July 27, 1948. N. MARCHAND 2,445,793

ROTARY HIGH FREQUENCY SWITCHING CIRCUIT

Filed Aug. 19, 1944 3 Sheets-Sheet 1

Fig. 1.

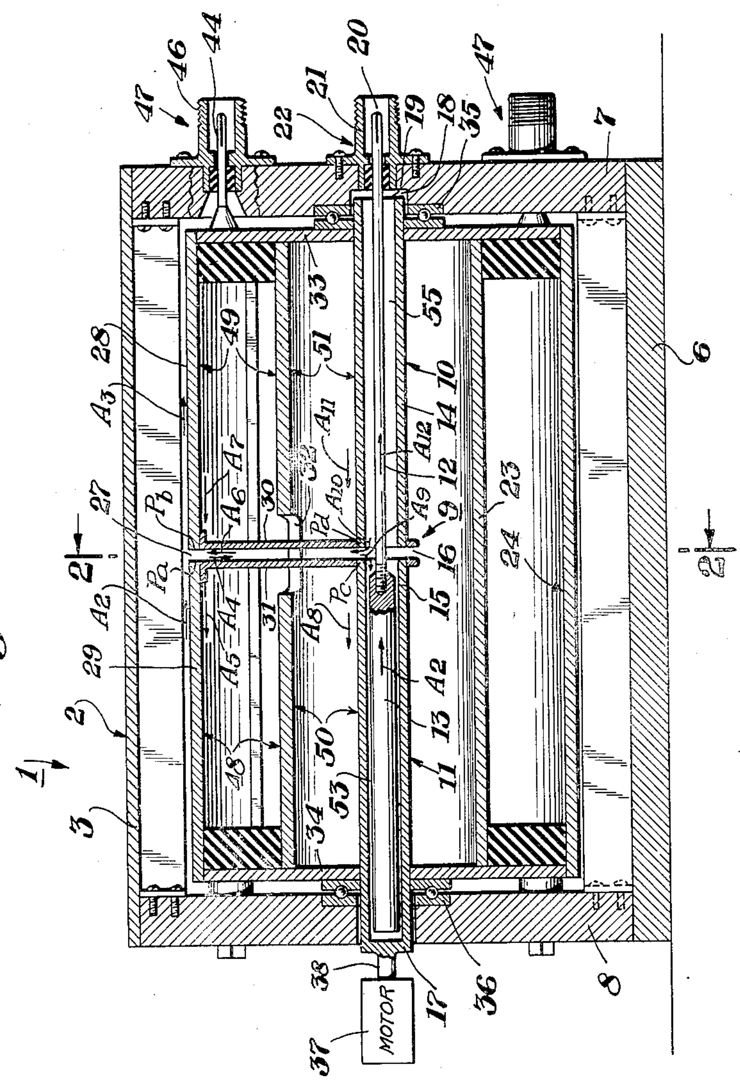

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Fig. 2.

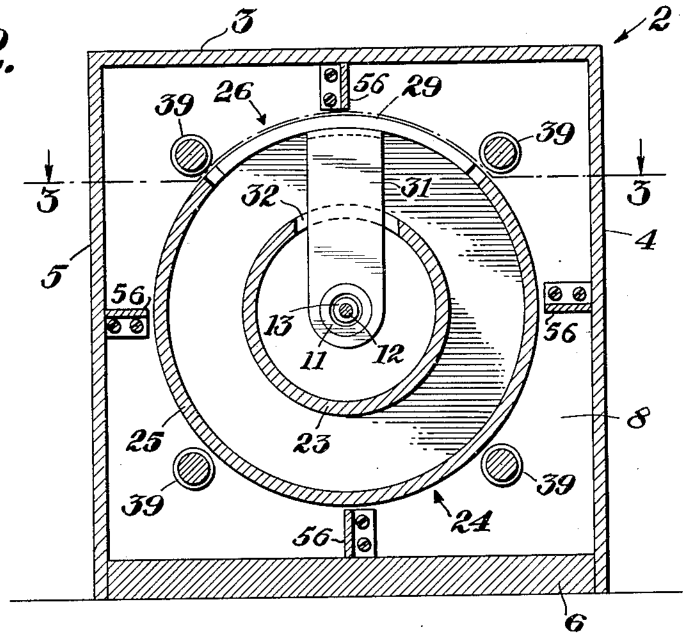

Fig. 3.

