June 2, 1953 D. C. ESPLEY 2,640,878

SWITCH FOR HIGH-FREQUENCY ELECTRICAL OSCILLATIONS

Filed Oct. 11, 1948

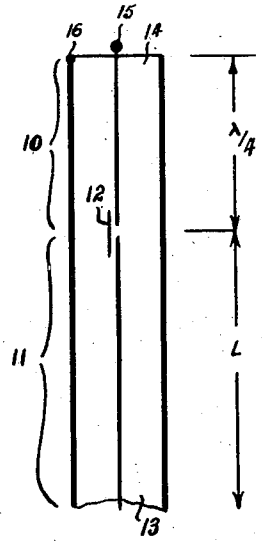
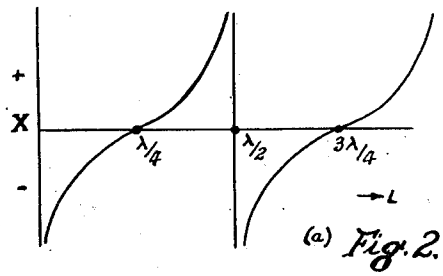


Fig. 1.



(a) Fig. 2. (a)

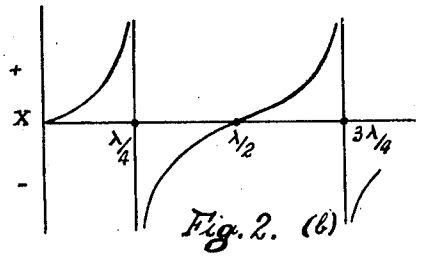


Fig. 2. (b)

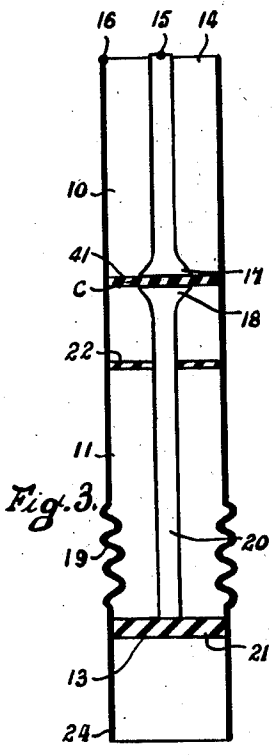


Fig. 3.

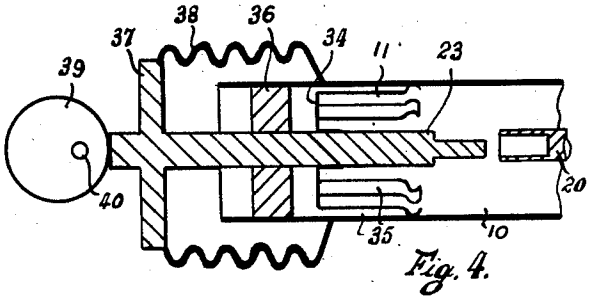


Fig. 4.

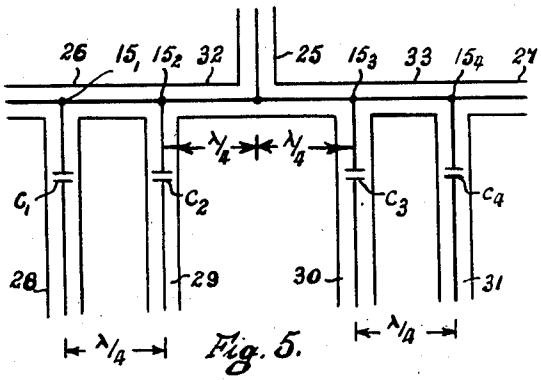


Fig. 5.

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SWITCH FOR HIGH-FREQUENCY ELECTRICAL OSCILLATIONS

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8 Claims. (Cl. 178—44)

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The present invention relates to switches for high frequency electrical oscillations. By a switch is meant a device by which the impedance between a pair of terminals can be made alternatively very large and very small.

