NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

April 5, 1971

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,419,827

Corporate Source : California Institute of Technology

Supplementary Corporate Source : Jet Propulsion Laboratory

NASA Patent Case No.: XNP-06507

Please note that this patent covers an invention made by an employee of a NASA contractor. Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of. . . ."

Gayle Parker

Enclosure:
Copy of Patent

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Dec. 31, 1968 JAMES E. WEBB 3,419,827
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INDEXING MICROWAVE SWITCH

Filed Dec. 27, 1966

FIG. 1

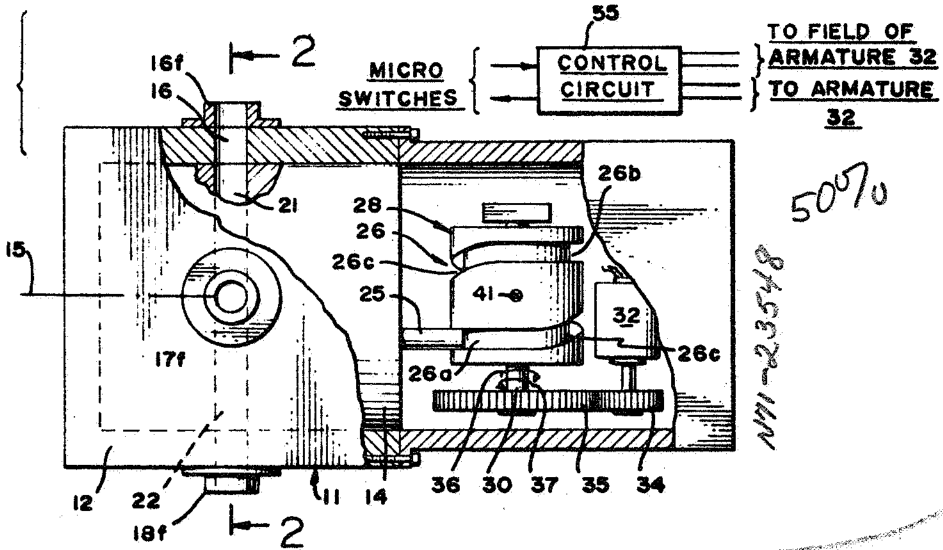

FIG. 2

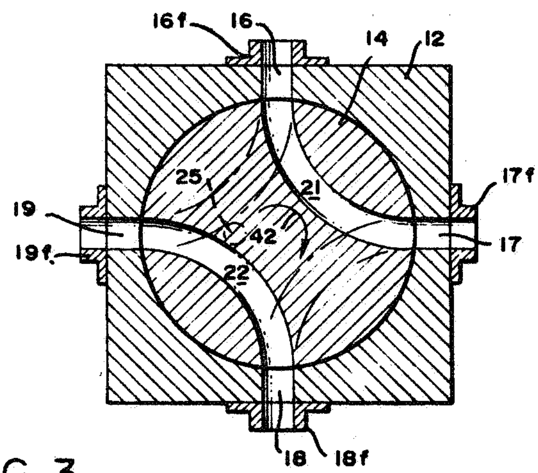

FIG. 3

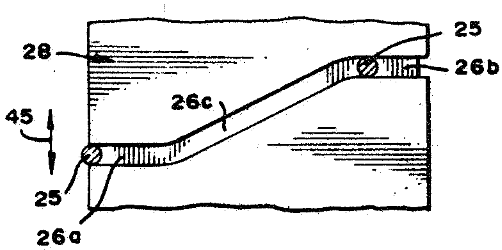

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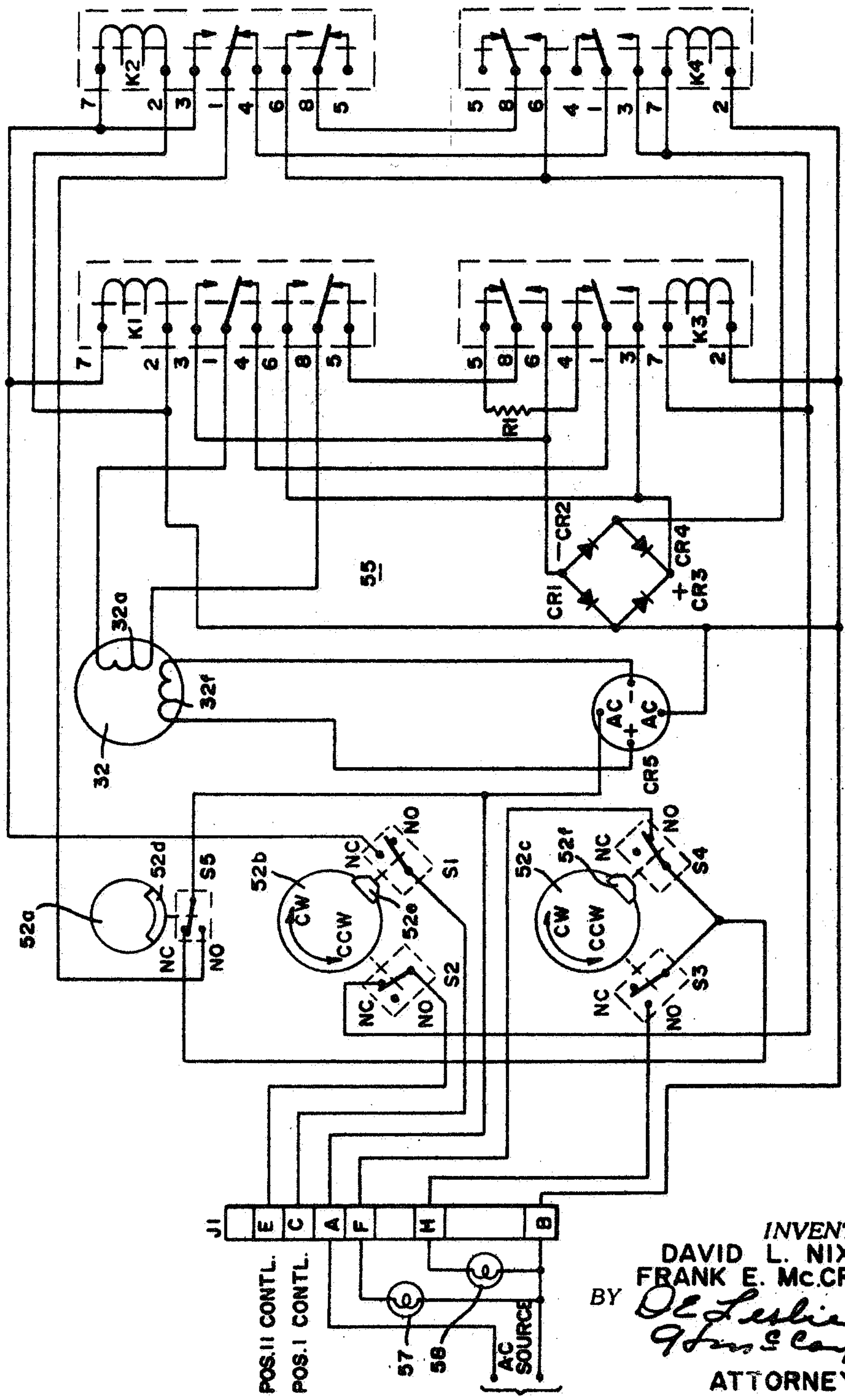
FIG. 4



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3,419,827
INDEXING MICROWAVE SWITCH

James E. Webb, Administrator of the National Aeronautics and Space Administration with respect to an invention of David L. Nixon, Arcadia, and Frank E. McCrea, San Gabriel, Calif.

Filed Dec. 27, 1966, Ser. No. 605,099
9 Claims. (Cl. 333—98)

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 USC 2457).

This invention relates to microwave circuitry, and more particularly to a waveguide switch.

A waveguide switch may be defined as an apparatus for control coupling different ports of waveguides so that energy may propagate therethrough. In the simplest form, such a switch includes a stationary member which defines the waveguide ports such as one inlet and two outlets. A movable or rotatable member, hereafter also referred to simply as the rotor, includes a waveguide section or channel which is positionable in either of two positions. In one position the channel's ends are aligned with the inlet and one of the outlets while in the other position the channel's ends are aligned with the inlet and the other outlet. Thus, the inlet is controllably coupled to either of the two outlets. More complex switches may include more than three ports and more than one channel so that at any given fixed position of the rotor, different ports are intercoupled by different channels.