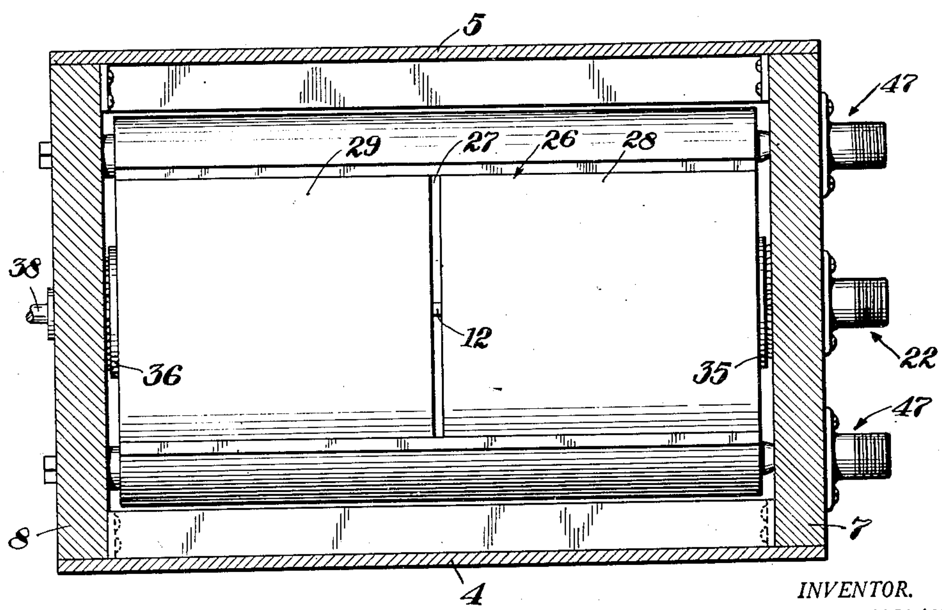

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Fig. 4.

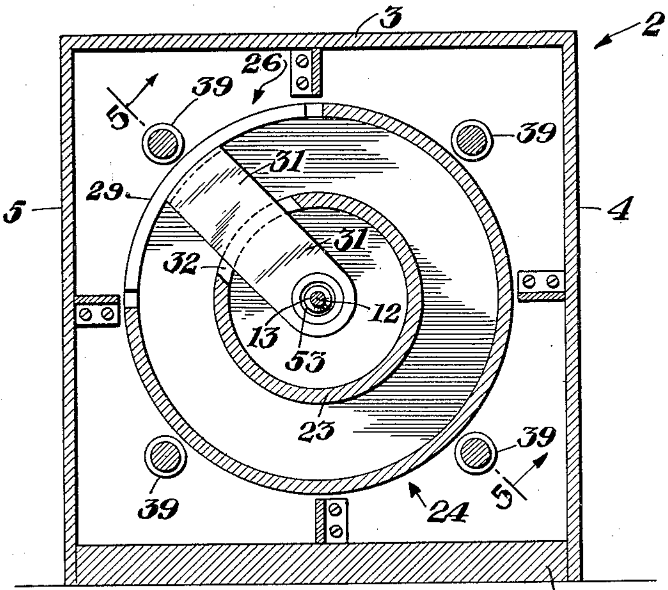
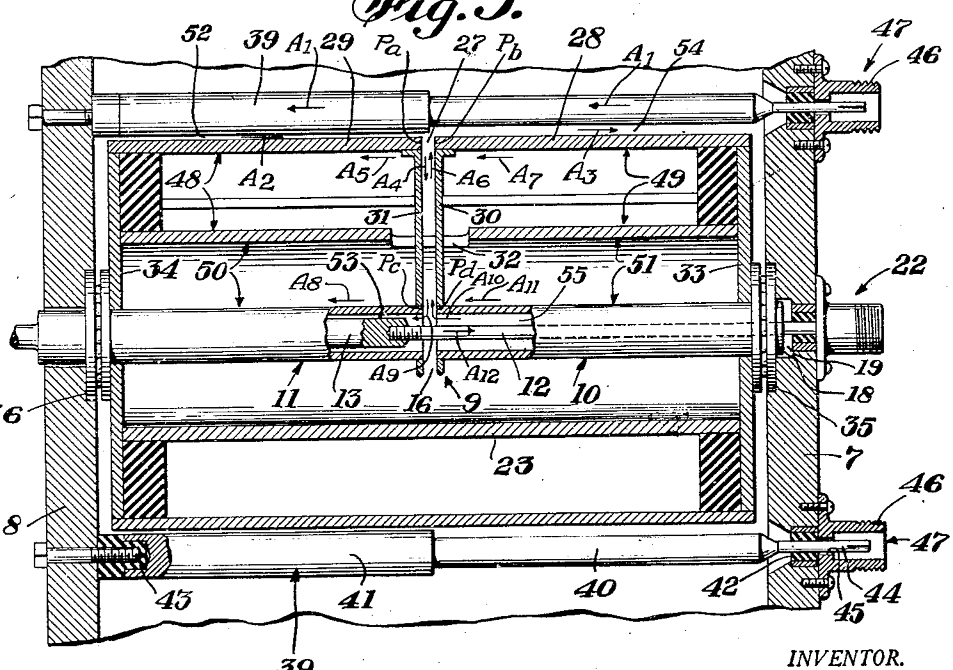


