguide, said line being dimensioned to propagate said signals within said one frequency band and said other frequency bands in the TE_{10} mode,

said waveguide being dimensioned so that it can prop-

agate said signals in the additional modes TE_{20} , TE_{11} and TM_{11} ,
 a tunable cavity mounted on one side of said waveguide, means for only coupling said cavity to said waveguide when a signal having a frequency within said one frequency band is propagated through said waveguide and for passing uncoupled and undeflected said signals within said other frequency bands, said coupling means being located asymmetrically with respect to the longitudinal center axis of said one side of the waveguide whereby said TE_{10} mode of only said signals within said one frequency band is split into said additional TE_{20} , TE_{11} and TM_{11} modes and only said signals within said one frequency band are deflected.

7. An antenna feed for providing conical scanning, said feed comprising
 an oversized waveguide,
 a transmission line connected to said waveguide for propagating to it signal in a dominant mode, said waveguide being dimensioned so as to support the propagation of said signal in higher-order modes,
 a resonant cavity mounted on each side of said waveguide, each cavity being coupled asymmetrically to said waveguide when the cavity is resonant to a signal passing through said waveguide whereby said signal is passed through said waveguide with said dominant mode of propagation split into said higher-order modes, and
 means for tuning the successive cavities positioned around said waveguide successively to resonance in a sine wave cycle so that each cavity is resonated 90 degrees out of phase with the preceding cavity.

8. An antenna feed comprising
 an oversized waveguide having two orthogonal symmetry planes,
 a matching waveguide section,
 a transmission line coupled to said oversized waveguide through said matching section, said line being dimensioned to propagate signals in either the TE_{10} mode or the TE_{01} mode or in both of said modes, said waveguide being dimensioned so that it can propagate signals in the additional modes TE_{20} , TE_{11} and TM_{11} ,
 means for introducing asymmetry into said waveguide whereby said first-mentioned modes are split into said additional TE_{20} , TE_{11} and TM_{11} modes, said last named means including a resonant cavity mounted on each side of said waveguide, each of said cavities being coupled asymmetrically to said waveguide for a signal propagated in at least one of said first-mentioned modes and of a frequency to which the cavity is resonant, and
 means for tuning said cavities to resonance successively in the same order in which they are positioned around the waveguide whereby said propagated signal is conically scanned when radiated.

9. An antenna feed comprising
 an oversized waveguide having two orthogonal symmetry planes,
 a transmission line coupled to said waveguide, said line being dimensioned to propagate signals in either the TE_{10} mode or the TE_{01} mode or in both of said modes, said waveguide being dimensioned so that it can propagate signals in the additional modes TE_{20} , TE_{11} and TM_{11} ,
 means for introducing asymmetry into said waveguide whereby said first-mentioned modes are split into said additional TE_{20} , TE_{11} and TM_{11} modes, said last means including a resonant cavity mounted on each side of said waveguide, each of said cavities being coupled asymmetrically to said waveguide for a propagated signal of a frequency to which the cavity is resonant,

each of said cavities having a wide side and being positioned with its wide side tilted at a certain angle with respect to a line drawn perpendicular to the longitudinal axis of said waveguide, the value of said certain angle being such that each cavity has an equal amount of coupling to both the TE_{10} and the TE_{01} exciting modes, and
 means for tuning said cavities to resonance successively in the same order in which they are positioned around the waveguide whereby said propagated signal is conically scanned when radiated.

10. An antenna feed comprising
 an oversized waveguide having two orthogonal symmetry planes,
 a transmission line coupled to said waveguide, said line being dimensioned to propagate signals in a certain mode, said waveguide being dimensioned so that it can propagate signals in the additional modes TE_{20} , TE_{11} and TM_{11} ,
 means for introducing asymmetry into said waveguide whereby said certain mode is split into said additional TE_{20} , TE_{11} and TM_{11} modes, said last named means including a resonant cavity mounted on each side of said waveguide,
 each of said cavities being coupled asymmetrically to said waveguide for a propagated signal of a frequency to which the cavity is resonant, and
 means for tuning said cavities to resonance successively in the same order in which they are positioned around the waveguide whereby said propagated signal is conically scanned when radiated, said means for tuning said cavities including
 means for varying the rate of said successive tuning so that the conical scanning of said radiated signal speeds up and slows down in accordance with the variation of said rate.

11. An antenna feed for providing conical scanning, said feed comprising
 an oversized waveguide,
 a transmission line connected to said waveguide for propagating to it signal in a dominant mode, said waveguide being dimensioned so as to support the propagation of said signal in modes which are multiples or harmonics of said dominant mode,
 a resonant cavity mounted on each side of said waveguide, each cavity being coupled asymmetrically to said waveguide when the cavity is resonant to a signal passing through said waveguide whereby said signal is passed through said waveguide with said dominant mode of propagation split into additional modes of propagation,
 means for tuning the successive cavities positioned around said waveguide successively to resonance in a sine wave cycle so that each cavity is resonated 90 degrees out of phase with the preceding cavity, and
 means for making said sine wave cycle occur at successively different frequencies.

References Cited

UNITED STATES PATENTS

2,433,368	12/1947	Johnson et al.	343—786 X
2,905,940	9/1959	Spencer et al.	343—768 X
3,021,524	2/1962	Kompfner	343—787 X

HERMAN KARL SAALBACH, *Primary Examiner.*WM. H. PUNTER, *Assistant Examiner.*

U.S. Cl. X.R.

333—21; 343—850, 854, 768, 777, 786, 787