

[54] STEP ATTENUATOR APPARATUS HAVING
ATTENUATOR STAGES SELECTIVELY
CONNECTED IN CASCADE BY CAM
ACTUATED SWITCHES

3,449,697 6/1969 Mison 333/81
2,999,202 9/1961 Ule 323/74
3,369,173 2/1968 Andrews 333/81 X
2,637,777 5/1953 Kilby et al. 323/74 X

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FOREIGN PATENTS OR APPLICATIONS

763,641 12/1956 Great Britain 333/81

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317/101 C, 101 CC; 323/74, 77, 80

[56] References Cited

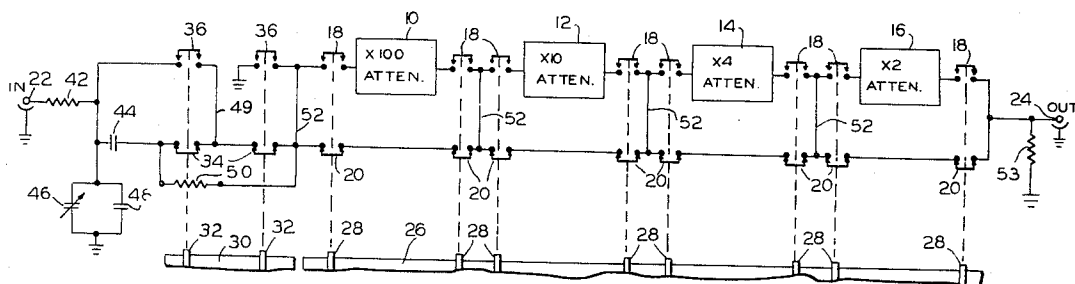
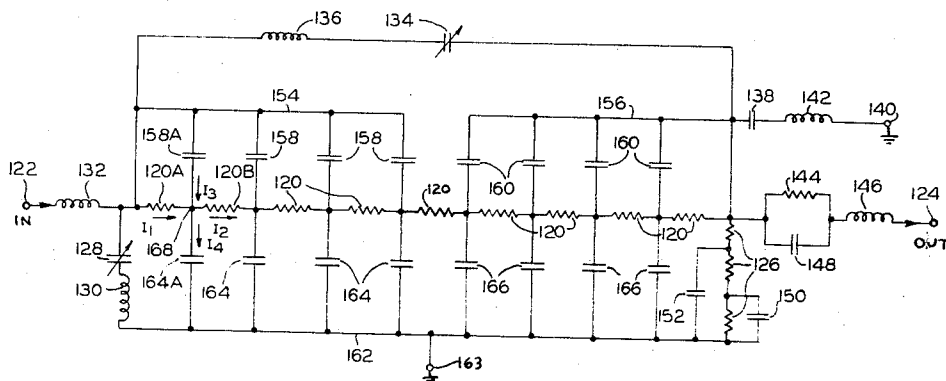
UNITED STATES PATENTS

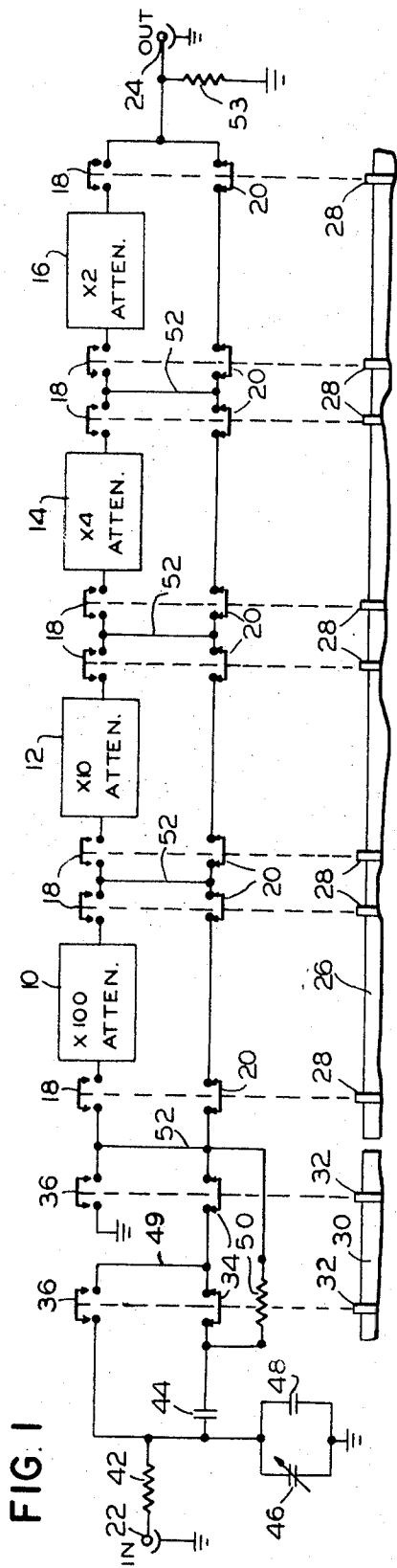
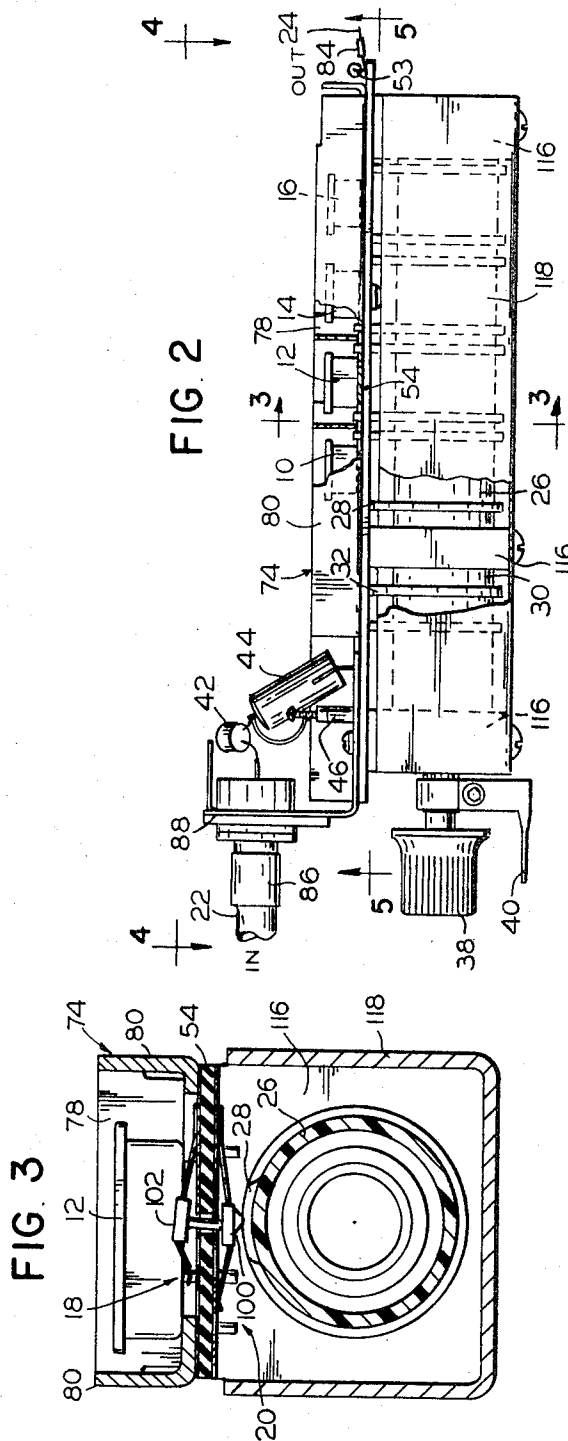
3,319,194 5/1967 Adam 333/81 R
3,014,187 12/1961 Sher et al. 333/81
3,551,820 12/1970 Bagwell 323/80 X

