

[54] HIGH VOLTAGE SUPPRESSOR FOR TRANSMISSION LINES

[75] Inventor: **Heinz M. Schlicke**, Fox Point, Wis.

[73] Assignee: **Allen-Bradley Company**, Milwaukee, Wis.

[22] Filed: **May 10, 1973**

[21] Appl. No.: **358,885**

[52] U.S. Cl. **317/61, 317/61.5, 338/21**

[51] Int. Cl. **H02h 1/04**

[58] Field of Search 179/184; 206/166, 222; 317/335 C, 49, 50, 61, 61.5; 333/70 CR, 70 S, 75, 76, 79, 80 R, 80 T, 97 R; 338/20, 21

[56] References Cited UNITED STATES PATENTS

2,665,376	1/1954	Kodama	333/79
3,268,744	8/1966	Kaiser et al.	307/93
3,457,527	7/1969	Matsushima et al.	333/79
3,506,936	4/1970	Loos et al.	333/79
3,521,200	7/1970	Matsushima et al.	333/79

3,572,247	3/1971	Warshall	333/79
3,693,053	9/1972	Anderson	317/61

Primary Examiner—J. D. Miller

Assistant Examiner—Patrick Salce

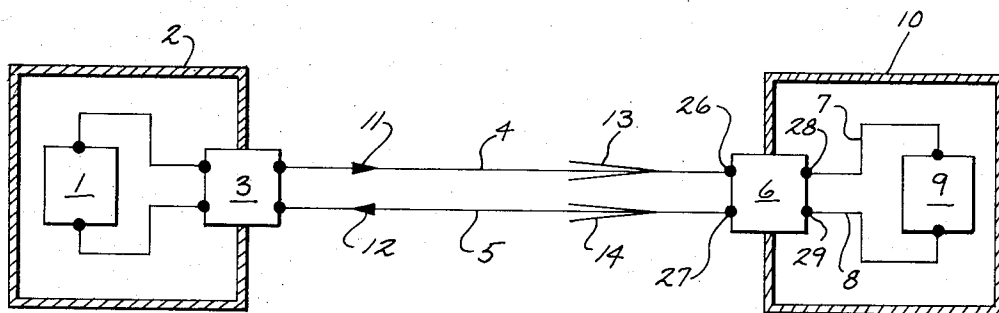
Attorney, Agent, or Firm—Quarles & Brady

[57]

ABSTRACT

A compensated high voltage suppressor for insertion in a transmission line is shown for shunting large interference voltages from the line to ground. The suppressor has a varistor material through which the large interference voltages are shunted, and this material also functions as a capacitor dielectric. Additional circuit components are connected with this capacitance to form a low pass filter in the transmission line which has a characteristic impedance substantially matching the line characteristic impedance. This impedance matching maintains effective transmission for power, or signals conducted along the line in the normal mode of operation.

13 Claims, 9 Drawing Figures



SHEET 1 OF 3

Fig. 1

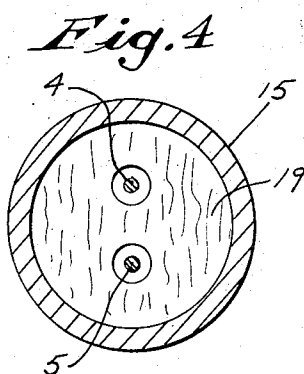
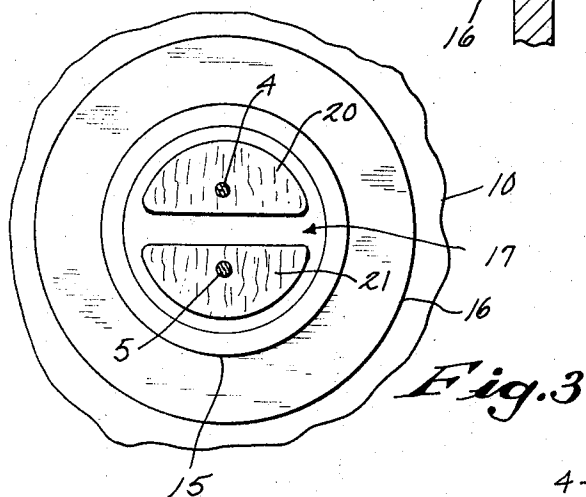
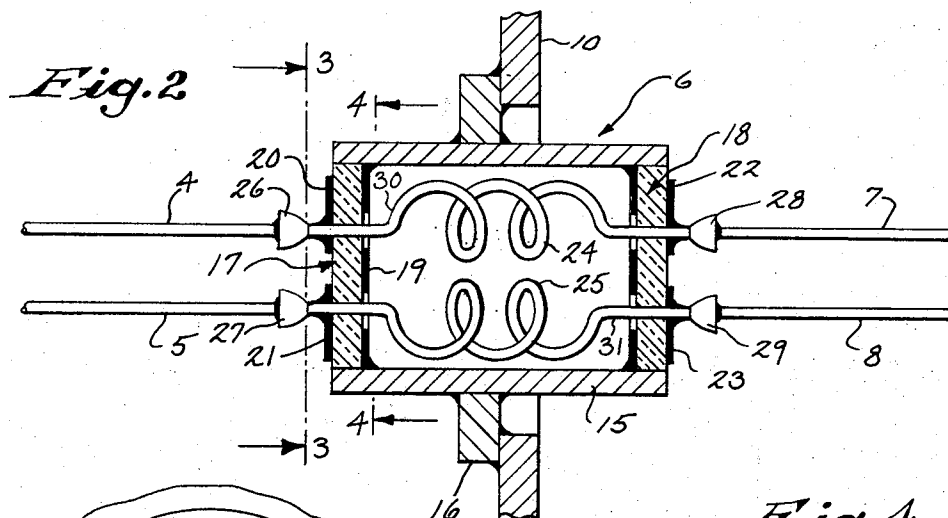
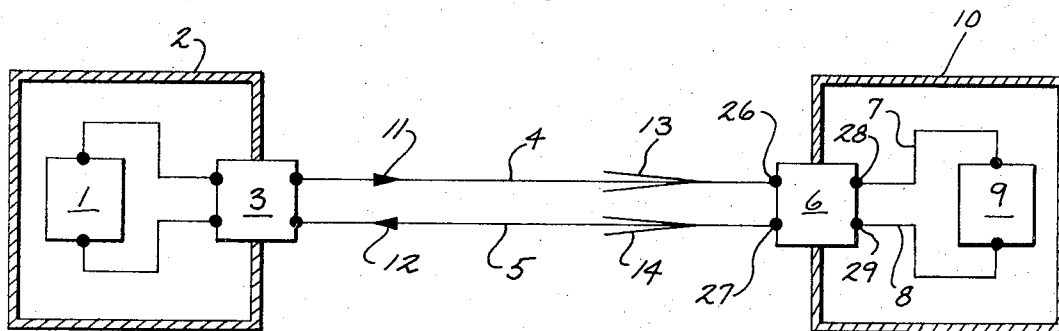