The invention is concerned with switches in which the desired change of impedance is obtained without making and breaking electrical contacts. One such switch, which forms the subject of Patent No. 2,404,832, comprises a uniform transmission line with distribution inductance and capacity, with substantially zero attenuation constant, of characteristic impedance Z_0 and of length substantially equal to $p\lambda/4$ where λ is the wavelength (or the mean wavelength) in the line of the oscillations to be switched and p is an odd integer. The outer and inner members of the line are connected at one end to the pair of terminals between which the impedance is to be changed, means are provided for approaching a conductor to the other (open) end of the line to provide a capacity C shunting the open end and a condenser of capacity C', connected permanently between the said pair of terminals, is made substantially equal to $1/4\pi^2f^2Z_0C$, f being the frequency of the oscillations. Preferably p is made equal to unity.

When the capacity C shunts the open end, the impedance between the said pair of terminals is substantially infinite and when the conductor is withdrawn to reduce C to a negligibly small value the said impedance is substantially zero.

It is found difficult in practice to arrange that the air gap between the conductor and the open end of the transmission line is small enough, and hence that C has a large enough value, to avoid the necessity for an inconveniently large value for C'. Moreover, the path of current at the open end is somewhat indeterminate and may include parts of the mechanism by which the conductor is moved towards and away from the open end. This presents difficulties in design. The present invention has for its object to provide an improved switch in which these difficulties are avoided or substantially reduced.

According to the invention a switch for high frequency electric oscillations of wavelength or mean wavelength λ comprises a substantially uniform line of electrical length $p\lambda/4$, where p is an integer, connected at one end to a pair of terminals between which switching is required, a second transmission line which at the wavelength λ has a reactance X and a conductor by which the other (open) end of the first-named transmission line can be coupled to the second line by a

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reactance which at the wavelength λ is substantially equal to $-X$, the conductor being capable of being withdrawn to render the coupling between the lines negligibly small. In this way, if p is an odd integer, when the conductor is in the approached position in which coupling between the lines is effected, the reactance at the open end of the first-named line is substantially zero and hence the impedance between the said terminals is substantially infinite. If on the other hand the conductor is withdrawn and the coupling between the lines is made negligibly small, the impedance at the open end of the first-named line is substantially zero.

If p is an even integer, when the conductor is in the approached position the impedance between the said terminals is substantially zero and when the conductor is withdrawn the impedance at the said terminals is substantially infinite.

The invention will be described, by way of example, with reference to the accompanying drawing in which

Figure 1 is a diagrammatic illustration of one embodiment of the invention,

Figure 2 contains at (a) and (b) two curves illustrating the determination of the appropriate length for the said second transmission line,

Figure 3 is a diagrammatic illustration in cross-section of one embodiment of the invention,

Figure 4 is a diagrammatic illustration in cross-section of a part of a further embodiment of the invention and

Figure 5 shows diagrammatically an application of the invention to two-way switching.

Referring to Figure 1, the first co-axial transmission line 10 has a length $\lambda/4$, that is to say p is made equal to unity, and the second co-axial transmission line 11 has its outer conductor continuous with that of the line 10. A capacitive coupling $C=1/\omega X$, where ω is the pulsatance corresponding to λ and X is positive, can be provided by bringing a member 12 close to the inner conductors of the two lines 10 and 11 and C can be made very low by removing the member 12. The end 13 of the line 11 remote from the coupling C is shown open-circuited. The end 14 of the first transmission line 10 has terminals 15 and 16 between which switching is desired.

In Figure 2 there is shown at (a) a curve of reactance of the line 11 plotted against its length as a function of the wavelength λ. Since the line 11 is required to have a positive reactance X, its length must be between $\lambda/4$ and $\lambda/2$, if a minimum length is required as is usually convenient. It could have a value between $3\lambda/4$ and λ or even

a greater length if desired. The length, if between $\lambda/4$ and $\lambda/2$, will usually be chosen fairly near to $\lambda/2$ since, as is seen in Figure 2(*a*), the value of the positive reactance X is then relatively large and consequently the required value of C can be made relatively small.

If the line **11** is short-circuited at the end **13**, its reactance will be related to its length as shown in Figure 2(*b*) and the length may then be chosen below $\lambda/4$ and preferably near to $\lambda/4$. If this length is too short for convenience a value between $\lambda/2$ and $3\lambda/4$ may be used.