Fig. 5.



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UNITED STATES PATENT OFFICE

2,445,793

ROTARY HIGH-FREQUENCY SWITCHING CIRCUIT

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Application August 19, 1944, Serial No. 550,196

11 Claims. (Cl. 178—44)

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This invention relates to a mechanical switching circuit for high frequencies and particularly to a rotary high frequency switch.

An object of the present invention is the provision of an improved high frequency mechanical switch.

Another object of the present invention is the provision of a switch of the type referred to hereinabove which will not upset the electrical balance or equilibrium of the circuits in which it is arranged.

A further object of the present invention is the provision of a switch of the type described which is adapted to efficiently handle a relatively wide band of frequencies.

A still further object of the present invention is the provision of such a switch which is adapted for continuous switching, for example, at a predetermined rate.

Still another object of the present invention is the provision of a switch of the type described which will wear well, has the minimum of friction, has no wiping contacts and is quiet and smooth in operation.

A still further object of the present invention is the provision of a switch of the type referred to above which provides an effectively continuous shield connecting the shields of the transmission lines between which switching occurs.

Other and further objects of the present invention will become apparent and the foregoing will be best understood from the following description of an embodiment thereof, reference being had to the drawings, in which:

Fig. 1 is a vertical sectional view taken longitudinally through the middle of a switch embodying my invention and further showing the mechanical connection thereof to a motor;

Fig. 2 is a transverse sectional view taken along the lines 2—2 of Fig. 1;

Fig. 3 is a longitudinal sectional view taken along the lines 3—3 of Fig. 2;

Fig. 4 is a view similar to Fig. 2 showing the coupling plates moved under one of the coupling conductors; and

Fig. 5 is a transverse sectional view taken along the lines 5—5 of Fig. 4;

Referring now to the drawings, the switch 1 is provided with a metallic housing 2 comprising

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a top wall 3, side walls 4 and 5, a bottom 6 and end walls 7 and 8.

A coaxial line section 9 is disposed in the center of the housing and consists of two portions, a right portion 10 and a left portion 11 having respectively inner conductors 12 and 13, and outer conductors 14 and 15, said inner conductors being connected together at their inner ends, said outer conductors being separated by a gap 16 separating their inner ends. The outer end of outer conductor 15 is closed as indicated at 17, while the outer end of outer conductor 16 is open as indicated at 18. Inner conductor 13 is larger in diameter than inner conductor 12. The outer end of inner conductor 12 extends through an opening 19 in the end wall 7 of the housing and is split as indicated at 20. The split end 20 is surrounded by a threaded member 21, which together serve as an external terminal or socket 22 for connection to a coaxial line, which connection may be made by means of a suitable plug device.

