Jan. 13, 1959 W. L. TEETER 2,869,081

HIGH POWER BROADBAND WAVEGUIDE SWITCH

Filed May 11, 1955 3 Sheets-Sheet 1

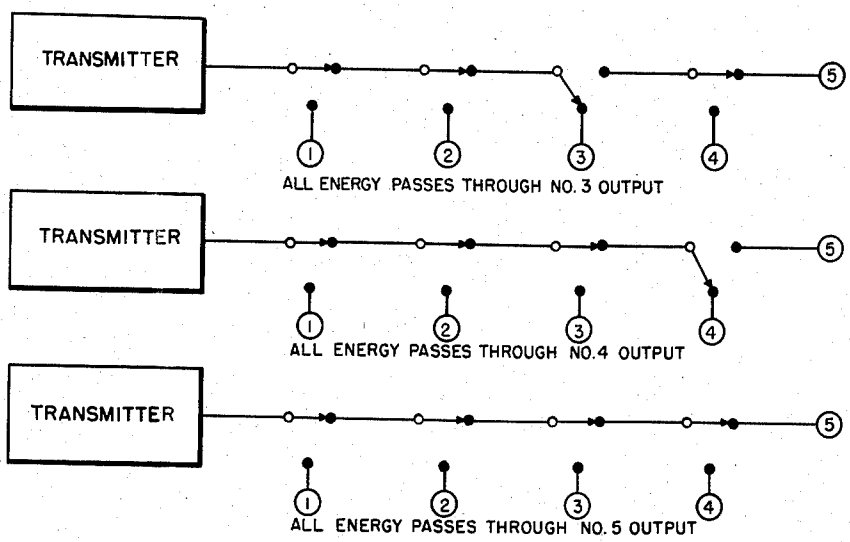


Fig. 1

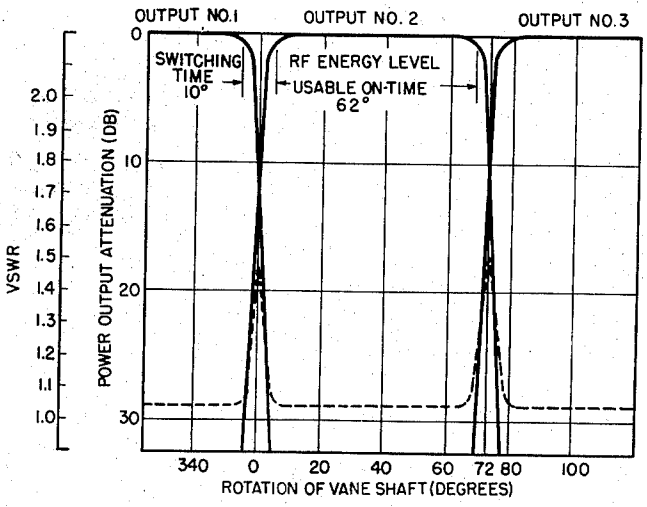


Fig. 5

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HIGH POWER BROADBAND WAVEGUIDE SWITCH