One of the major disadvantages of prior art switches is the need to periodically service the switch to insure proper alignment of the rotor with respect to the ports, so that at any fixed rotor position the rotor's channel or channels are properly aligned with a different pair or pairs of ports. The misalignment can be generally attributed to the manner in which the rotors of prior art switches are switched or rotated from one position to the other. Generally, a high peak torque, during a very short period is applied to the rotor to abruptly switch it from one position to the other. A Geneva cam mechanism is one example of arrangements used in the prior art.

The abrupt change in the rotor's position results in excessive high forces between the rotor and the stationary member which result in excessive wear of the various parts. In particular, the slamming action produces misalignment of the rotor at the fixed positions, resulting in improper alignment of the rotor's waveguide channel with the stationary parts, causing undesired radio-frequency (RF) energy losses. These misalignments are corrected by periodically servicing the switches, which is often most undesirable, especially when the switches are part of a remote radar installation, or where the servicing of the switches inconveniently disrupts continuous operation.

Accordingly, it is an object of the invention to provide a new waveguide switch which is not limited by prior art limitations.

Another object is to provide a simple waveguide switch which requires minimal maintenance.

A further object is the provision of a waveguide switch in which the change of position of the rotor is controlled to minimize wear on the switch's related waveguide sections.

Still a further object is to provide a new relatively simple switch in which the change in position of the rotor is controlled to minimize misalignment of the rotor with respect to the switch's waveguide parts and thereby minimize RF energy losses.

These and other objects are achieved by providing a waveguide switch in which the rotational position of the rotor is controlled by means of a cam follower, extending from the rotor in a direction parallel to its axis of rotation and displaced therefrom. The switch includes a cylindrical cam, rotatable about an axis of rotation perpendicular to the axis of rotation of the rotor. The cam's cylindrical surface defines a modified spiralling groove in which the cam follower is inserted. The orientational characteristics of the groove are controlled, so that irrespective of a constant rate of rotation of the cam provided by a motor, the rate of change in laterial position of the cam follower is not constant. More importantly, the rate of rotation of the rotor is controlled so that the rotor rotates gradually, rather than abruptly, toward each of its fixed positions and remains in such position despite any backlash, caused by suddently stopping the motor. As a result, proper alignment of the rotor can be maintained over a very large number of operational cycles and thereby minimize the maintenance requirements. Also, the smooth, gradual rotation of the rotor minimizes any wear between the stationary and the rotatable waveguide sections of the switch.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a front side view of one embodiment of the novel waveguide switch of the present invention, with a portion of the exterior surface removed;

FIGURE 2 is a cross-sectional view along lines 2—2;

FIGURE 3 is a simplified two-dimensional diagram of the groove defined in the cam utilized in the novel switch of the present invention to control the rotational characteristics of the switch's rotor;

FIGURE 4 is a block and schematic diagram of control circuitry of the waveguide switch of the present invention actually reduced to practice in one embodiment thereof.

Attention is now directed to FIGURES 1 and 2 wherein a waveguide switch **11** is shown comprising a stationary member **12**, hereafter also referred to as the stator and a rotor **14** mounted therein. The rotor is rotatable about an axis of rotation designated by numeral **15**. The stator **12** defines a purality of ports designated by numerals **16** through **19**, each associated with a waveguide type flange designated by **16f** through **19f** respectively. The flanges may be welded or fastened by any conventional means to the exterior of stator **12** so that any conventional waveguide section may be coupled thereto to supply microwave energy to any of the ports or receive energy therethrough.

In the particular arrangement shown in FIGURES 1 and 2, the rotor **14** is shown defining waveguide sections or channels, **21** and **22**, each section being aligned with two of the stator's ports. As is appreciated, the function of each rotor channel is to provide a path for microwave enery to propagate between the two ports with which is the aligned, while the basic function of the switch is to control the rotational position of the rotor so that any pair of ports are in communication by means of one of the channels so that energy may propagate therebetween.