Coaxial line 9 is surrounded by a concentric cylindrical metallic shield 23 which is in turn surrounded by a larger concentric metallic cylindrical member 24. The member 24 is divided into two arcuate segments: a large arcuate segment 25 which serves as a grounding plate, and a smaller arcuate segment 26 which is split transversely across the middle thereof to provide a gap 27 separating arcuate coupling plates 28 and 29 which serve to switch current to and from various transmission lines. In the embodiment illustrated, segment 25 occupies approximately 270° of the circle formed by member 24 and segment 26 occupies about 90°. The inner ends of plates 28 and 29, adjacent gap 27, are connected to the corresponding inner ends of outer conductors 14 and 15 respectively of the coaxial line, adjacent gap 16, by means of two conductor members 30 and 31 which pass through an opening 32 in the shield 23. Conductor members 30 and 31 act as a balanced dual transmission line.

Outer conductors 14 and 15 of coaxial line section 9, shield 23 and cylindrical member 24 including the large segment 25 and coupling plates 28 and 29 are all adapted to rotate together around the inner conductors 12 and 13 which remain stationary. For this purpose circular end plates 33 and 34 are arranged at opposite ends of said rotatable cylinders, and serve to close the openings therebetween at the outer ends thereof and to mechanically fix them together so that they will all rotate simultaneously. A ballbearing **35** is provided between rotatable end plate **33** and end wall **7** of the housing and a similar bearing **36** is likewise arranged between end plate **34** and end wall **8**. The rotatable portion of the structure may be driven by any suitable motor **37** by means of a shaft or similar mechanical transmission means **38** which may be attached to end **17** of outer conductor **15**.

A plurality of coupling conductors **39**, of which there are four in the embodiment herein described, are symmetrically arranged around at equal distances from and closely adjacent the path of cylindrical member **24**. Energy is transferred between said coupling conductors **39** and the coupling plates **28** and **29** as said plates pass adjacent said conductors. Coupling conductors **39** each consist of a thinner portion **40** and a thicker portion **41** (see Fig. 5). Conductors **39** are mechanically supported by end walls **7** and **8** but are electrically insulated therefrom by insulating means **42** and **43**. The thinner portion **40** of each of conductors **39** terminates in a still thinner portion **44** which is split at the end and projects through an opening **45** in wall **7** into a threaded member **46** to thus form a socket **47** similar to socket **22** hereinbefore described. Fixed shielding plates **56** (see Fig. 2) are arranged between each of the coupling conductors **39** and are supported by and electrically connected to the walls of the housing.

In use switch **1** is connected by means of socket **22** and sockets **47** to various coaxial lines which are provided at their ends with plugs engaging said sockets. These plugs which may be of any of the various known types so engage threaded members **46** and **21** of sockets **47** and **22** respectively that any current flowing on the outside of the outer conductors of these coaxial lines cannot enter inside. Switch **1** is electrically effectively enclosed by the metallic housing **2** which is an effectively continuous shield and consequently any current flowing on the outside conductors of the coaxial lines attached to switch **1** cannot enter said switch or the coaxial lines attached thereto.

Socket **22** may be the input terminal and sockets **47** the output terminals or, vice versa, sockets **47** may be the input terminals and socket **22** the output terminal. If, for example, switch **1** is used in a direction finding apparatus, then four antenna elements are connected to sockets **47** and socket **22** is connected to the receiver. By continuously rotating the rotatable portion of said switch, the various antenna elements are alternately connected to the receiver, thus providing the required antenna switching for such systems. On the other hand, in a beacon system, the transmitter would be connected to socket **22** thus making it the input terminal and sockets **47** would be connected to various antennas and thus be the output terminals.

Switch **1** is designed to handle a wide band of high frequencies without dissipating an undue amount of energy, or causing unbalances, or producing material phase distortion, and with a minimum of impedance mis-matching. In accomplishing this, the electrical dimensions of the various elements of the switch are relatively critical.