[57] ABSTRACT

A step attenuator device has a plurality of attenuator stages interconnected via uniform impedance transmission lines. The attenuator stages are switched in a cascade mode of operation using a high frequency contact arrangement permitting high bandwidths. This mode of operation has the advantage of being adapted for use with both high and low impedance circuitry.

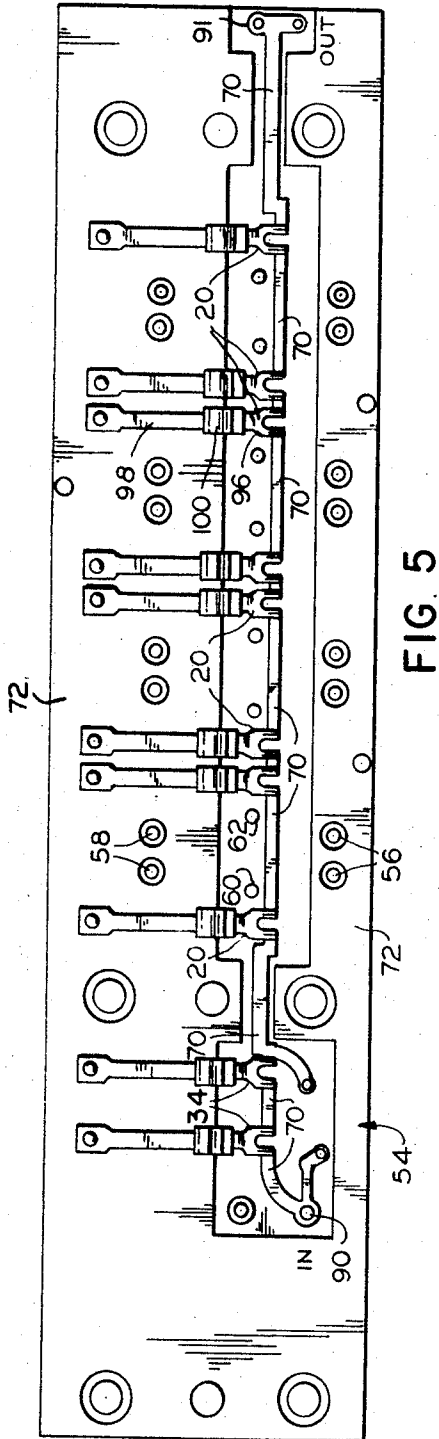
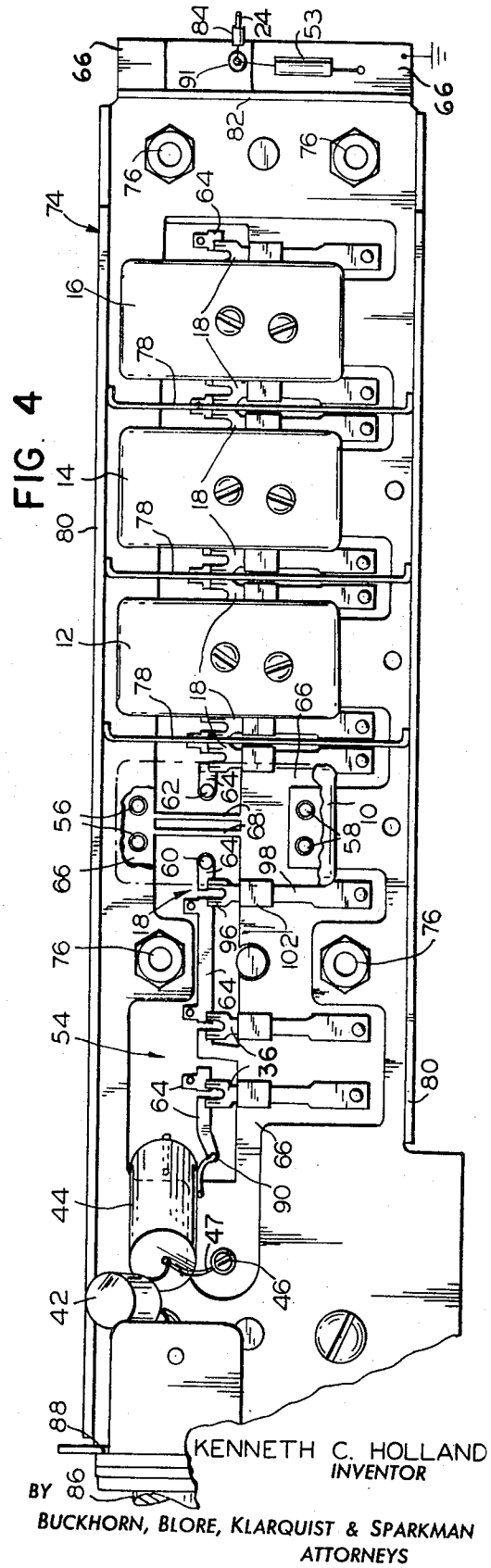
19 Claims, 9 Drawing Figures