Filed May 11, 1955 3 Sheets-Sheet 2

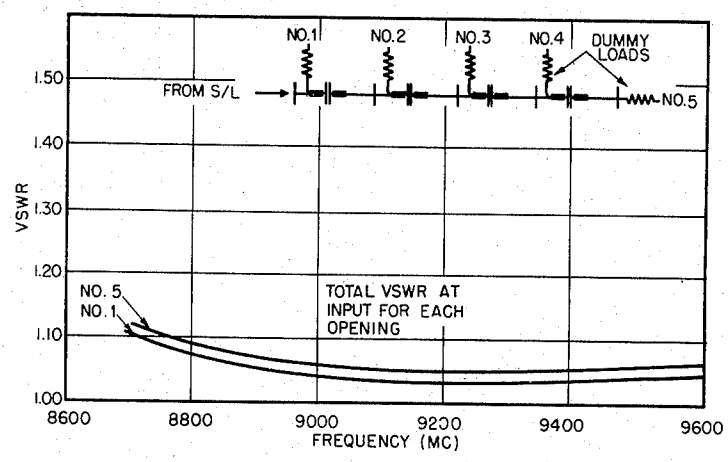


Fig. 6

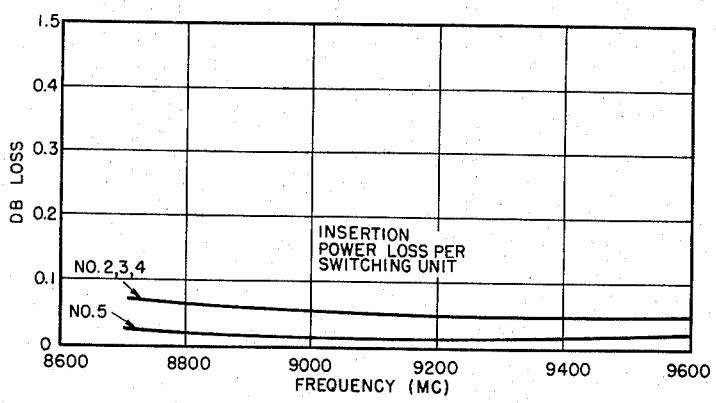


Fig. 7

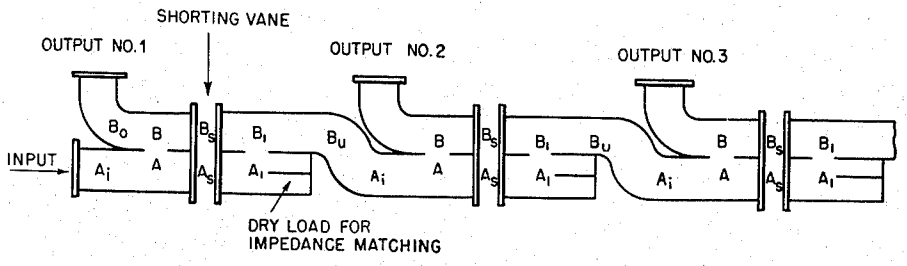


Fig. 2

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HIGH POWER BROADBAND WAVEGUIDE SWITCH