The following are substantially the electrical dimensions of the elements of the switch as expressed in terms of the mean wavelength, λ, of the band of frequencies at which the switch is designed to operate:

Coupling conductors 39 each	$=\frac{\lambda}{2}$
Thinner portion 40 of each of coupling conductors 39	$=\frac{\lambda}{4}$
Thicker portion 41 of each of coupling conductors 39	$=\frac{\lambda}{4}$
The large arcuate segment or grounding plate 25 of cylindrical member 24 whose length between end plates 33 and 34	$=\frac{\lambda}{2}$
Coupling plates 28, and 29, as measured from gap 27 to end plates 33 and 34 respectively each	$=\frac{\lambda}{4}$
Metallic shield 33 as measured from end plates 33 to 34	$=\frac{\lambda}{2}$
Outer conductor 14 and inner conductor 12 as measured from gap 16 to end 18	$=\frac{\lambda}{4}$
Outer conductor 15 and inner conductor 13 as measured from gap 16 to end 17	$=\frac{\lambda}{4}$

(Because of the capacitance effect across the gaps 16 and 27 the lengths of the above must be varied slightly to attain the mean of the band of wavelengths covered.)

Assuming that the sockets **47** are input terminals and socket **22** is the output terminal, energy from the coaxial lines connected to sockets **47** will flow into the switch (along the inner surfaces) of threaded members **46** and the outer surface of **44** thus providing a flow along coupling conductors **39**. Assuming further that the instantaneous direction of the current is as indicated by the arrow A—**1** in Fig. 5, current A—**1** flows along both the thinner portion **40** and the thicker portion **41** of coupling conductors **39**.

Coupling conductors **39** may be considered in relationship to the arcuate segments **25** and **26** as being a single wire transmission line over ground or over a wide flat plane. Currents along the line induce currents of opposite direction on said ground or wide flat plane. Likewise when the larger arcuate segment or grounding plate **25** is adjacent a particular coupling conductor **39**, current will flow on the outer surface of said grounding plate **25** in a direction opposite that indicated by arrow A—**1**. Because of the capacitance effect between the end walls **7** and **8** and the end plates **33** and **34**, the current flowing on the outside of the grounding plate will flow across the space between the end plates and end members and out along the inner surface of threaded members **46**. Thus it will be seen that when the grounding plate **25** is under one of the coupling conductors, the energy delivered will be short-circuited to ground (considering the inner surface of the outer conductors of the attached coaxial lines to be at ground potential).

On the other hand, when the coupling plates **28** and **29** are under one of the coupling conductors **39**, the current indicated by arrow A—**1**, in Fig. 5, will cause a current flow along the outer surfaces of plate **29** in the direction indicated by arrow A—**2** in Fig. 1 and along the outer surface of plate **28** in the direction indicated by arrow A—**3** in the same figure. Current A—**2** will tend to divide in two directions, as indicated by arrows A—**4** and A—**5**. Since, however, the inner surface of plate **29** and the opposing outer surface of metallic shield **23** form a shorted quarter wavelength section **48** at the mean frequency, at said frequency no current will flow along the direction A—5. However, as the frequency departs from said mean frequency, the current will tend to flow, as indicated by arrow A—5. This current flow is, however, balanced by a similar current flow through the opposite shorted quarter wavelength section at the mean frequency including the inner surface of coupling plate 28. Indicating the inner ends of members 28 and 29 as points P_a and P_b, it will be seen that in accordance with Kirchoff's law, there will tend to flow toward point P_b, currents A—6, and A—7, equal to current A—3 flowing away from said point. However, at the mean frequency, there will be no current A—7 since the impedance of the closed quarter wave section will be so great as to prevent current flow. However, as this mean frequency is deviated from, there will be a current A—7 varying in magnitude in accordance with the deviation from said mean frequency. The current A—7 and the current A—5 will, however, balance each other so that the potentials at points P_a and P_b will be equal and opposite. Conductors 30 and 31 will, therefore, act as a balanced dual transmission line.

The dual transmission lines 31 and 30, is connected to points P_c and P_d on opposite sides of gap 16. At point P_c, current indicated by arrow A—4 tends to split in two directions indicated by A—8 and A—9. Likewise at point P_d, current indicated by the arrow A—8 tends to go in two directions as indicated by the arrows A—10 and A—11. Since, however, the outside of outer conductors 15 and 16 and the portions of the inner surface of metallic shield 23 facing them each form shorted quarter wavelength sections 50 and 51, at mean frequency currents A—8 and A—11 will be extremely small or negligible as explained hereinabove in regard to currents A—5 and A—7. As mean frequency is deviated from, currents A—8 and A—11, will reach some magnitude in accordance with the amount of said deviation but said currents will balance each other and therefore not upset the balance of lines 30 and 31.