Fig. 3

Fig. 4

Fig. 5

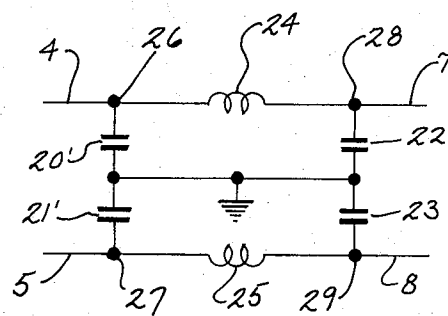


Fig. 6

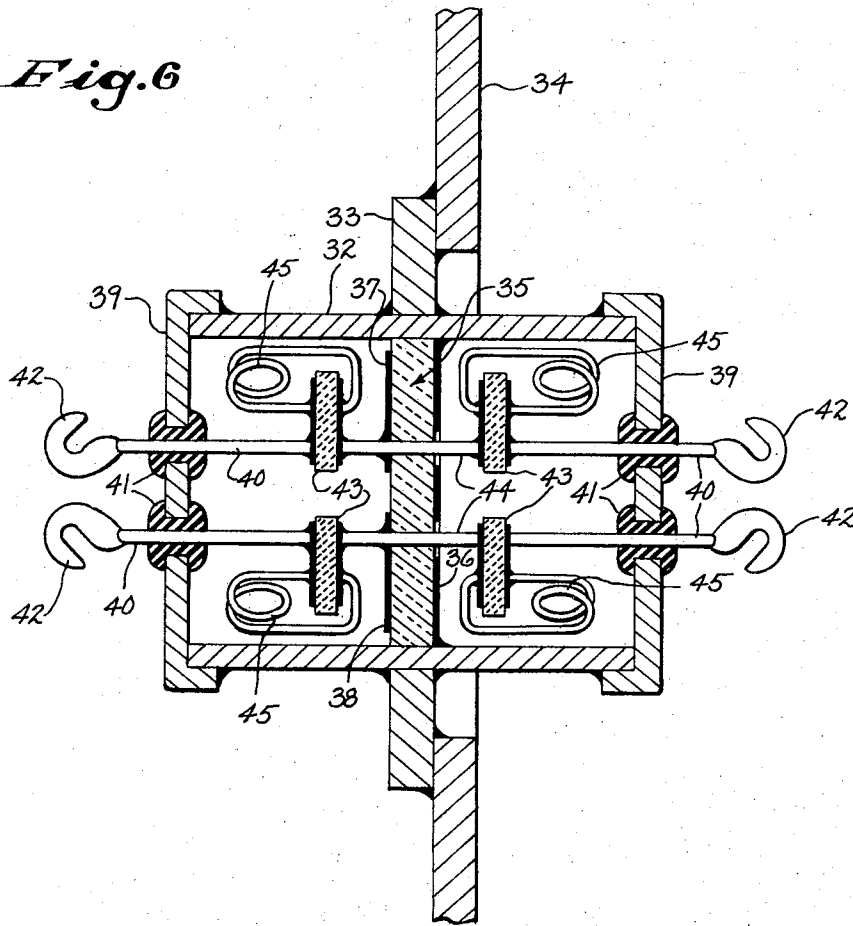


Fig. 7

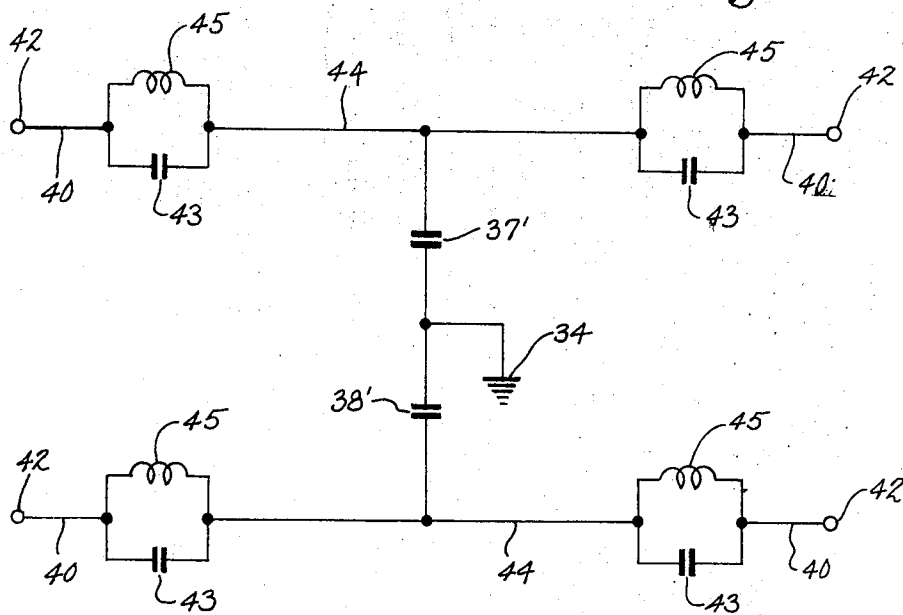


Fig. 8

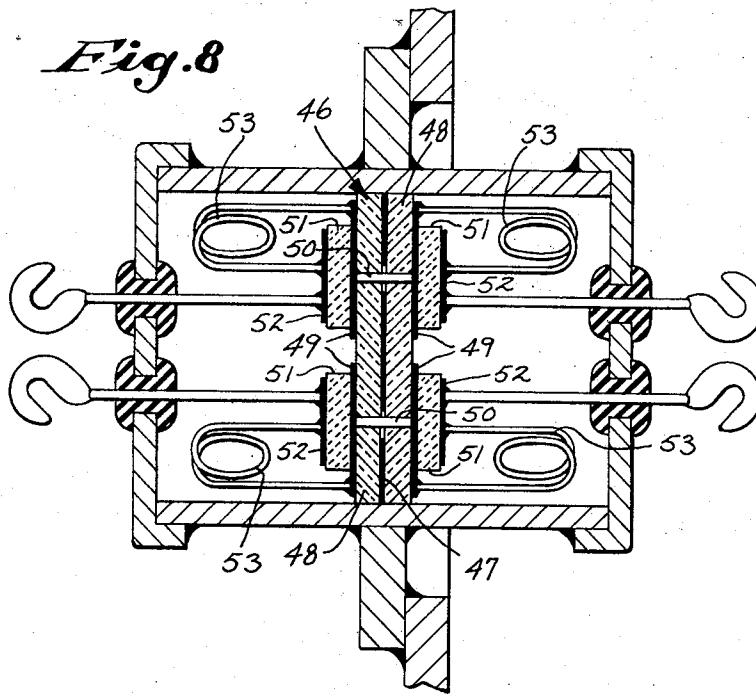
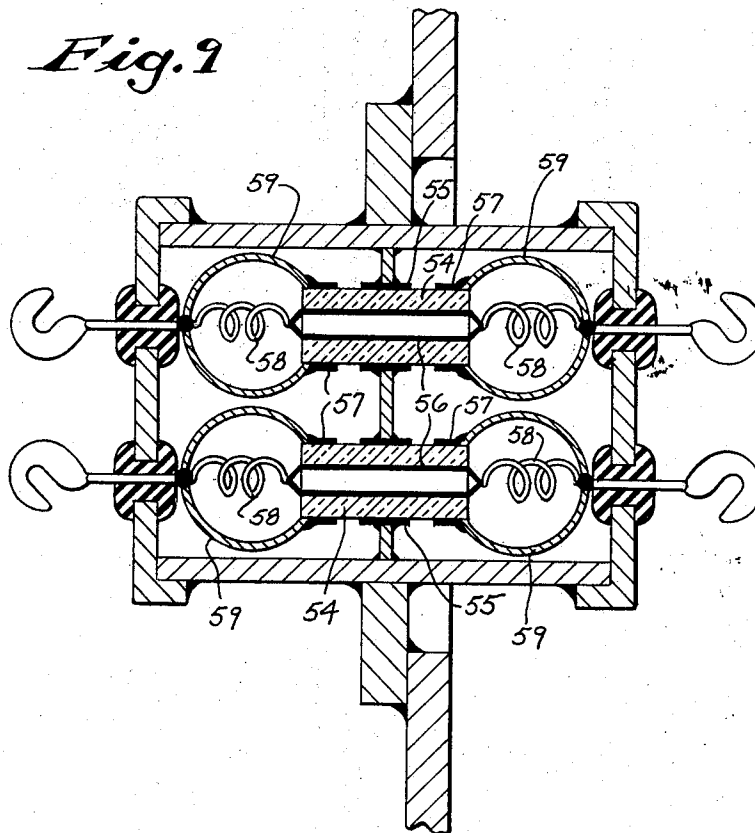


Fig. 9



HIGH VOLTAGE SUPPRESSOR FOR TRANSMISSION LINES

BACKGROUND OF THE INVENTION

This invention relates primarily to the suppression of large amplitude interference voltages that may appear upon a transmission line for the purpose of protecting electrical apparatus connected to such line.

Large interference voltages that may appear on an electrical line are usually abrupt transients that are spike-like in character. Very often they propagate along both wires of a line in the same direction, and this is referred to as a common mode operation, as distinguished from the normal mode of operation occurring in regular power or signal transmission in which the wires of a line are conducting in opposite directions. These transients may arise from a number of sources, such as lightning, electromagnetic interference, inductive switching, or other phenomena, and to shunt them off an electrical line some form of a direct current path to ground is desirable. In the instance of a transmission line that must effectively conduct power, or a signal from one point to another the presence of any such direct current path will, however, adversely affect normal transmission.