Filed May 11, 1955 3 Sheets-Sheet 3

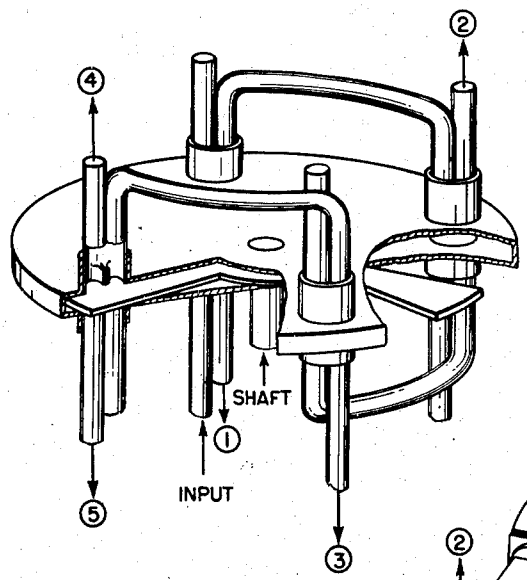


Fig. 4

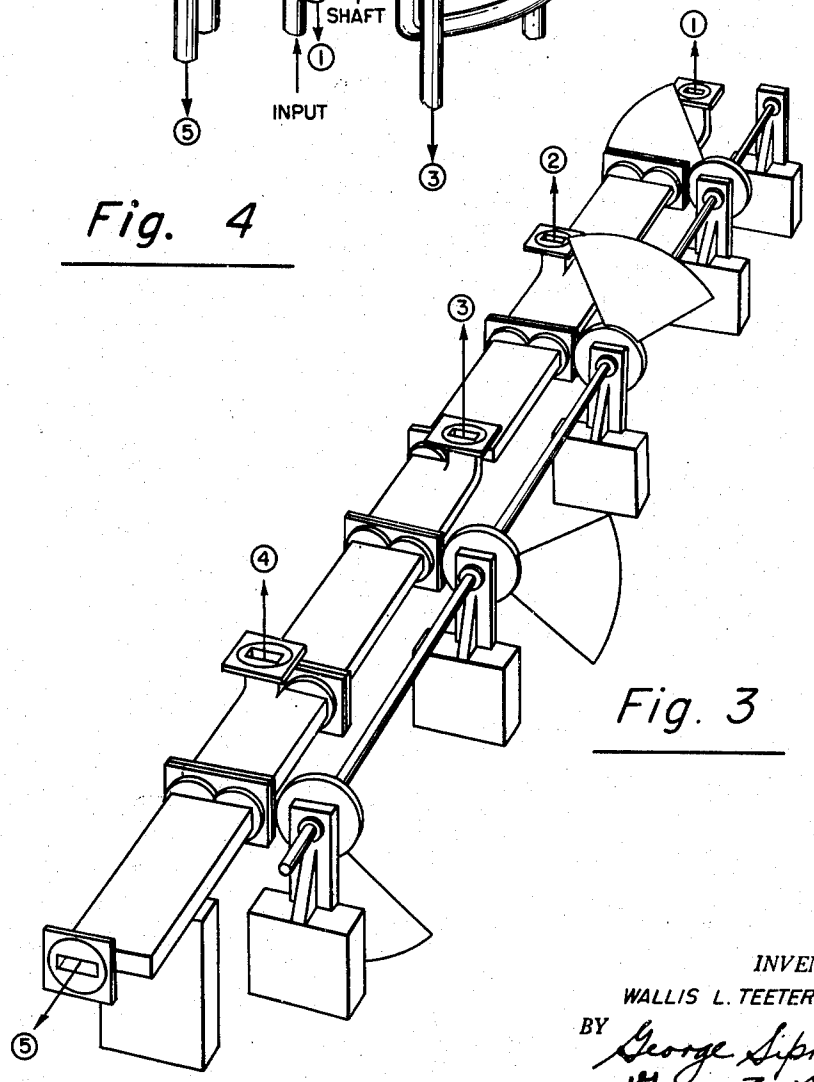


Fig. 3

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HIGH POWER BROADBAND WAVEGUIDE SWITCH

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Application May 11, 1955, Serial No. 507,753

5 Claims. (Cl. 333—7)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to waveguide switches and more particularly to high power broadband waveguide switches for switching a single R.-F. signal source to several outputs, one at a time, as desired.

High power switching devices heretofore have been of the resonant type, did not have broad band coverage and have not been satisfactory for the purposes for which the switch comprising this invention is intended. These switches required high rotational speeds and tight mechanical tolerances to obtain electrical symmetry and bandwidths of 1 to 3 percent.

The waveguide switch herein disclosed is capable of switching a 250 kw. R.-F. energy pulse into five outputs consecutively at the rate of 1800 pulses per second with one pulse per output per switching cycle. The switch, with shorting vanes revolving at 3600 R. P. M., presents a maximum VSWR of 1.1 from 8900 to 9600 mc. during "on-time," and 1.4 during switching.

This switch comprises a plurality of units or sections of rectangular copper or aluminum tubes, one unit or section less than the desired number of outputs, forming a spiral ring with a motor driven shorting vane passing between the sexeral output connections to selectively fully energize each output. A plurality of vanes may be used, if desired, to vary the switching sequence. No impedance matching is necessary.

An object of this invention is the provision of an improved waveguide switch.

Another object is the provision of a high power broadband switch capable of making 1800 switches per second without excessive shorting vane rotational speed.

Another object is the provision of a waveguide switch in which the addition of more units will provide more outputs and which may be adapted to any size waveguide by scaling the dimensions thereof to the desired size without affecting the characteristics thereof.

A further object is the provision of a waveguide switch, which when the shorting vanes revolve at 3600 R. P. M., presents a maximum VSWR of 1.1 from 8900 to 9600 mc. during "on-time," and 1.4 during switching.

Still another object is the provision of lightweight, inexpensive waveguide switching components easily assembled, of rugged construction, requiring a minimum of maintenance and giving dependable service.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a diagram illustrating the method of operation of the broadband switch;

Fig. 2 is a fragmentary schematic diagram of a single switching unit showing the initial three sections;

Fig. 3 is a pictorial view of a straight-run switch;

Fig. 4 is a diagram of the high-speed switch spiraled

and forming a ring around a single shorting plate rotor having several vanes;

Fig. 5 is a graph of the switching time showing attenuation vs. angle or time;

Fig. 6 is a graph of VSWR vs. frequency; and

Fig. 7 is a graph showing the insertion loss vs. frequency.