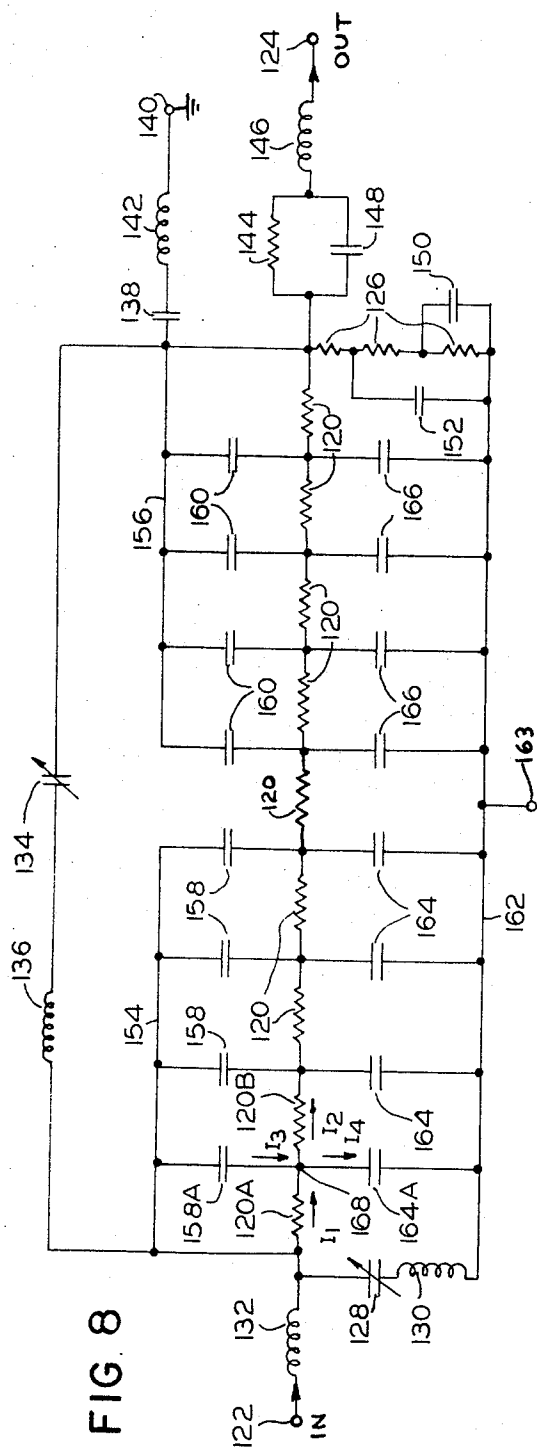
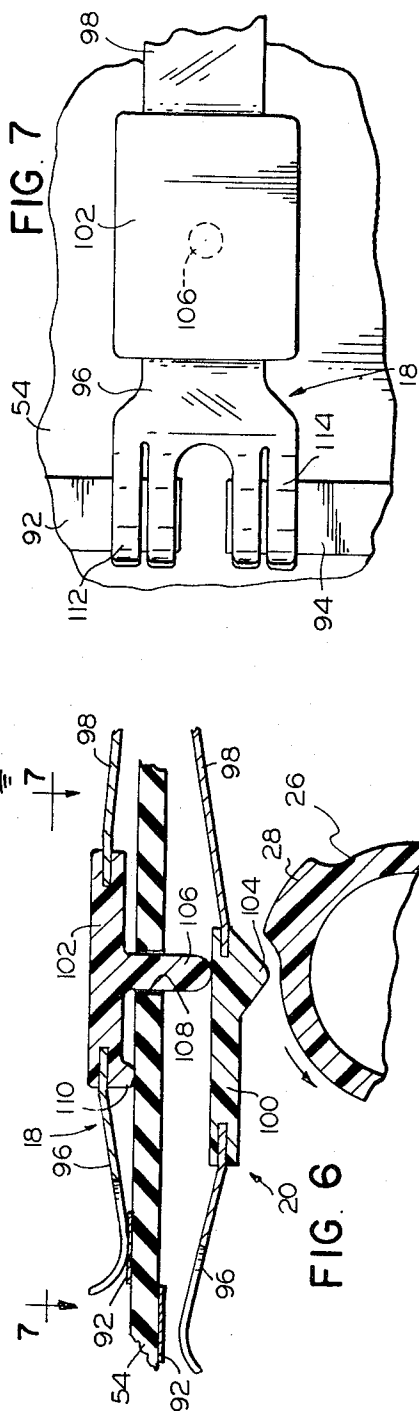