Thus, a requirement for a high voltage suppressor connected to a transmission line is that the impedance it introduces must not attenuate the regular signals carried over the line, or disrupt the efficiency of energy transfer between the line and electrical apparatus connected to the line. For optimum energy transfer from a transmitter to a transmission line, and from the line to a receiver, the impedances of the transmitter and receiver should match the characteristic impedance of the line. A voltage suppressor inserted in the line to shunt large transient voltages from the line to ground, so as to protect the associated electrical apparatus, should not upset this impedance matching. A simple high voltage protector that comprises a shunt path to ground will, however, introduce an extraneous impedance that upsets effective transmission along a line. An example of such a voltage protector would be the use of varistors that act as a low resistance in the presence of large voltages, and as a high resistance in the absence of such voltages. A varistor would be connected as a simple shunt path from each wire of the transmission line to ground, and their presence would materially affect the line impedance. The result would be impaired electrical transmission along the line. Some alternative device is needed for protection of transmission lines from large, transient interference voltages, and the present invention is directed to a solution of this problem.

SUMMARY OF THE INVENTION

The invention resides in a high voltage suppressor having an electrical bypass for high voltage inserted between a transmission line and ground that functions both as an electrical path for large voltage transients and as a capacitance, and additional components are incorporated into the circuit to form with the capacitance a low pass filter network having a characteristic impedance that matches the transmission line characteristic impedance for a selected range of frequencies.

Preferably, the protective voltage suppressor is inserted in a transmission line at the point where the line connects to transmitting or receiving apparatus. The suppressor presents an impedance between the line and the associated apparatus, and such impedance should be compatible with pre-existing circuit characteristic impedances. The suppressor must also pass normal operating signals carried along the transmission line, but shunt off of the line harmful voltages in excess of normal transmission amplitudes. These requirements are met in preferred forms of the invention by inserting a varistor type of material between the line and ground, and recognizing and utilizing its capacitive characteristic in addition to its variable resistance characteristic. A varistor presents a resistance across its terminals which varies with applied voltage, and a typical varistor may comprise a wafer of zinc oxide with electrodes attached to opposite sides of the zinc oxide. In a usual varistor application, the varistor is connected across some device such as a set of relay contacts to function as an overload protection. In the presence of normal voltages it acts as a very large resistance blocking current flow, but in the presence of a high voltage its resistance abruptly decreases and current is then conducted to provide the desired protection. Examples of this usual type of application are given in U.S. Pat. Nos. 3,710,058; 3,710,061 and 3,710,187, and also in the publication "GE-MOV Varistors-Voltage Transient Suppressors" by General Electric Company in December 1971. This publication also recognizes capacitive effects of zinc oxide varistors.

In the present invention additional components including an inductance are placed in circuit with a varistor-capacitor to obtain a compensated voltage suppressor in the form of a filter network. The varistor-capacitor then functions both as part of a low pass filter and as a low resistance for conducting ohmic current to ground upon the occurrence of large transient voltages. The low pass filter conducts normal mode signals of regular transmission, so that the compensated suppressor will not interfere with ordinary line operation.

Capacitors with the varistor material as a dielectric are placed between the individual wires of a transmission line and ground, and for normal transmission signals the capacitor elements do not conduct, for conduction would adversely attenuate the desired transmission of such signals. The presentation of this capacitance to the transmission line circuit presents an impedance at normal, working frequencies that would interfere with power or signal transmission if there be no compensation. The characteristic impedance of the line would no longer be matched with the impedance of the associated electrical apparatus, because of the intervening insertion of this shunting capacitance into the circuit. To overcome the mismatch of impedances that would result, an additional impedance is inserted in series with the transmission line of such value that the total suppressor characteristic impedance matches the characteristic impedance of the line and the impedances of associated electrical apparatus over a range of normal operating frequencies. The suppressor then functions as a low pass filter for transmission of the normal working frequencies. For a telephone line the pass band for this low pass filter should extend as high as 10 kilo-Hertz, for carrier telephone transmission the pass band should extend as high as 200 kilo-Hertz, for VHF

television transmission the pass band should extend to 300 mega-Hertz, and for UHF television the pass band should extend to 1,000 mega-Hertz. The varistor material of the shunting capacitor elements is selected and dimensioned to become a low resistance in the presence of voltages which are somewhat greater than normal voltages. Ohmic current due to these voltages is then shunted off the transmission line through a low resistance path, and the rapid current drain "clips" the interference voltages, so that they are not impressed upon the associated electrical apparatus connected to the transmission line.

The varistor material should be one in which the transition from the characteristic of a very high resistance with capacitor dielectric properties to the characteristic of a low resistance is abrupt. The relationship between current and voltage for a varistor is given as:

$$I = KE^\alpha$$

in which K is a constant and α depends upon the material selected and the manner of processing it into a finished form. The relationship between current and voltage is an exponential curve, and the higher the value of α the more abrupt is the transition from high resistance to low resistance as voltage increases. Also, for a higher value of α the high resistance-dielectric characteristic is maintained at more optimum values of low or negligible conductivity until the low resistance-ohmic current conducting characteristic begins to dominate. Metal oxides have been found to be a preferred varistor material and particularly zinc oxide with additives of other metal oxides. Not only does this material have desirable values of α , but it has been found that it can be prepared with a desirable dielectric constant ϵ . This material can then be properly proportioned to be compatible with the voltages, frequencies and characteristic impedances encountered in working with a transmission line. It also provides a relatively stable dielectric constant with temperature variation which makes it ideal for protecting a transmission line subject to variable climatic conditions.