Referring now to Fig. 1 a plurality of switches connect the transmitter selectively to each of five outputs. Fig. 1*a* shows a switch connected to pass all energy to the number 3 output, Fig. 1*b* shows switching to the number 4 output and Fig. 1*c* shows switching to the number 5 output. The switch arms are moved by electrical means to propagate energy into the desired output. No resonant lengths or cavities are involved. Fundamentally, the switch in this illustration is composed of four units or sections like the three shown in Fig. 2, plus a rotating vane, a motor on a shaft, and usually a synchronizing means to coordinate the rotation with the timing of the transmitted pulses. In Fig. 3 the contact switches of Fig. 1 are replaced with rotating vanes. To propagate energy into output 3, for example, the shorting plate vane is merely placed in the third unit behind the number 3 output.

Referring now to Fig. 2 the R.-F. energy enters the wave-guide at A_1, proceeds down one path to the slot at A where the energy splits into two paths and proceeds toward B_s and A_s. If the shorting vane #1 is across B_s and A_s, the energy is reflected and passes out B_0 to output #1. If the shorting vane is not at B_s and A_s the energy at B_s and A_s proceeds down both paths to the slot at B_1 and A_1 where all enrgy recombines to proceed past B_u and into A_i of the next unit. The process is now repeated until a shorting vane is met and the energy is reflected out the nearest clear opening. Inserting shorting vane #1 sends the energy to output #1; inserting shorting vane #2 sends the energy to output #2 and so on. The switch in Fig. 2 shows energy coming out #3. The 3 db coupling slot shown at A—B is a hybrid principle developed by Henry J. Riblet and explained in detail by Henry J. Riblet in "The Short-Slot Hybrid Junction," Institute of Radio Engineers, Proceedings, vol. 40, No. 2, February 1952, pp. 180–184. Energy proceeding past A_1 goes along one path to the slot at A and B. Half the energy proceeds along the previously mentioned path toward A_s and the other half passes "through" (effectively) the slot with 90° phase delay from A into B, and proceeds along the other path toward B_s. The energy is now split into A_s and B_s where the field of B_s is 90° behind A_s. Another coupler slot is placed at A_1 and B_1. The energy of A_s passes to A_1, likewise B_s to B_1. Here the A_1 energy from one path couples into B_1 in the other path (A_1 energy is now delayed 90° in passing through the slot). B_1 and A_1 are now in phase and combine as they pass B_u to the next unit. The dry load is place at A_1 in the initial path to properly terminate A_1 so that no reflection occurs to generate a field that would destroy the hybrid characteristics. Returning now to B_s and A_s, suppose the shorting vane is inserted so that energy at A_s in one path and B_s in the other path is reflected. The A_s energy will be delayed (effectively) 90° in passing through the slot where it will be in phase with the field due to the reflected energy at the B_s short. The two fields are in phase and will reinforce to send energy out outlet B_0 to output 1. The process is repeated in successive units until a shorting vane is encountered, and the energy is reflected out the nearest opening. Energy will not pass back through A_i, since the field coupled back through the slot from B_s (shorted) and the reflected field from A_s will be 180° different in phase. They will cancel, and

if no field is present no power will be transmitted. Shorting vanes may be one vane on one shaft, or any number of vanes on many shafts. Only one shorting vane may be in at once, or any combination may be in at one moment. Any combination of vanes and layout may be used, depending on the desired opening sequence, vane speed and mechanical size. Any number of units may be connected together. The present switch has four units and five outputs.

Fig. 4 shows another embodiment in which the switch is in the form of a spiralled ring, similar to a screen-door spring bent into a circle. In this case only one rotor is needed and the motor may be conveniently mounted in the center. With six vanes on the rotor and five outputs, thirty switches are achieved per rotor revolution, or at 3600 R. P. M., 1800 switches per second.

Fig. 5 shows electrical switching time or angle versus attenuation on the straight-run type switch. The energy level at output **1** is shown first, then switched to output **2**, then to **3**, etc. Only three of the output levels are shown since they are repetitive. With full energy at output **1**, the rotor is rotated until the shorting vane enters the gap after output **2**. As the rotation continues, the energy to load **1** is reduced more than 30 db and at the same time all output is switched into load **2**. Rotation continues from 5 degrees to 67 degrees, during which period (62 degrees) all energy passes to load **2**. It is now ready to start another switching cycle, between outputs **2** and **3**.