The rotor **14** is provided with rotational forces by means of a cam follower **25** (FIGURE 1) which is located in a groove **26** of a cylindrical cam **28**. The cam follower in essence comprises a member extending from rotor **14** in a direction prependicular to the axis of rotation **15**, while being displaced therefrom, while cylindrical cam **28** is mounted on a shaft **30** which defines an axis of rotation prependicular to the axis **15** of rotor **14**. A reversible motor **32** is coupled to shaft **30** by means of reduction gears **34** and **35**, to provide rotational forces to the shaft **30** so as to rotate the cam **28** in either a clockwise direction, as indicated by arrow **36**, or in a counter-clockwise direction as indicated by arrow **37**.

As is appreciated by those familiar with the art, if groove **26** were shaped in the form of a conventional spiral the rotation of rotor **14** will be directly related to that of cam **28** and, therefore any backlash of reversible motor **32** will affect the positioning of rotor **14**. However, in accordance with the teachings of the present invention, the shape of groove **26** is in the form of a modified spiral in which the groove is spirally shaped between flat groove portions, which are oriented in directions prependicular to the axis of rotation of the cam. The shape of the groove **26** is diagrammed in a single plane in FIGURE 3 to which reference is made herein. For the particular embodiment described herein, in which the rotor **14** is to be positioned in either of two rotational positions, the groove **26** defines two straight portions **26*a*** and **26*b***, each having a directional orientation which is perpendicular to the axis of rotation on the cam, or parallel to the axis of cam follower **25**. Thus, as long as the cam follower is located in either of the straight groove segments, the rotor is in a stationary position, irrespective of slight rotational movement of a cam. Only when the cam follower is located in a sloping or S-shaped segment **26*c*** of groove **26** is lateral motion supplied to the cam follower which is in turn converted to rotational motion of rotor **40**. The slope of segment **26*c*** is controlled so that the rate of rotation of rotor **14** varies as the rotor is rotated from one fixed rotational position to the other. For example, as seen in FIGURE 3, the slopes of segment **26*c*** adjacent segments **26*a*** and **26*b*** is less than the slope along the center portion thereof so that the rates at which rotor **14** rotates when cam follower **25** is in groove segment **26*c*** varies as a function of the slope thereof.

In practice, the rotor **14** is rotated and positioned so that channels **21** and **22** are properly aligned with respect to the stator's ports. Then, cylindrical cam **28** is positioned on threaded shaft **30** and secured thereon by means of one or more set screws **41**, with the cam follower **25** located substantially in the center of any of the straight segments of the groove which define the fixed rotational positions of the rotor. To change the position of the rotor, motor **32** is energized to thereby rotate cam **28** to provide rotary motion to cam-follower **25** and thereby cause the rotation of rotor **14** to turn to a new position.

Due to the varied slope of segment **26*c***, the rotor tends to accelerate gradually from a present position and thereafter move more rapidly towards the next position with the subsequent lower slope of segment **26*c***, enabling the rotor to decelerate into a subsequent position, which is defined by the subsequent straight groove segment in which the cam follower **25** is located. For example, let us assume that with cam follower **25** in segment **26*a*** of groove **26**, the rotor **14** is in the position shown in FIGURE 2 defining a rotor position 1 and a clockwise rotation of cam **28** produces clockwise rotation of rotor **14** as indicated by arrow **42** (FIGURE 2). Then, from the foregoing, it should be appreciated that as long as cam follower **25** remains in groove segment **26*a***, as the cam is rotated the rotor remains in the position shown in FIGURE 2 with the two channels still aligned with respect to the four ports. Only when came **28** has rotated clockwise sufficiently for segment **26*c*** to engage cam follower **25**, upward lateral motion is provided the cam follower, which starts turning rotor **14** in a clockwise direction. However, the initial turning is quite gradual due to the lower slope of segment **26*c*** adjacent segment **26*a***. Then, as the cam continues to turn, the rate of rotation increases due to the increased slope of segment **26*c***. Then, as the cam continues to rotate and cam follower **25** is located towards the upper portion of segment **26*c*** where the slope thereof is again lower, the rate of rotation of the rotor decreases again until the cam follower **25** enters the straight segment **26*b*** of the groove, at which time the rotor is secured in its other fixed rotational position, whereby channel **21** couples ports **17** and **18** and channel **22** couples ports **16** and **19** defining a rotor position II. Any additional coasting of cam **28** will not effect the accurate positioning of the rotor since the cam can continue to rotate a portion of a cycle without effecting the position of the rotor as long as cam follower **25** is in the straight portion of groove segment **26*b***. In FIGURE 3, double arrow **45** represents the range of lateral motion of cam follower **25** as a function of its location in any point along groove **26**.