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3,753,170

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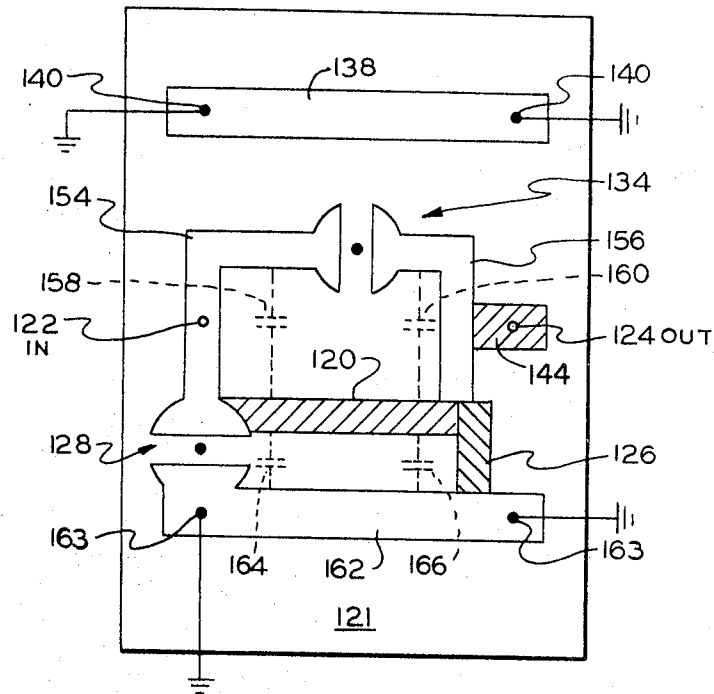


FIG. 9

STEP ATTENUATOR APPARATUS HAVING ATTENUATOR STAGES SELECTIVELY CONNECTED IN CASCADE BY CAM ACTUATED SWITCHES

BACKGROUND OF THE INVENTION

The subject matter of the present invention relates generally to electrical attenuators and associated switch apparatus, and in particular to a step attenuator apparatus in which a plurality of attenuator stages of different value, mounted on a circuit board, are selectively connected in cascade between the input and output terminals by switch means on such circuit board, as well as to an attenuation circuit and switch contacts used in such attenuator apparatus.

The attenuator apparatus of the present invention is especially useful to change the gain of a vertical amplifier of a cathode ray oscilloscope because it is capable of extremely wide band frequency response from DC to 1,000 megahertz and high attenuation of greater than 1,000 to 1. Previous step attenuators have been of the rotary type in which a plurality of attenuator sections of different values are mounted on the periphery of a turret or drum which selectively switches such section into the circuit by rotation of such drum. The attenuation apparatus of the present invention is of smaller size and lower cost than such turret attenuators due in part to the fact that it employs fewer attenuator stages which are mounted on a circuit board and are selectively connected in cascade by switches thereon. The switches may be actuated by a rotary cam drum mounted on the other side of the circuit board. The circuit board is provided with a transmission line of uniform characteristic impedance including a signal conductor formed in sections connected through the switches to the attenuator stages. The switches are of extremely low capacitance and low inductance and they do not cause any appreciable discontinuity in the transmission line. The switches include movable contacts which are insulated from their mounting springs. Each of the movable contacts are provided with two parallel leg portions joined together at one end and having free ends which engage two fixed contacts to short circuit them, so that current flows in opposite directions in the leg portions to reduce their inductance because the two induced magnetic fields oppose each other. As a result, the attenuator apparatus of the present invention is capable of a higher frequency response.

The attenuator devices forming the different stages each contain an improved attenuation circuit which includes a series resistor connected between the input and output terminals of the circuit and formed by a plurality of distributed series resistances. A ground conductor extends along one side of the series resistances and a pair of other conductors extend consecutively along the other side of such series resistances with one of such pair connected to the input and the other connected to the output terminal, to form a plurality of distributed capacitances between such conductors and the series resistance. These distributed capacitances are made small so that the series current through two adjacent series resistances is many times greater than the shunt current flowing through the two distributed capacitances connected to the junction of such adjacent resistances. Thus, when such shunt current is less than 5 percent of the series current, the circuit has a frequency response of DC to about 1,000 megahertz.

It is therefore one object of the present invention to provide an improved step attenuator apparatus of simple, compact, and inexpensive construction which is capable of high attenuation ratios and has an extremely wide band frequency response.

Another object of the invention is to provide such an attenuator apparatus in which a plurality of attenuator stages mounted on a circuit board are selectively connected in cascade by switches on such circuit board to change the attenuation ratio so that few attenuator devices are required.

A further object of the present invention is to provide such an attenuator apparatus in which strip transmission lines are provided on the circuit board including a signal conductor formed in sections which are connected together through cam actuated switches at the input and output of each attenuator stage to provide a very high frequency response.

An additional object of the present invention is to provide an improved attenuator circuit of extremely high frequency response employing a series input resistor formed by a plurality of distributed resistances with a ground conductor plane extending along one side and a pair of other conductor planes extending consecutively along the other side of such distributed resistances, such pair of conductor planes being connected respectively to the input and output of the series resistor to provide distributed capacitances of small value between such conductor planes and the distributed resistance so that the series current flowing through two adjacent distributed resistances is many times greater than the shunt current flowing through the two distributed capacitors connected to the junction of such adjacent resistances.