A convenient form which the device of Figure 1 may take is illustrated in Figure 3. In this form the inner conductors of the two lines **10** and **11** at their adjacent ends **17** and **18** are made of increased area in order to increase the capacity between them for a given spacing. At the lower end of the outer conductor of the line **11** is provided a bellows **19** of conducting material and the inner conductor **20** of this line is mounted upon an insulating support **21**, since it is again assumed that the end **13** is to be open-circuited. A guide plate **22** of insulating material is provided to guide the inner conductor **20**. By applying suitable tension or compression at the end **13**, the capacitance C between **17** and **18** can be made negligibly small or equal to $-1/\omega X$ respectively. An insulating plate **41** is provided between the opposing faces of **17** and **18** to ensure that the desired value of C is obtained when pressure is applied to the end **13**. When a short-circuited line is desired for the line **11**, the support **21** may be made of conducting material.

The desired increased area of the opposing ends of the inner conductors of the lines **10** and **11** may be obtained by simply attaching plates to these ends.

The outer conductor of the line **11** may be extended below the support **21** as shown at **24** in Figure 3 in order to prevent appreciable energy loss from the open end **13** and its lower end may be closed. The design of lines to attain this result is well understood. The space within the bellows and the remainder of the outer conductor of the line **11** (and if desired also the space within the outer conductor of the line **10**, the end **14** being, if necessary, suitably closed with insulating material), may be filled with any desired atmosphere or liquid.

Many other means for varying the coupling at C may be used. Thus for instance the inner conductor **20**, or an insulating extension thereof, may be made slidable through an aperture in the member **21** and the bellows **19** may be dispensed with. The two inner conductors may be fixed and a third member may be approached to the gap between their adjacent ends when coupling is desired as described with reference to Figure 1.

In the embodiment shown in Figure 4, the capacity C is formed between a spigot on one end of the inner conductor **23** of the line **11** and a recess in the adjacent end of the inner conductor **20** of the line **10**. There is fixed to the inner conductor **23** a contact member **34** having a number of spring fingers **35** making contact with the inner surface of the outer conductor of the line **11**. The inner conductor **23** passes through a guide **36** in which it is slidable and has a flange **37** to which is fixed one end of a bellows **38**, the other end of which is fixed to the outer conductor. The bellows may be of metal or insulating material such for example as rubber. The guide **36** is preferably of metal. The inner conductor **23** may be moved, when the capacitive coupling is desired, by means of an eccentric **39** rotatable on a spindle **40**, or otherwise. The bellows **38** forms a hermetic seal for the arrangement.

Figure 5 shows how the invention may be applied to provide two-way switching whereby a line **25** may be placed in effective connection with either of two lines **26** and **27**. In this example a switching system comprising four switches according to the invention is provided as shown at **28**, **29**, **30** and **31**. The line **25** is connected to the lines **26** and **27** by two lines **32** and **33** respectively, each $\lambda/2$ in length. The switches **29** and **30** are arranged at a distance $\lambda/4$ on either side of the line **25** and the switches **28** and **31** are arranged at a distance of $\lambda/4$ from the switches **29** and **30** respectively. The couplings C in the four switches are represented by condensers C_1, C_2, C_3 and C_4 respectively.

If C_1 and C_2 are operative and C_3 and C_4 are withdrawn, the impedances at the terminals 15_1 and 15_2 in parallel across the line **26** are approximately infinite and those at the terminals 15_3 and 15_4 are approximately zero. Since the points 15_2 and 15_3 are spaced $\lambda/4$ from the line **25**, the impedance presented by the line **32** to the adjacent terminals of the line **25** is the normal impedance of the line **26** and the impedance presented by the line **33** to the same terminals is approximately infinite. Hence the two-way switch is set to couple line **25** to line **26** and to disconnect it effectively from line **27**. Obviously a reversal of the conditions of the four switches reverses the two-way switch.

Suitable means are preferably provided for approaching the conductors to form the capacitances C_1 and C_2 and simultaneously withdrawing those forming the capacitances C_3 and C_4.