From the foregoing, it should thus be appreciated that by providing a cylindrical cam, with a modified spiral groove, which is assumed to represent a groove having at least two straight segments and a spiralling segment of controlled slope, the rotor **14** may be rotated from one fixed rotational position to another without excessive high forces. Rather, the change in position of the rotor is gradually accomplished with the rotor gradually accelerating as the rotor is turned from one position to the other, as well as gradual deceleration when the rotor finally reaches a subsequent rotational position to which it is switched. Also, by providing the straight groove segments, such as **26*a*** and **26*b***, any effects of motor or gear backlash on the final position of the rotor is eliminated, since slight rotation of the cam may be tolerated without effecting the rotor's position. Thus, rotor positioning problems are greatly simplified, reducing the maintenance problems considerably.

The operation of the novel waveguide switch of the present invention is greatly enhanced by the use of a control circuit, shown in FIGURE 1 by a block **55** and schematically diagrammed in FIGURE 4, to which reference is made herein, and a plurality of microswitches designated, S1 through S5. Motor **32** is assumed to be a DC reversible motor and is shown comprising a field winding **32*f*** and an armature winding **32*a***. Circuit **55** includes diodes CR1 through CR4, arranged in a full wave rectifying bridge to rectify current from an AC source (not shown) for winding **32*a***, while a diode bridge CR5 rectifies the current for the field winding **32*f***.

Circuit **55** also includes multicontact relays K1 through K4 and an input plug on board J1. The relays K1 and K4 are shown in their deenergized state, and the switches are shown when the rotor **12** is in position I. In addition, the waveguide switch includes a cam plate **52*a*** which defines a groove **52*d***. In practice plate **52*a*** is positioned on cam **28** (FIGURE 1) so that whenever cam follower **25** (FIGURE 1) is in either straight segment **26*a*** or **26*c***, i.e. the rotor **12** is in either position I or II, the normally closed (NC) contact of S5 is closed (as shown). The waveguide switch also includes cam plates **52*b*** and **52*c*** which define lobes **52*c*** and **52*f***, respectively. Plates **52*b*** and **52*c*** are mounted on rotor **12** and adjusted so that when the rotor is in position I lobes **52*c*** and **52*f*** activate switches S1 and S4, respectively (as shown), while switches S2 and S3 are activated by lobes **52*c*** and **52*f*** respectively, when the rotor is in position II.

As previously stated, J1 in FIGURE 4 represents an input plug or board for circuit **55**. Alternating current (AC) from an AC source (not shown) is supplied through terminals A and B of J1. Terminal E of J1 is used to supply a control signal to switch the rotor to position II, designated "POS II CONTROL," while terminal C is used to provide a control signal to switch the rotor **12** to position I, designated "POS I CONTROL." Terminal F is connected to a lamp **57** which is energized when the rotor **12** is in position I, while terminal H is connected to another lamp **58** which indicates when energized, that the rotor **12** is in position II. In FIGURE 4 assumed to represent the element when rotor **12** is in position I, lamp **57** is energized, since AC current is applied thereto through terminal A of J1, the normally-closed contact of S5 and the normally open-contact S4.