BRIEF DESCRIPTION OF DRAWINGS

Other objects and advantages of the present invention will be apparent from the following detailed description of a preferred embodiment thereof and from the attached drawings of which:

FIG. 1 is a partially schematic diagram of an attenuator apparatus made in accordance with the present invention showing the operation of the cam actuated switch;

FIG. 2 is a side elevation view of one embodiment of the attenuator apparatus of FIG. 1 with parts broken away for clarity;

FIG. 3 is a vertical section view taken along the line 3—3 of FIG. 2;

FIG. 4 is a plan view taken along the line 4—4 of FIG. 2 with one of the attenuator devices removed for purposes of clarity;

FIG. 5 is a horizontal section view taken along line 5—5 of FIG. 2 showing the bottom side of the circuit board;

FIG. 6 is an enlarged section view of a cam actuated switch employed in the attenuator apparatus of FIGS. 1 to 5;

FIG. 7 is a plan view taken along line 7—7 of FIG. 6; and

FIG. 8 is a schematic diagram of an attenuator circuit used in the attenuator apparatus of FIGS. 1 to 5.

FIG. 9 is a top view of the physical embodiment of the circuit of FIG. 8.

DESCRIPTION OF PREFERRED EMBODIMENT

As shown in FIG. 1, one embodiment of the attenua-

tor apparatus of the present invention includes four attenuator stages 10, 12, 14 and 16 having attenuation values of 100 to 1, 10 to 1, 4 to 1, and 2 to 1, respectively. These attenuator stages are provided as plug-in attenuator devices mounted on one side of an etched circuit board and selectively connected through upper switches 18 on the same side of the circuit board, as well as by lower switches 20 on the other side of the circuit board, in cascade between an input terminal 22 and an output terminal 24 of the attenuator apparatus. The upper and lower switches 18 and 20 are arranged in pairs having their movable contacts ganged together by a coupling member extending through a hole in the circuit board in a manner hereafter described with reference to FIG. 6. A rotary cam drum 26, also shown in FIGS. 2 and 3, having raised cam portions 28 actuates the movable switch contacts of the lower switches 20 to close such switches and at the same time opens the upper switches 18 as shown in FIG. 3.

Another cam drum 30 shown in FIG. 1 having raised cam portions 32 is employed to operate a pair of lower switches 34 and a pair of upper switches 36 whose movable contacts are ganged together in a similar manner, which in response to movement of cam 30 between AC, DC and ground positions, connect the input terminal 22 through an AC coupling or a DC coupling, or connect to ground the output terminal 24 or the inputs of different ones of the attenuator stages 10, 12, 14 and 16 depending upon the position of cam drum 26. Both of the cam drums 26 and 30 are mounted on the same side of the circuit board with the control shaft for drum 26 extending through a hollow control shaft for drum 30. As shown in FIG. 2, a knob 38 is connected to the shaft controlling the cam drum 26 while a lever arm 40 is connected to the shaft controlling the cam drum 30. In the AC coupling position, shown in FIG. 1, both lower switches 34 are closed and both upper switches 36 are open so that an input signal applied to input terminal 22 is transmitted through a coupling resistor 42 of 91 ohms and a coupling capacitor 44 of 0.019 microfarads in series therewith through switches 34 to the input of any of the attenuator stages. The AC coupling network also includes a variable shunt capacitor 46 of 0.2 to 1.5 picofarads connected by lead 47 between the common terminal of the resistor 42 and capacitor 44 and ground. A fixed capacitor 48 of one picofarad is connected in parallel with the variable shunt capacitor 46. A shorting connection 49 is connected between the output contacts of the left upper and left lower switches 36 and 34. In the DC position of cam drum 30, the left lower switch 34 is open and the left upper switch 36 is closed, while the right lower switch 34 is closed to transmit the input signal from input terminal 22 through coupling resistor 42 and the shorting connection 49 to the attenuator stages. In the ground position of cam 30, the lower switches 34 are both open and the upper switches 36 are both closed. The right upper switch 36 has its left fixed contact grounded so that when closed, such switch connects this ground to the attenuator stages or directly to the output terminal. A resistor 50 of 1 megohm is connected between the right hand terminal of the coupling capacitor 44 and the ungrounded fixed contact of the right upper switch 36 to charge and to discharge the coupling capacitor 44 in the ground position. Thus, in a first ground position, a DC voltage source is connected to input terminal 22 to charge the coupling capacitor 44 through resistors 42

and 50 to a voltage approximately equal to the DC voltage level of a high voltage input signal to be transmitted through the attenuator apparatus. Then the cam 30 is moved to the "AC" position to apply such input signal to input terminal 22, but only the AC component of such input signal is transmitted through capacitor 44 because of the DC voltage charge stored on such capacitor. This prevents high voltage input signals from driving the trace off of the oscilloscope screen. After this precharging of the coupling capacitor 44, it can be discharged through resistor 50 by moving cam 30 back to the ground position.

There are a plurality of shorting connections 52 extending between the fixed contacts of two adjacent pairs of switches 18 and 20 which are provided between each of the attenuator stages and at the input of attenuator stage 10. A load resistor 53 of 1 megohm is connected between the output terminal 24 and ground which is in parallel with a stray output capacitance of 5 to 7 picofarads.

The shorting contacts 52, together with the cam actuated switches 18 and 20, enable any different combination of attenuator stages to be connected between the input terminal 22 and the output terminal 24. As a result, fewer attenuation stages are required than would be employed with a conventional turret attenuator to provide the same number of attenuation steps. For example, using the four attenuator stages shown, ten different attenuation steps are provided for the vertical amplifier of an oscilloscope including vertical scale factors of 5, 10, 20, 50, 100, 200 and 500 millivolts, as well as 1, 2 and 5 volts per centimeter or graticule division.