It is an object of this invention to provide a compensated voltage suppressor for protecting electrical apparatus connected to a transmission line upon which large voltage transients may appear.

It is another object of this invention to provide a compensated voltage suppressor for a transmission line that forms a low pass filter for normal transmission signals, but also which is a shunt to ground for large transient voltages.

It is another object of this invention to provide a compensated voltage suppressor for a transmission line with a characteristic impedance that substantially matches the line characteristic impedance for a range of normal operating frequencies.

It is another object of this invention to provide a voltage suppressor having components that function as a low resistance shunt path to ground in the presence of large transient voltages, but which are capacitive components of a low pass filter during normal signal transmission.

The foregoing and other objects and advantages of the invention will appear from the following description. In the description reference is made to the accompanying drawings which form a part hereof, and in which there is shown by way of illustration and not of

limitation two preferred embodiments of the invention. Such embodiments do not represent the full scope of the invention, but rather the invention may be employed in many different embodiments, and reference is made to the claims herein for interpreting the breadth of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of an electrical system in which compensated voltage suppressors embodying the invention are inserted between a transmission line and electrical apparatus connected to the line,

FIG. 2 is a view in cross section of one of the voltage suppressors of FIG. 1,

FIG. 3 is an end view taken through the plane 3—3 indicated in FIG. 2,

FIG. 4 is a view in cross section taken through the plane 4—4 indicated in FIG. 2,

FIG. 5 is a schematic representation of the circuit of the voltage suppressor of FIGS. 2-4,

FIG. 6 is a view in cross section of a second embodiment of the invention,

FIG. 7 is a schematic representation of the embodiment of FIG. 6,

FIG. 8 is a view in cross section of a third embodiment which is a modification of the construction shown in FIG. 6, and

FIG. 9 is a view in cross section of a fourth embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 there is shown a transmitter 1 within a metallic shielding enclosure 2. The transmitter 1 is connected through a voltage suppressor 3, embodying the present invention, to a transmission line comprised of a pair of parallel wires 4 and 5. The wires 4, 5 connect to the input terminals 26 and 27 of a second voltage suppressor 6 that embodies the invention, and the suppressor 6 has its output terminals 28 and 29 connected to a pair of leads 7 and 8 joined to a receiver 9. The receiver 9 and the leads 7, 8 are within a second shielded enclosure 10, and the principal purpose of the enclosures 2 and 10 is to isolate the transmitter 1 and the receiver 9 from electromagnetic interference that may be propagated through the air. In FIG. 1 the normal mode of signal transmission over the wires 4, 5 is indicated by the arrows 11 and 12 pointing in opposite directions. Such normal mode of transmission must pass directly through the suppressors 3 and 6 without attenuation or reflection. The large arrows 13 and 14 illustrate interference voltages larger than normal transmission voltages that may appear on the wires 4, 5. These interference voltages are at energy levels above that safely tolerated by the transmitter 1 or receiver 9, and they are usually an abrupt transient, as discussed hereinbefore, with wide frequency spectrums that may range from zero frequency upward to very high values of frequency. The arrows 13, 14 are in the same direction to indicate a usual propagation of high interference voltages, and this sameness of direction illustrates the common mode type of operation.

Referring now to FIG. 2, it shows the suppressor 6 in cross section, and on an enlarged scale from that of FIG. 1. Suppressor 3 is duplicative thereof, and hence the description of suppressor 6 will suffice for a description of both. A tubular, metallic shell 15 has a

mounting ring 16 snugly encircling and secured to its outer surface, and this ring 16 is soldered to the shielding 10 to form a conductor that presents an electrical path that is a bypass to ground. A pair of varistor-capacitor elements 17 and 18 are fitted in the shell 15 to form end walls. Each element 17, 18 is preferably composed of a metal oxide material that has a dielectric constant presenting a capacitance. The two varistor-capacitor elements 17, 18 are mirror images of one another, with the element 17 being at the input end of the suppressor 6, and the element 18 being at the output end.

Referring to the element 17, there is an electrode 19 covering most of its inner surface, as illustrated in FIG. 4, with the exception of two circular areas through which conductors 30 and 31 extend as continuations of the individual wires 4, 5. The outer surface of the element 17 is shown in FIG. 3, and it is seen that this outer surface is coated with a pair of electrodes 20 and 21. The electrode 20 is connected through the input terminal 26 to the conductor 30, and the electrode 21 is connected through the input terminal 27 to the conductor 31. The two electrodes 20 and 21 are spaced from one another, so that in effect a pair of input capacitors are formed. Each input capacitor is connected between a conductor 30 or 31 and ground, and this arrangement is shown schematically in FIG. 5. In FIG. 5 the input capacitor of which the electrode 20 is a part is designated 20', and the input capacitor of which the electrode 21 is a part is designated 21'.