The effectiveness of switching is, as already known, greatly increased by employing two or more switches **28**, **29** or **30**, **31** spaced by $\lambda/4$ (or an odd multiple of $\lambda/4$) rather than only a single switch in each line **26** and **27**.

I claim:

1. A switch for high frequency electric oscillation of mean wave length λ, comprising a first transmission line of electrical length $p\lambda/4$ where p is an integer, a second transmission line having such an electrical length, and being terminated at one end in an impedance of such a nature, that at the wave length λ it has an input impedance measured at its second end which is substantially a pure positive reactance, a coupling element, means guiding said coupling element for movement over a predetermined fixed path, and means for limiting the normal movement of said coupling element over said path so that at one limit of the normal movement of the coupling element said second end of the second transmission line is coupled to one end of the first transmission line by an impedance which at the wave length λ is substantially a pure negative reactance of equal magnitude to said positive reactance and at the other limit of the normal movement of the coupling element said second end of the second transmission line is substantially decoupled from said one end of the first transmission line.

2. A switch according to claim 1, in which said first and second transmission lines are both coaxial lines and the outer conductors of the two coaxial lines are continuous.

3. A switch for high frequency electric oscillations of mean wave length λ, comprising a first

coaxial line of electrical length $p\lambda/4$, where p is an interger, a second coaxial line having an outer conductor continuous with the outer conductor of said first coaxial line, said second coaxial line having such an electrical length, and being terminated at the end remote from said first coaxial line in an impedance of such a nature, that at the wave length λ it has an input impedance measured at the end adjoining said first coaxial line which is substantially a pure positive reactance, means guiding the inner conductor of said second coaxial line for longitudinal movement, and means for limiting the normal longitudinal movement of the inner conductor of the second coaxial line so that at one limit of the normal movement of said inner conductor the effective capacity between adjacent ends of the inner conductors of the two coaxial lines has at the wave length λ a negative reactance substantially equal in magnitude to said positive reactance and at the other limit of the normal movement of the inner conductor of the second coaxial line said effective capacity is substantially zero.

4. A switch according to claim 3, in which one of said adjacent ends is of smaller cross-sectional area than the remainder of the inner conductor of which it forms part, and the other of said adjacent ends is bored to permit entry of the first named adjacent end without electrical contact between the adjacent ends.

5. A switch according to claim 3, in which both said adjacent ends are of greater cross-sectional area than the remainder of the respective inner conductors of which they form part.

6. A switch according to claim 3, in which said means guiding the inner conductor of the second coaxial line comprises a bellows providing a mechanical coupling between the inner and outer conductors of the second coaxial line.

7. A switch according to claim 6, in which part at least of the space enclosed by the outer conductors of the first and second coaxial lines is hermetically sealed from the exterior thereof, said bellows forming part of the hermetic seal.

8. A two-way switch system for switching high frequency electric oscillations of mean wave length λ between a main transmission line and either of two subsidiary transmission lines, ends of all said lines being electrically connected at a single junction, said switching system comprising a first switch device connected to one of said subsidiary lines at a pair of terminals at an electrical distance $p_1\lambda/4$ from said junction where p_1 is an odd integer, and a second switch device connected to the other of said subsidiary lines at a pair of terminals at an electrical distance $p_2\lambda/4$ from said junction where p_2 is an odd integer, said first and second switch devices each comprising a first transmission line of electrical length $p\lambda/4$ where p is an integer, connected at one end to the appropriate pair of terminals, a second transmission line having such an electrical length, and being terminated at one end in an impedance of such a nature, that at the wave length λ it has an input impedance measured at its second end which is substantially a pure positive reactance, a coupling element, means guiding said coupling element for movement over a predetermined fixed path, and means for limiting the normal movement of the coupling element over said path so that at one limit of the normal movement of the coupling element said second end of the second transmission line is coupled to the end of the first transmission line remote from said terminals by an impedance which at the wave length λ is substantially a pure negative reactance of equal magnitude to said positive reactance and at the other limit of the normal movement of said coupling element said second end of the second transmission line is substantially decoupled from the end of the first transmission line remote from said terminals.

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