As shown in FIGS. 2, 3, 4 and 5 the attenuator devices 10, 12, 14 and 16 are each plugged into holes in an etched circuit board 54 of conventional type including spaced conductive strips of metal on an insulator support plate. Each attenuator device is provided with two pairs of ground pins 56 and 58 at the opposite ends thereof, as well as an input pin 60 and an output pin 62 between such pairs of ground pins. The circuit board 54 includes a plurality of signal conductor sections 64 provided on the upper side between a pair of ground conductor portions 66. The signal conductor sections 64 are connected together through switches 18 and the attenuator stages to form a transmission line of substantially uniform characteristic impedance of about 110 ohms. The two ground conductors 66 are connected together at the ends of the signal conductor as well as by four pairs of shorting strips 68 extending between the input pin 60 and the output pin 62 of each of the attenuator stages, as shown in FIG. 4 where a portion of the attenuator device 10 has been broken away. In a similar manner, a plurality of signal conductor sections 70 are provided on the other side of the circuit board between a pair of ground conductors 72 to provide another transmission line of substantially uniform characteristic impedance of about 110 ohms. Adjacent signal conductor portions 70 are connected together through switches 20.

A ground plate member 74 is secured to the upper side of the circuit board by nuts 76 which are threaded onto bolts extending through holes in the circuit board. The ground plate member is in contact with the ground conductors 66 on such circuit board and includes three partition portions 78 which separate adjacent attenua-

tor sections from each other. The partitions 78 are attached between two side portions 80 of the ground plate which extend upward substantially perpendicular to the circuit board. These partitions 78, side portions 80 and right end portion 82 provide compartments containing each of the attenuator sections to shield them from each other and from external fields.

An insulated lead wire 84 is attached to the circuit board adjacent the end portion 82 and acts as the output terminal 24 of the attenuator apparatus. A coaxial cable connector 86 is attached at its ground conductor to a left hand end portion 88 of the ground plate to provide the input terminal 22 of the attenuator apparatus. Thus, the grounded mounting member 88 for the signal input means 22, 86 is formed integral with the ground plate member 74 to provide an improved grounding system which enables high attenuation of large amplitude input signal over the wide frequency bandwidth of the attenuator apparatus. The central signal conductor of the connector 86 is connected through resistor 42 and the input plate of capacitor 44 to a common input terminal 90 of the signal conductors 64 and 70 on the circuit board, while the lead wire 84 is connected to a common output terminal 91 of such signal conductors on such circuit board.

As shown in FIGS. 3, 6 and 7, the switches 20 and 18 each include a pair of fixed contacts 92 and 94 formed by conductive strips on the circuit board 54, integral with the signal conductors 64 and 70 and a movable contact member 96. As shown in FIG. 6, the fixed contacts 92 and 94 on the upper side of the circuit board 54 is displaced to the right of the fixed contacts 92 and 94 on the lower side of such circuit board, as are the signal conductors 64 and 70 corresponding thereto, to reduce the capacitance formed therebetween. Each movable contact member 96 is insulated from its mounting spring 98 by an insulator member 100 or 102 molded out of a suitable plastic material with the ends of the mounting spring and movable contacts embedded therein. Insulator member 100 is provided with a cam follower projection 104 which engages the raised cam portion 28 of cam drum 26 when such cam drum closes switch 20. The other insulator member 102 is provided with a coupling element 106 molded integrally therewith and extending through a hole 108 in the circuit board into engagement with the inner surface of the other insulator member 104. Thus, the movable contacts of switches 18 and 20 are ganged together by the coupling element 106 so that movement of the insulator 100 toward the circuit board to close switch 20 causes a corresponding movement of insulator 102 away from the circuit board to open switch 18. Insulator member 102 is provided with a spacer portion 110 projecting toward the circuit board so that it contacts the surface of the circuit board in the closed position of switch 18 and thereby sets the amount of bending of the movable contact 96 of such switch. By insulating the movable contacts 96 of switches 18 and 20, with insulator members 100 and 102, the movable switch contacts are provided with much lower stray capacitance. In addition, the inductance of such switch contacts is reduced because current no longer flows through the mounting springs 98. Also, both mounting springs 98 of switches 18 and 20 may be attached by a common rivet eyelet to the circuit board since this does not connect the movable contacts together.

As shown in FIG. 7, the movable contacts 96 may each be provided with a pair of spaced parallel leg portions 112 and 114 whose free ends engage fixed contacts 92 and 94, respectively, and whose other ends are joined in common and attached to the insulator member 100 and 102. Thus, the movable contact 96 acts to short circuit fixed contacts 92 and 94 so that current flows through leg portions 112 and 114 in opposite directions and induces opposing magnetic fields which tend to cancel each other and thereby further reduce the inductance of the movable contacts. It should be noted that the free ends of the movable contacts may be split into two halves to provide bifurcated contacts for better electrical contact.

The rotary cam drums 26 and 30 are mounted in bearing members 116 attached to the circuit board as shown in U. S. Pat. No. 3,562,464 of Vollum et al granted Feb. 9, 1971. A metal housing 118 is provided about the cam drums for shielding purposes and to prevent dirt from getting on the cam surfaces.

Each of the attenuator devices 10, 12, 14 and 16 is provided with an attenuation circuit as shown in FIG. 8, and 9 including a series resistor 120 whose resistance is distributed uniformly along its length to provide a plurality of distributed resistances 120 connected between an input terminal 122 and an output terminal 124 of such circuit. For the 10 to 1 attenuation stage, each of the nine series distributed resistances 120 is 100 kilohms, giving a total series resistance of 900 kilohms. A shunt resistor 126 including three distributed resistances 126 is connected between the output of the series resistance and GROUND. In the example given, the total shunt resistance is 111.1 kilohms so that each distributed resistance 126 is 37.033 kilohms. It should be noted that the distributed series resistor 120 and the distributed shunt resistor 126 are formed by resistive coatings on an insulator substrate 121 such as a ceramic plate. A variable standardizing capacitor 128 of 2.8 to 7.7 picofarads is connected between the input of the series resistor 120 and ground, and a distributed inductance 130 of 14 nanohenries is formed by the lead between such capacitor and ground. In a similar manner, the lead connecting input terminal 122 to the input of the series resistances has a distributed inductance 132 of 15 nanohenries. A variable coupling capacitor 134 of 1.7 to 4.0 picofarads is connected between the input and output of the series resistance 120 and includes a lead inductance 136 of 12 nanohenries in series with such capacitor. A fixed capacitor 138 of 16.7 picofarads is connected between the output end of the series resistance 120 and a ground terminal 140 through a lead inductance 142 of 12 nanohenries. A damping resistor 144 of 55 ohms is connected between the common junction of the series resistance 120 and the shunt resistance 126, and the output terminal 124 through a lead inductance 146 of 12 nanohenries. A distributed capacitance 148 of 0.045 picofarads is in parallel with the damping resistor 144. In addition, a distributed capacitance 150 of 0.042 picofarads is provided in parallel with the third distributed shunt resistance 126 and another distributed capacitance 152 of 0.042 picofarads is provided parallel with the second and third distributed shunt resistances.