In similar fashion, there are two output capacitors at the right hand side of the suppressor 6. The first is a capacitor 22 that is connected on one side to the conductor 30 and the lead 7, and on the other side to ground. The second is a capacitor 23 which is between ground on one side and the conductor 31 and the lead 8 on the other side. The conductors 30, 31 are embedded in and extend directly through the varistor-dielectric material forming the capacitor elements 17 and 18, and similarly they are embedded in and extend through the varistor-dielectric material forming the capacitor element 18. The capacitor electrodes may be applied as a silver paste, and then heated to drive off the organic carrier and to set the material in place, similarly as in other capacitor and filter constructions. In effect, the leads 7, 8 are continuations of the conductors 30, 31, which in turn are continuations of the transmission line wires 4, 5, so that the suppressor 6 can be said to be inserted in the transmission line, or between the line and the receiver 9.

A first inductance 24 is formed in the conductor 30, so as to be between the wire 4 and the lead 7. This inductance 24 is housed within the shell 15. A second inductance 25 is formed in the conductor 31, so as to be electrically inserted between the wire 5 and the lead 8. It is also housed within the shell 15. The inductances 24 and 25 are effectively shielded from the exterior by the combination of the metallic shell 15 and the metallic electrodes of the varistor-capacitor elements 17, 18 which overlap one another so as to effectively present shielding across the shell ends. The inductances 24, 25 are therefor isolated from external electromagnetic, air propagated interference, and they will serve as inductors for the frequencies of the normal signals moving along the transmission line wires 4, 5, through the suppressor 6, and out along the leads 7 and 8 to the receiver 9.

It is the purpose of the inductances 24 and 25 to form in combination with the capacitors 20', 21', 22 and 23 a filter network as illustrated in FIG. 5. This is a low pass filter which passes the signals transmitted in the normal mode along the transmission line comprised of the parallel wires 4 and 5. Further, the characteristic impedance of this low pass filter, as seen from the wires 4, 5 and also from the leads 7, 8, is to substantially match the characteristic impedance of the transmission line over a range of regular working frequencies. The impedance of the receiver 9 will also be of similar value in accordance with usual practice. In this fashion, the suppressor 6 will not create reflections or adversely attenuate or shunt the signals of the normal mode of transmission, and maximum power transfer is maintained.

High energy interference voltages that appear on the wires 4, 5 as abnormal signals, such as illustrated by the common mode arrows 13 and 14 in FIG. 1, will appear across the input capacitors 20' and 21'. In the presence of these high voltages the varistor material forming the capacitor dielectrics will present low resistance paths to ground. The interference voltages drive the varistor material beyond the transition point of its non-linear characteristic curve, and the material will conduct ohmic current through a low resistance path to ground for clipping the peak values of the transient interference voltages. Any high voltage that may pass through the inductances 24, 25 will be similarly shunted through the output capacitors 22 and 23, so that the leads 7 and 8 at the output terminals 28, 29 of the suppressor 6 are free to the interference voltages. Thus, there is a suppression of interference voltages that appear on the wires 4 and 5 to protect the receiver 9. The suppressor 3 protects the transmitter 1 in similar fashion.

Of the metal oxides, zinc oxide with additives is a particularly suitable varistor material which can be formulated with both a desirable alpha value and dielectric constant ϵ . For the purposes herein, it is desirable to have a low or moderate dielectric constant which will not introduce such a capacitance which would require excessive compensating inductance. A range of up to about 500 for ϵ is satisfactory for most cases. The lower the value of ϵ the greater may be the pass band of the low pass filter presented in the suppressor 6. A varistor material of zinc oxide can be formulated which also has an alpha value in the relationship $I = KV^n$, at a satisfactorily high level. This value should be 10 or greater for then the transition of the varistor-dielectric material from the function as a non-conductive capacitor to the function of a low resistance path in the presence of a higher voltage values usually will be satisfactorily sharp.

The chemistry and manner of preparation of zinc oxides as varistor materials has been investigated and published in considerable detail in U.S. Pat. Nos. 3,496,512; 3,570,002; 3,598,763; 3,632,528; 3,632,529; 3,634,337; 3,642,664; 3,658,725; 3,663,458; 3,687,871; 3,689,863; 3,670,216 and 3,670,221. The zinc oxide is modified with minor amounts of other oxides, such as beryllium oxide, bismuth oxide, lanthanum oxide, yttrium oxide, cobalt oxide, etc., as discussed in the foregoing patents. The formulations and manner of processing zinc oxide mixes are not deemed to be a part of the present invention.

The invention as shown in FIGS. 2-5 provides a voltage suppressor for transmission lines that meets multiple requirements. It uses a varistor material as a capacitor dielectric, and combines the resulting capacitance with inductance to match transmission line characteristic impedance, and it also relies on the varistor characteristic to shunt high, transient voltages to ground. When a pair of individual wires make up a transmission line the filter network should have symmetry with respect to ground. The two wires will have like interference voltages with a common propagation, as shown by the arrows 13, 14 in FIG. 1, and each should be shunted to ground in like manner. Thus, the capacitors 20' and 21' are preferably similar, and so are the capacitors 22 and 23. The inductances 24, 25 should likewise equal one another. The impedance presented by the suppressor should have the symmetry of being the same from each end. Thus capacitors 22, 23 are placed in the circuit network. They should match the capacitance at the input side of the suppressor 6, although they need not be of a varistor material if the capacitors 20', 21' will adequately shunt the anticipated interference voltages.

ALTERNATIVE EMBODIMENTS

The embodiment of FIGS. 2-5 comprises a low pass filter that is symmetrical as seen from the two ends, and also it is symmetrical with respect to ground. With regard to this latter symmetry, the circuit network appears as a pair of pi-type filters. As an alternative to the pi-type configuration, an inductance could be inserted to the front, or input side of each capacitor 20', 21' and the capacitors 22, 23 removed, to thus have an equivalent T-filter configuration. Both a pi- and a T-configuration can be designed to provide a characteristic impedance that substantially matches line characteristic impedance over a working range of frequencies.