Currents A—9 and A—10 will induce a current A—12 in inner conductors 13 and 12 respectively. Current A—12 will travel outwardly through socket 22 to the inner conductor of the coaxial line to which said socket is connected. Currents A—9 and A—10 which are in the same direction will reach the inner surface of said coaxial cable by virtue of the capacitance effect across the open end 35 of the outer conductor 14 to the adjacent portions of end member 7 as well as through the galvanic connection provided by the ballbearing 35. Said current will then flow outwardly through opening 19 along the inner surface of threaded member 21 and thence along the inner surface of the outer conductor of the coaxial cable secured to said threaded member 21.

While the current flowing through lines 30 and 31 is balanced due to the arrangement of the aforementioned closed quarter wave sections 48—51, as the mean frequency is deviated from, the length of the sections is no longer a quarter wave and these sections function primarily as inductances or capacitances introducing a given amount of phase distortion. This phase distortion is substantially compensated, however, by an opposite phase distortion produced in the open-ended quarter wave sections 52 and 53 in series with points P_a and P_c, said section 52 consisting of the thicker portion 41 of coupling conductor 39 and the surface of coupling plate 29 arranged thereunder, and section 53 consisting of the inner surface of outer conductor 15 of coaxial line 9 and the inner conductor 13 of said coaxial line.

In order to limit impedance mismatching to a minimum, the surge impedances of the various sections forming said switch are calculated at the mean frequency as follows.

Assuming that the input impedance as presented at socket 47 is Z_{in}, then if Z_{54} is the surge impedance of the open-ended quarter wave section 54 consisting of the thinner portion 40 of coupling conductor 39 and the coupling plate 28 acting as the ground plane therefor, then,

$$Z_{54}=Z_{in} \tag{1}$$

The surge impedances of sections 48 and 49 are equal and their combined surge impedances may be designated as

$$Z_{48}+Z_{49}, \text{ or } 2Z_{48}, \text{ or } 2Z_{49}$$

The surge impedance of section 52 should be chosen such that

$$Z_{52}=\frac{(Z_{54})^2}{2Z_{48}} \tag{2}$$

The input impedance Z_{in} looking from points P_a and P_b towards socket 47 is

$$Z_{in}=\frac{(Z_{54}-jZ_{52}\cot\theta)(2jZ_{48}\tan\theta)}{Z_{54}-jZ_{52}\cot\theta+2jZ_{48}\tan\theta} \tag{3}$$

where θ=the electrical length in degrees of section 52.

Simplifying Equation 3

$$Z_{in}=Z_{54}\frac{1-j\frac{Z_{52}}{Z_{54}}\cot\theta}{1-\frac{Z_{52}}{2Z_{48}}\cot^2\theta-j\frac{Z_{54}}{2Z_{48}}\cot\theta} \tag{4}$$

Substituting the value of Z_{52} of Equation 2

$$Z_{in}=Z_{54}\frac{1-j\frac{Z_{54}}{2Z_{48}}\cot\theta}{1-\left(\frac{Z_{54}}{2Z_{48}}\cot\theta\right)^2-j\frac{Z_{54}}{2Z_{48}}\cot\theta} \tag{5}$$

It can be seen from Equation 5 that the only term preventing a perfect transition from socket 47 to points P_a and P_b is the cotangent square term in the denominator. As long as Z_{48} and Z_{49} or $2Z_{48}$ is kept at least twice as large as Z_{54}, Equation 5 shows that an excellent transition will occur from socket 47 to points P_a and P_b at a three to one frequency range.

A similar transition from points P_c and P_d to socket 22 is likewise obtained using the foregoing equations and making the following substitutions: Substitute

Z_L for Z_{in}
Z_{50} for Z_{48}
Z_{51} for Z_{45}
Z_{53} for Z_{52}
Z_{55} for Z_{54}
θ' for θ

where Z_L is the load impedance at socket 22; Z_{55} is the surge impedance of the coaxial section 55 consisting of inner conductor 12 and outer conductor 14; and θ' is the electrical length of said section 55.

In the foregoing equations, the capacitance effect across gaps 27 and 16 is neglected. These gaps should preferably be as small as practicable. By employing the relative constants as indicated in the above equations, the input impedance is matched to points P_a and P_b and the load impedance is matched to points P_c and P_d, thus producing matching between the load and input impedances of the switch.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of my invention as set forth in the objects and the claims.