A first conductor plane 154 and a second conductor plane 156 are provided consecutively along the series resistor 120 spaced adjacent to the input portion and output portion of the series resistor. The first and sec-

ond conductors 154 and 156 may be provided by the terminal plates of the coupling capacitor 134. Thus, conductor plane 154 is connected to the input terminal 122 while conductor plane 156 is connected to the output terminal 124 whose voltages set the potentials on these conductive planes. The first conductor plane 154 forms a plurality of distributed shunt capacitances 158 of 0.022 picofarads value between such conductor plane and the series distributed resistances of the input portion of the series resistor. The second conductor plane 156 forms a plurality of second distributed shunt capacitance 160 of 0.027 picofarads between such conductor plane and the distributed resistance of the output portion of the series resistor. In the example given, with nine distributed series resistances 120, there are four first distributed capacitances 158 connected, respectively, to the junction of the first and second resistance, the junction of the second and third resistance, the junction of the third and fourth resistance, and the junction of the fourth and fifth resistance. There are also four second distributed capacitances 160 which are connected to the junction of the fifth and sixth resistor, a junction of the sixth and seventh resistor, the junction of the seventh and eighth resistor, and the junction of the eighth and ninth resistor. A third conductor plane 162 is provided on the opposite side of the series resistor 120 from the first and second ground plane 154 and 156 and is connected to a ground terminal 163 to provide a ground plane. This third conductor plane is spaced from and extending along the entire length of the series resistor. As a result, four distributed shunt capacitors 164 of 0.017 picofarads are formed between the third conductor plane and the distributed resistances of the input portion of the series resistor 120, and four other distributed capacitances 166 of 0.015 picofarads are formed between the distributed resistances of the output portions of such series resistor and such conductor plane. The different values of capacitances 164 and 166 are achieved by varying the spacing between the ground plane 162 and the series resistor 120.

As a result of the extremely small values of the distributed shunt capacitances 158, 160, 164 and 166, the shunt current I_3 and I_4 flowing through the two distributed capacitances 158A and 164A is much smaller on the order of 5% or less than the series current I_1 and I_2 flowing through the two adjacent distributed resistances 120A and 120B whose common terminal 168 is connected in common to such distributed capacitors. As a result, the current I_1 flowing through the first distributed resistance 120A is substantially the same as current I_2 flowing through the second distributed resistance 120B within the operating frequency range of DC to 1,000 megahertz. Therefore, the distributive capacitances have no appreciable effect in limiting the high frequency response below 1,000 megahertz. This relationship of shunt current through the distributive capacitance being 5 percent or less than the series current through the series resistances is maintained along the entire series resistor. Therefore, even with an unbalance in the shunt current, so that I_3 is not equal to I_4 , there is no appreciable unbalance of the series current and I_1 still is approximately equal to the I_2 . Ideally, the current I_1 should be exactly equal to the current I_2 but this is only possible if the capacitor current I_3 is exactly equal to the capacitor current I_4 which is not possible because of size limitations, manufacturing tolerances,

etc. In the particular example given, the shunt current I_3 and I_4 is about 5 percent of the series current I_1 and I_2 .

As stated above, the series resistances 120 and the shunt resistances 126 along with the conductor planes 154, 156 and 162 are formed as coatings of resistance material and conductive material respectively on a ceramic substrate member 121. In addition to these distributed components, the real capacitors 128, 134 and 138 are also formed by conductive coating on the ceramic substrate except for the movable contacts of the variable capacitors 128 and 134. The result is a hybrid attenuator device of distributed and real components which is of extremely compact size and can be mounted within a plug-in attenuator device to enable easy replacement for repair or change of attenuation value.

It will be obvious to those having ordinary skill in the art that many changes may be made in the details of the above described preferred embodiment of the present invention. Therefore, the scope of the present invention should only be determined by the following claims.

I claim:

1. An attenuator device comprising:

a first resistor having resistance distributed along its length connected between the input and output terminals of the device;

a second resistor connected between said output and ground;

a first conductor plane extending along in spaced relationship to an input part of said first resistor to form a plurality of first distributed capacitances between said first conductor plane and the distributed resistance portions of said input part;

a second conductor plane extending along in a spaced relationship to an output part of said first resistor to form a plurality of second distributed capacitances between said second conductor plane and the distributed resistance portions of said output part; and

a third conductor plane extending along in spaced relationship to both the input and output parts on the opposite side of the first resistor from said first and second conductor planes to form a plurality of third distributed capacitances between said third conductor plane and the distributed resistances of the input and output parts of said first resistor;

said distributed capacitances being of a small value so that the series current flowing through two adjacent distributed resistances of the first resistor is many times the value of the shunt current flowing through the two distributed capacitances connected to the junction of said adjacent resistances and including one of the third capacitances and one of the first or second capacitances.