In FIGS. 6 and 7 there is shown another embodiment, for which the image impedance may stay substantially at the same value for a wider range of frequencies. It is symmetrical from the ends, and is also symmetrical around a ground connection, and for each transmission line wire it presents a T-type low pass filter. The arms of the T each have an inductance and a capacitance in parallel, and a filter of this configuration is known as a shunt *m*-derived filter. The embodiment in FIGS. 2-5 is, on the other hand, known as a constant-*k* filter.

Referring specifically to FIG. 6, there is a tubular, metallic shell 32 with a mounting ring 33 snugly encircling the shell 32 at its midsection. The ring 33 is in electrical connection with the shell 32 and is fastened to the periphery of an opening in a grounded wall 34 to thereby provide an electrical bypass conductor for shunting large, transient voltages from a transmission line.

Mounted inside the shell 32 at its center is a varistor-capacitor 35 similar to the elements 17 and 18 in the embodiment of FIGS. 2-5. The varistor-capacitor 35 has a body of varistor material that also exhibits a dielectric property making it suitable for use as a capacitor, similarly as in the first embodiment. On one face of the varistor-capacitor 35 is an electrode 36 which covers the entire face except for two circular areas, again being similar to a varistor-capacitor of the first embodiment. On the opposite face there are a pair of electrodes 37 and 38, so that each electrode 37, 38

forms a capacitor 37', 38' respectively with the electrode 36.

On each end of the shell 32 is a metallic cap 39 which together with the shell 32 form a shielded enclosure for the suppressor components. Extending through each cap 39 is a conductor 40 supported in an insulator 41. Each conductor 40 presents a terminal 42 at its outer end, and its inner end connects with one side of a capacitor 43. The other side of each capacitor 43 connects with an end of one of two middle conductors 44 that pass through the varistor-capacitor 35. Looped across the electrodes of each capacitor 43 is an inductor 45, so as to have a parallel arrangement for each capacitor-inductor pair.

The circuit for the compensated suppressor of FIG. 6 is schematically shown in FIG. 7. The terminals 42 are for connection between the wires of a transmission line and an associated apparatus, such as a transmitter or receiver. The entire circuit network is a low pass filter that passes regular working signals, or power. If a voltage appears in some preselected amount, for which the circuit is designed, above normal voltage values the varistor-capacitor 35 acts as a resistance path to ground for clipping the voltage. The varistor-capacitor 35 is therefore the main high voltage suppressing element, and the other impedances in the circuit network compensate for the presence of the varistor-capacitor 35. They do this by combining with the capacitance of the varistor-capacitor 35 which is present during normal mode of operation to form a low pass filter having a characteristic impedance which matches, quite closely, the characteristic impedance of the transmission line over a range of normal working frequencies. FIG. 8 shows a suppressor that is a modification of that shown in FIG. 6. The varistor-capacitor 35 and capacitors 43 of FIG. 6 are combined in a multi-layered sandwich 46, for the purpose of shortening the conductors 44 shown in FIG. 6 to minimize the inductance of these conductors.

The sandwich 46 has a central electrode 47 connected to ground which corresponds to the electrode 36 in FIG. 6. On each side of the electrode 47 is a layer of varistor-dielectric material 48, and on these layers is a set of four electrodes 49. The electrodes 49 are paired by short connections 50 extending through the varistor-dielectric material 48, this completes a varistor-capacitor corresponding to the varistor-capacitor 35 of FIG. 6.

On the outer side of each electrode 49 is a layer of dielectric material 51 on which there is a capacitor electrode 52. Thus, there is a set of four capacitors each formed of a dielectric 51 and two associated electrodes, which capacitors correspond to capacitors 43 of FIG. 6. A set of four inductances 53 are connected into the circuit which are similar to inductances 45 in FIG. 6. Thus, the embodiment of FIG. 8 reduces lead inductance in the filter network of the voltage suppressor.

Turning to FIG. 9, a voltage suppressor is shown having tubular dielectric materials, and the circuit again takes a T-configuration as illustrated in FIG. 7. There are a pair of tubular bodies 54 each with a central, band-like electrode 55 that connects to ground. A conductive layer 56 on the inner wall of each body 54 is in capacitive relation with the electrode 55, so as to have a varistor-capacitor corresponding to 35 of FIG. 6. Outer electrode bands 57 on the ends of the bodies 54 form capacitors corresponding to 43 of FIG. 6. Induc-

tances 58 are connected in series with the conductive layers 56, and to connect the electrodes 57 into the circuit non-inductive metallic shells 59 are employed, which each house one of the inductances 58.

In the various embodiments described a low pass filter will have a cut-off frequency above the spectrum of normal signal transmission, and by having such a cut-off frequency very high, low energy interference frequencies on the wires 4, 5 that are above cut-off can be shunted through the varistor-capacitors to ground.

In the embodiments shown, the characteristic impedance can be maintained at a desired level over an increased frequency range by taking advantage of the so-called dispersion of the dielectric property of the varistor-capacitors. By the term dispersion is meant the decrease in the dielectric constant of the material with increasing frequency. A dielectric material is selected with a desired decreasing dielectric constant. Then, for higher frequencies the capacitance decreases, so that the shunt path to ground by virtue of capacity is lessened. Therefore the impedance increases over that which would occur for a dielectric constant that had no variance with frequency. Although a varistor-dielectric material has been described for the preferred embodiments of the drawings, there is the possible use of air alone between the electrodes of the bypass to ground. Then, ϵ would be unity and alpha would approach infinity.