To switch the rotor 12 from position I, as shown, an AC control signal on J1–E completes the return circuit of K3, and K4 close to supply power to the other side of the armature winding rectifier CR5. Contacts 1, and 4, and 5 and 8, on K3 open to remove dynamic loading resistance, represented by R1, from the armature winding 32*a*. Closure of contacts 1 and 3, and 8 and 6, on K3 permit current from the armature rectifier bridge formed by CR1–CR4 permit current from the armature rectifier to be applied to the armature winding 32*a* through contacts 5 and 8 on K1. The polarity of the current is such that the motor will cause the rotor 12 to be rotated in the clockwise (CW) direction. As movement starts, normally-open contact of S5 closes, producing through contacts 1 and 4 of K1 and 1 and 3 of K4, holding current for relays K3 and K4. Movement continues until the rotor 12 reaches position II, when the normally-closed contact of S5 closes again. Also, normally-open contact of S2 closes. As the result, the holding current for relays K3 and K4 is interrupted, causing the relays to drop out. Resultant openings of contacts 1 and 3 on K3 disconnects the armature winding 32*a* from the armature rectifier (CR1–CR4). At the same time, when K3 is deenergized, R1 is again connected across the armature winding to provide dynamic braking, through closure of contacts of 1 and 4, and 8 and 5, on K3. Simultaneously, with the stopping of the rotor 12 at position II, the normally-open contact of S3 closes, providing AC current from J1–A and through S5 to lamp 58, connected to J1–H to indicate that the rotor 12 is in position II.

When the rotor is in position II, the normally-closed contacts of S2 are open, disabling position II control input through J1–E. The normally-closed contacts of S1 are closed, to connect the return side of the coils K1 and K2 to the position I input control at J1–C. Completion of the return circuit (position I control signal) at the microwave switch control assembly causes K1 and K2 to be energized. When this occurs, closure of contacts 8 and 6 on K2 applied input power to the armature rectifier (CR1–CR4), and opening of contacts 8 and 5 on K1 disconnects one side of R1 from the armature winding 32*a*. Closure of contacts 6 and 8, and 1 and 3. on K1 connects the armature winding, causing the motor to operate. Under these conditions, the polarity of the current from the armature rectifier (CR1–CR4) applied to the armature winding is opposite to that when operation to switching position II was initiated. Thus, the rotor is turned to position I.

From the foregoing, it should be appreciated that relays K1–K4 and the microswitches S1–S5 can be advantageously employed to control the rotation of the rotor 12 from one position to another, as well as indicate at which position the rotor is positioned. The use of one microswitch, S5, which is activated whenever the cam follower 25 (FIGURE 1) is in a straight portion of the cam groove, i.e. whenever the rotor is in either position and a second microswitch such as S1 used to control the rotation of the rotor to position I, and S2 for controlling the rotation to position II greatly enhances the accuracy with which the rotor's position can be controlled with relatively simple microswitches and relays. Also, the manner in which the microswitches and relays are interconnected, when the rotor is in position I, terminal C of J1 is in essence disconnected from the circuit 55 so that a control signal to switch the rotor to position I has no effect. Similarly, S2 prevents a position II control signal at J1–E from affecting the circuit when the rotor 12 is in position II. In addition, the use of S5 and S3 and S4 to energize the position-indicating lamps 57 and 58 is most desirable for position display purposes.

Although, in the foregoing. the novel waveguide switch of the present invention has been described in conjunction with a rotor defining two channels rotatable by 90°, to be positioned in either of two positions I or II, it should be appreciated to those familiar with the art, that the invention need not be limited thereto. Rather, the rotor may include any number of desired channels, each one of which may be in communication with a pair of ports at each of the rotors' rotational positions. Also, the cam's groove may be shaped to include any number of fixed rotational positions of the rotor, so that whenever the cam follower 25 is urged into a straight segment of the groove by cam 28 being rotated about its axis of rotation, the rotor is in one of the desired channels, each one of which may be in communication with a pair of ports at each of the rotor's rotational positions. Also, the cam's groove may be shaped to include any number of fixed rotational positions of the rotor, so that whenever the cam follower 25 is urged into a straight segment of the groove by cam 28 being rotated about its axis of rotation, the rotor is in one of the desired positions. As herebefore indicated, microswitches may be provided to activate and deactivate motor 32 whenever cam follower 25 is in any of the straight groove segments to inhibit the continuous rotation of the cam and the subsequent altering of the rotor's position until it is desired to rotate the rotor to another of its fixed positions.

There has accordingly been shown and described herein a novel waveguide switch in which the rotational positions of the switch's rotor are controlled by means of a cam follower following a cylindrical cam which defines a modified spiral groove, whereby the gradual or coasting rotation of the rotor from one fixed position to another may be achieved. It is appreciated that those familiar with the art may make modifications and/or substitute equivalents in the arrangements as shown without departing from the true spirit of the invention. Therefore, all such modifications and/or equivalents are deemed to fall within the scope of the invention as claimed in the appended claims.