2. An attenuator device in accordance with claim 1 in which said shunt current is less than 5 percent of said series current over the operating frequency range of the device.

3. An attenuator device in accordance with claim 1 in which the third conductor plane is grounded, the first conductor plane is connected to the input terminal, and the second conductor plane is connected to the output terminal.

4. An attenuator device in accordance with claim 3 in which a first coupling capacitor is connected between the input and output terminals, and the terminal

plates of the coupling capacitor form the first and second conductor planes.

5. An attenuator device in accordance with claim 4 in which the second conductor plane is connected to ground through a second coupling capacitor.

6. An attenuator apparatus comprising:

a plurality of attenuator devices containing attenuator circuits of different attenuation values;
an electrical circuit board having conductive strips divided into portions electrically insulated from each other on an insulator member;

mounting means for mounting said attenuator devices on the circuit board to connect the attenuator circuits between certain of said portions of said conductive strips; and

switch means for selectively electrically connecting said portions to connect said attenuator devices in cascade between an input terminal and an output terminal on said circuit board;

said switch means including a plurality of switches formed by fixed contacts on said portions, movable contacts carried by said circuit board and an actuation means for selectively moving the movable contacts between an open position disengaged from the fixed contacts and a closed position engaging the fixed contacts;

said movable contacts each including two spaced leg portions joined together at one end by a common connector portion and extending substantially parallel from said one end to their free ends which engage two different fixed contacts to short-circuit them in the closed position of the switch.

7. Attenuator apparatus in accordance with claim 6 in which the mounting means is a plug-in mounting for releasable attachment to the circuit board.

8. Attenuator apparatus in accordance with claim 6 in which the common connector portion of the movable contact is attached to an insulator member of electrical insulating material and a mounting spring is attached between said insulator member and the circuit board.

9. Attenuator apparatus in accordance with claim 6 in which a ground member is attached to the circuit board and connected to ground conductors thereon, said ground member including a plurality of partition portions each extending between two adjacent attenuator devices to form a plurality of compartments each containing a different attenuator device to shield them from each other.

10. An attenuator apparatus in accordance with claim 9 in which a signal input means for applying an input signal to said input terminal on said circuit board, is mounted on said ground member so that said ground member also provides a ground connection for said signal input means.

11. An attenuator apparatus comprising:

a plurality of attenuator devices containing attenuator circuits of different attenuation values;
an electrical circuit board having a plurality of conductive strips on one side of an insulator member;
mounting means for mounting said attenuator devices on the circuit board to connect the attenuator circuits to said conductive strips; and

switch means for selectively connecting said attenuator devices in cascade between an input terminal and an output terminal on said circuit board;

said plurality of conductive strips including a first signal conductor divided into portions electrically insulated from each other, and a pair of first ground conductors spaced from said first signal conductor and on opposite sides thereof to form a first transmission line of substantially uniform characteristic impedance;

said attenuator devices each having ground terminals at their opposite ends which are connected to said pair of first ground conductors, and have input and output signal terminals intermediate said ends which are connected to different insulated portions of the first signal conductor;

said switch means including a plurality of switches formed by fixed contacts on said portions, movable contacts carried by said circuit board, and an actuation means for selectively moving the movable contacts between an open position disengaged from the fixed contacts and a closed position engaging the fixed contacts.

12. Attenuator apparatus in accordance with claim 11 in which the circuit board also has a plurality of conductive strips on its other side including a second signal conductor divided into portions electrically insulated from each other and connected to the fixed contacts of others of said switches and a pair of second ground conductors spaced from said second signal conductor on opposite sides thereof to form a second transmission line of substantially uniform characteristic impedance equal to that of said first transmission line.

13. Attenuator apparatus in accordance with claim 12 in which the pair of second ground conductors are connected together and the pair of first ground conductors are connected together to form ground planes.

14. An attenuator apparatus in accordance with claim 12 in which the second signal conductor is laterally displaced from the first signal conductor.

15. Attenuator apparatus in accordance with claim 12 in which the switches are arranged in pairs of first and second switches on opposite sides of the circuit board with the movable contacts of the first and second switches being ganged together by a movable coupling member extending through a hole in said circuit board.

16. Attenuator apparatus in accordance with claim 15 in which the actuation means includes a cam actuator means mounted on the circuit board for engagement with a cam follower connected to the movable contact of the first switch of each pair of switches.

17. Attenuator apparatus in accordance with claim 16 in which the cam actuator means includes a rotary cam drum on the opposite side of the circuit board from the attenuator devices.

18. Attenuator apparatus in accordance with claim 17 in which another rotary cam drum is mounted on the circuit board to rotate between AC, DC and ground positions for actuating switches thereon which selectively connect the inputs of the transmission lines to an AC coupling network or a DC coupling, or grounds the inputs of the attenuator devices or the output of the transmission lines depending upon the position of the first mentioned cam drum.

19. An attenuator apparatus comprising:

a plurality of attenuator devices containing attenuator circuits of different attenuation values;
an electrical circuit board having conductive strips divided into portions electrically insulated from each other on an insulator member providing a sig-

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nal conductor and a ground conductor spaced from each other to form a transmission line of substantially uniform characteristic impedance;
 mounting means for mounting said attenuator devices on the circuit board to connect the attenuator circuits to said conductive strips;
 switch means for selectively connecting said attenuator devices in cascade through said signal conductor between an input terminal and an output terminal on said circuit board;
 said switch means including a plurality of switches formed by fixed contacts on said portions and mov-

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able contacts carried by said circuit board and an actuation means for selectively moving the movable contacts between an open position disengaged from the fixed contacts and a closed position engaging the fixed contacts;
 said attenuator devices each having ground terminals at their opposite ends which are connected to the ground conductor, and having input and output signal terminals intermediate said ends which are connected to different insulated portions of the signal conductor.

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