Notice the flat top between the 6- and 66-degree marks (Fig. 5). For practical purposes the marks at 5 and 67 can be used to measure the usable time. Since the vane in this test represents 72 degrees of rotation, then 10 (72—62—10) degrees are needed for switching from one load to any other. Thus the electrical switching time is 10 degrees, whereas the mechanical switching time is 13 degrees. The short electrical switching time is a result of the shorting vane acting as a non-resonant iris before it completely covers the waveguide opening.

The spiral switch in Fig. 4 is similar except that the usable on-time is less, the rotor having 6 vanes of 12 degrees width.

Fig. 6 shows total VSWR versus frequency, measured at the input, for each output from 1 through 5. Curves for outputs **2**, **3**, and **4** lie between **1** and **5** and for the sake of simplicity are not shown in the figure.

Fig. 7 shows insertion loss of each unit versus frequency. Insertion loss for output **5** is below the nominal 0.05-db figure of the other outputs, since it is merely the output of unit **4**.

While the preferred embodiment has been shown and described, many variations are possible. The number of outputs may be changed simply by adding or subtracting the number of units. The switching time may be changed by changing the number and size of the vanes on the rotor and its revolution rate. The rotor in this switch could be replaced with a gas tube or a ferrite slug. The latter would require an external coil to place the proper D.-C. magnetic field across the ferrite to make the ferrite have an electrical polarization change effect similar to the rotor at microwave frequencies.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A broadband high speed high power waveguide switch comprising a plurality of serially arranged non-resonant waveguide sections each having two non-resonant outlets, one outlet being connected to the next successive section, the other outlet forming a non-resonant energy output, said switch having an energy input for energizing said outlets and having means for sequentially energizing individually one of each said section's two outlets by interrupting the flow of energy serially through said sections and reflecting said energy to each of said energy outputs to be energized, said means comprising a high speed driven shaft having at least one vane connected thereto, said vane passing through each of said sections between said two outlets.

2. A broadband high speed high power waveguide switch for receiving a predetermined radio frequency energy pulse comprising a plurality of non-resonant waveguide sections, each said non-resonant waveguide section having an inlet, two paths therethrough and two non-resonant outlets, said non-resonant waveguide sections being serially connected, each said non-resonant section except the terminal non-resonant section having one of said non-resonant outlets connected to said inlet of its next successive section, said initial section's inlet being adapted to receive said predetermined radio frequency energy pulse, means for sequentially energizing said non-resonant sectional outlets, said means comprising a rotatable shaft having a plurality of shorting vanes mounted thereon wherein the number of shorting vanes are equal in number to said waveguide sections, each shorting vane being rotatable for high speed blocking of said coincident waveguide section to the passage of said energy pulse, and means for positioning each said vane to reflect said energy pulse sequentially into each of said non-resonant outlets.

3. A broadband high speed high power waveguide switch for receiving a predetermined radio frequency energy pulse comprising a plurality of non-resonant waveguide sections, each non-resonant waveguide section having an inlet, two paths therethrough and two non-resonant outlets, said sections being serially connected whereby each said non-resonant section except the terminal non-resonant section having one of said non-resonant outlets connected to said inlet of its next successive section, said initial section's inlet being adapted to receive said predetermined radio frequency energy pulse whereby said energy pulse is normally transferred to the next serially connected section through one of said outlets, the other of said outlets receiving said energy pulse when said paths are blocked, and means for sequentially energizing said outlets.

4. A broadband high speed high power waveguide switch for receiving a predetermined radio frequency energy pulse comprising a plurality of non-resonant waveguide sections, each non-resonant waveguide section having a non-resonant inlet, two paths therethrough and two non-resonant outlets, said sections being serially connected whereby each said non-resonant section except the terminal non-resonant section has one of said outlets connected to said inlet of its next successive section, said initial section's inlet being adapted to receive said predetermined radio frequency energy pulse whereby said energy pulse is normally transferred to the next serially connected section through one of said outlets, the other of said outlets receiving energy when said paths are blocked, and means for blocking said paths and alternately reflecting said energy pulse into the other of said outlets.

5. A broadband high speed high power waveguide switch as in claim 4 wherein said means comprises a motor driven shaft having at least one vane rotatable therewith for blocking said paths intermediate said outlets.

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