The examples given herein are in connection with a two wire transmission line. The invention need not be so limited in its application. A further variation may be the direct incorporation of the suppressor into a transmitter or receiver, or other associated equipment, connected to a line. The compensated voltage suppressor could function as the input or output terminus of the equipment.

I claim:

1. In a voltage suppressor for an electrical line exhibiting a characteristic impedance for a normal mode of operation, the combination comprising:

an electrically shielding shell with a shunting terminal for conducting currents to ground;

input and output conductors entering and leaving said shell connectable to said electrical line;

a shunting element associated with said shell having a dielectric of varistor material with electrodes on opposing sides thereof, one electrode in connection with one of said conductors, the other electrode in connection with said shunting terminal;

an impedance element within said shell and in series connection with said conductors forming a low pass filter with said shunting element during said normal mode of operation; and

said dielectric exhibiting capacitive characteristics in said normal mode of operation, and having an ohmic current conducting characteristic according to the relationship $I = KV^\alpha$ in which the exponent alpha is greater than 10 and ohmic current flows for voltages above those of said normal mode of operation.

2. A voltage suppressor as in claim 1, wherein the characteristic impedance of said low pass filter substantially matches said line characteristic impedance for said normal mode of operation.

3. A voltage suppressor as in claim 1, wherein the dielectric constant of the varistor material is less than 500 and the value of alpha is at least 10.

4. A voltage suppressor as in claim 1, wherein the dielectric constant of the varistor material decreases with increasing frequency.

5. In a voltage suppressor for connection to a transmission line comprised of a pair of paths over which regular signals are conducted, the combination comprising:

an electrical bypass to ground;

a capacitance for between each transmission line path and said bypass, each capacitance having a dielectric material that has a transition to low resistance at selected voltages above those of regular signals;

impedances for series relation with each transmission line path, the capacitances and impedances presenting a low pass filter network with a characteristic impedance substantially matching the characteristic impedance of the transmission line for a range of regular transmission frequencies; and such impedances are each an inductor and capacitor in parallel, and form T-filters with the capacitances having a varistor dielectric material.

6. In a voltage suppressor for a pair of transmission line paths, the combination comprising:

a shielding enclosure;

a pair of inputs and a pair of outputs for the enclosure;

a bypass connection disposed outside the enclosure;

input capacitor elements at one end of said enclosure having: dielectrics of varistor material, electrode surfaces connected to said inputs, and electrode surfaces connected to said bypass connection;

output capacitor elements at the other end of said enclosure having dielectrics of varistor material, electrode surfaces connected to said outputs, and electrode surfaces connected to said bypass connection; and

inductances within said enclosure disposed between the capacitor electrodes that are joined to the inputs and outputs.

7. A voltage suppressor as in claim 6, wherein the inductances and capacitor elements present a characteristic impedance matching the characteristic impedance of the transmission line paths.

8. A voltage suppressor as in claim 6, wherein the varistor material is a zinc oxide having an alpha of at least 10 and a dielectric constant less than 500.

9. A voltage suppressor as in claim 6, wherein the varistor material has a dielectric constant that decreases with frequency.

10. In a voltage suppressor for connection to a pair of transmission line paths, the combination comprising:

a shielding;

a bypass conductor on said shielding;

a first input capacitor element having a varistor material dielectric, such capacitor element electrically disposed between one of said paths and said bypass conductor;

a second input capacitor element having a varistor material dielectric, such capacitor element electrically disposed between the other of said paths and said bypass conductor;

a first inductance disposed within said shielding joined to the first input capacitor on the side opposite the bypass conductor;

11

a second inductance disposed within said shielding joined to the second input capacitor on the side opposite the bypass conductor;

a first output capacitor element having a varistor material dielectric connected between one of said inductances and said bypass conductor; and

a second output capacitor element having a varistor material dielectric connected between the other of said inductances and said bypass conductor.

11. A voltage suppressor as in claim 10 wherein the characteristic impedance of the suppressor matches the characteristic impedance of the transmission line paths.

12. In a voltage suppressor for a transmission line, the combination comprising:

a tubular metallic shell;

an end wall at each end of the shell formed of dielectric material; at least one of said end walls also being a varistor type material;

a pair of conductors passing through the shell and the end walls, such conductors having inductance at points between said end walls;

first capacitor electrodes, each on a surface of one of said end walls, which are spaced from the conduc-

12

tors, such electrodes being connected to said shell; and

second capacitor electrodes on surfaces of the end walls opposite from the first electrodes that are each individually connected to one of said conductors, to provide capacitance between each conductor and said shell.

13. In a voltage suppressor for a transmission line, the combination comprising:

a tubular metallic shell having end caps;

a varistor-capacitor element inside said shell having a body of varistor material that also presents a capacitive dielectric constant, and further having a first electrode on one side that is connected to said shell, and second electrodes of the opposite side; a pair of conductors each joined at a point between its ends to one of said second electrodes;

a set of four capacitors inside said shell each connected to an end of one of said conductors;

a set of four inductors inside said shell each across one of said set of four capacitors; and additional conductors extending from said four capacitors to the exterior of the shell.

* * * * *

25

30

35

40

45

50

55

60

65