I claim:

1. A high frequency switch comprising a plurality of terminals, an elongated conductor connected to one of said terminals, a conductive switching member adapted to be moved into and out of coupling relationship with said conductor and in said coupling relationship extending a substantial distance adjacent to and parallel with said conductor, said member having a transverse gap intermediate the ends thereof separating it into two parts, a second elongated conductor connected to another of said terminals, a coupled conductive member coupled with and extending adjacent to and parallel with said second elongated conductor, said coupled member having a transverse gap intermediate the ends thereof separating it into two parts, and means connecting the ends of said switching member facing each other across its gap with the ends of said coupled member facing each other across its gap.

2. A high frequency switch according to claim 1, wherein said coupled member is the outer conductor of a coaxial line section, and said second elongated conductor is the inner conductor of said coaxial line section.

3. A high frequency switch according to claim 1, wherein said coupled member is the outer conductor of a coaxial line section and said second elongated conductor is the inner conductor of said coaxial line section and wherein said switching member is relatively wide in comparison with said first-mentioned elongated conductor, said first-mentioned elongated conductor and said switching member forming, when they are coupled together, a single conductor over a wide plane transmission line section.

4. A high frequency switch according to claim 1, wherein said coupled member is the outer conductor of a coaxial line, said second elongated conductor is the inner conductor of said coaxial line, said switching member is carried on said coupled member and said coupled member is adapted to be rotated about said second elongated conductor to thereby move said switching member in a circular path, and said first-mentioned elongated conductor is so arranged adjacent said path, so that upon rotation of the coupled member past the switching member, the switching member is brought into and out of coupling relationship with said first-mentioned elongated conductor.

5. A high frequency switch according to claim 1, wherein said coupled member is the outer conductor of a coaxial line whose inner conductor is said second elongated conductor, said outer conductor being adapted to be rotated about said inner conductor, said switching member is relatively wide and arcuate in cross section and is carried on said outer conductor to thereby travel in a circular path upon rotation of said outer conductor, said first-mentioned elongated conductor being so arranged adjacent said path that upon rotation of said outer conductor said switching member is brought into and out of coupling relationship with said first-mentioned elongated conductor.

6. A high frequency switch comprising a plurality of terminals, a central elongated conductor connected to one of said terminals, a plurality of other elongated conductors arranged around said central conductor and each connected to one of the other terminals, a conductive switching member adapted to be moved into and out of coupling relationship with one of said other conductors at a time, and in said coupling relationship extending a substantial distance adjacent to and parallel with the conductor to which it is coupled, said member having a transverse gap intermediate the ends thereof separating it into two parts, a coupled conductive member coupled with and extending adjacent to and parallel with said central conductor, said coupled member having a transverse gap intermediate the ends thereof separating it into two parts, and means connecting the inner ends of said switching member at its gap with the ends of said coupled member at its gap.

7. A high frequency switch according to claim 1 in which said means consists of a balanced dual transmission line.

8. A high frequency switch according to claim 1 in which said means is a balanced dual transmission line, and further including a pair of effectively quarter wave shorted sections as measured at the mean frequency of the band of frequencies at which said switch is designed to operate, one leg of one of said quarter wave sections being connected with one leg of the other quarter wave section and the other legs of said sections constituting the parts of said switching member, and a second pair of similar quarter wave sections, one leg of each of said sections of said second pair being common with said connected leg of each of said sections of said first pair and the other legs of said sections of said second pair constituting the parts of said coupled member.

9. A high frequency switch according to claim 1 in which the surge impedance of the section consisting of the first-mentioned elongated conductor and the switching member as measured from the terminal to the gap of said switching member is equal to the surge impedance of the section consisting of the second elongated conductor and the coupled member as measured from the terminal to the gap of said coupled member.

10. A high frequency switch in accordance with claim 1, wherein said means consists of a dual transmission line and further including means for balancing the electrical phenomena on said dual transmission line.

11. A high frequency switch according to claim 1, wherein the cross-sectional area of said elongated conductors is enlarged at the portions thereof on the side of the gap opposite the terminals.

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