What is claimed is:

1. In a waveguide switch of the type having a stationary member comprising a plurality of waveguide ports, a rotor having an axis of rotation and defining at least one waveguide channel threthrough, a source of energy for rotating said rotor to selected rotational positions, whereby at each position said channel is aligned with another pair of ports, improved means for controlling the rotation of said rotor from one position to another comprising:
  a cam having an axis of rotation;
  means coupling said cam to said source of energy for rotating said cam about its axis of rotation, said cam defining a modified spiralling groove about its surface; and
  control means including a cam follower rotor, frictionally engaging said cam in the groove thereof to control the rotation of said rotor, as a function of the rotation of said cam and the shape characteristics of said groove.

2. The waveguide switch defined in claim 1 wherein the axis of rotation of said cam is substantially perpendicular to the axis of rotation of said rotor and the directional orientation of said groove with respect to an axis perpendicular to the cam's axis of rotation is controlled to control the manner of rotation of said rotor from one rotational position to another.

3. The waveguide switch defined in claim 2 wherein at least one segment of said groove is in a direction perpendicular to the cam's axis of rotation defining a straight groove segment to inhibit the rotation of said rotor when the cam follower extending therefrom is located in said straight groove segment, the ends of the channel in said rotor being aligned with a pair of ports in said stationary member when the cam follower is in said straight groove segment which is perpendicular to the cam's axis of rotation.

4. The waveguide switch defined in claim 3 wherein said rotor defines a plurality of channels, said groove defining a plurality of substantially parallel straight groove segments each perpendicular to said cam's axis of rota-

tion, each straight groove segment defining a rotational position of said rotor in which the ends of each channel are aligned with another pair of ports, when the cam follower is located therein, said control means including a control for controlling the rotation of said cam to control the rotational position of said rotor.

5. The waveguide switch defined in claim 4 wherein the slope of the groove segment between parallel segments is controlled to control the rotation of said rotor as it is rotated from one rotational position to another.

6. A waveguide switch comprising:

a stator defining a plurality of waveguide parts;

a rotor defining an axis of rotation about which said rotor is rotatable, said rotor mounted in said stator, defining at least one waveguide channel having first and second ends; and

positioning control means coupled to said rotor for controlling the rotational position thereof whereby each end of said channel is aligned with one of said waveguide ports; said positioning control means including a cam rotatable in either of opposite directions about an axis of rotation which is perpendicular to the axis of rotation of said rotor, said cam defining a modifier spiralling groove about its surface, said groove comprising of first and second straight groove segments perpendicular to the axis of rotation of said cam and a substantially S-shaped segment connecting said first and second straight groove segments, means for controllably rotating said cam in either of said opposite direction; and a cam follower extending from said rotor and engaging said cam in the groove thereof whereby said rotor is rotated as a function of the rotation of said cam, said rotor being in a first rotational position with the waveguide channel ends aligned with a first pair of waveguide parts when the cam follower is in said first straight groove segment and rotor being in a second rotational position with the ends of said waveguide channel being aligned with a second pair of waveguide ports.

7. The waveguide switch as recited in claim 6 wherein said means for controllably rotating said cam includes a reversible motor, means coupling said motor to said cam: and switching and relay means responsive to a first control signal when said rotor is in said second position to energize said motor to rotate said cam until said cam follower is in said first straight groove segment, defining said first position, said switching and relay means being further responsive to a second control signal.

8. The waveguide switch as recited in claim 7 wherein said switching and relay means include a first microswitch activatable when said came follower is either in said first straight groove segment or in said second straight section and second and third microswitches, said second switch being activatable when said rotor is in said first position and said third switch being activatable when said rotor is in said second position, said second and third swtches controlling the response of said switching and relay means to said first and second control signals, respectively.

9. The waveguide switch as recited in claim 8, further including first and second position indicating means which are coupled to said switching and relay means and energized when said rotor is in said first and second positions, respectively, to indicate the rotational position of said rotor.

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U.S. Cl. X.R.

74—89.14, 96; 137—625.23, 625.43; 251—251; 318—265, 468