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(54) **Title:** IMPROVED ELECTRICAL WIRING ASSEMBLY

(57) **Abstract**

A method of improving an electrical wiring assembly for a device such as vehicle airbag pyrotechnic actuator by replacing the usual twisted pair of wires by an untwisted pair of wires for greater ease of constructing the wiring harness, while the attenuation of parasitic signals is maintained or enhanced because at least one of the untwisted wires is at least partly enclosed (preferably substantially completely enclosed) in: a) an inner layer of a high–dielectric polymeric composition, preferably PVDF, which inner layer is at least partly enclosed (preferably substantially completely enclosed) in b) an overlying lossy layer at least partly composed or oganic polymeric material, preferably thermoplastic elastomer and/or ferrite, and which lossy layer is least partly enclosed (preferably substantially completely enclosed) in c) an overlying electrically–insulating polymeric jacket layer, preferably ETFE or polyester, wherein the layers are capable of acting as a parallel filter to attenuate (preferably by more than 20dB per metre, more preferably at least 25dB per metre) parasitic signals: i) at electrostatic discharge frequencies of less than 300 MHz, preferably also at frequencies less than 200 MHz, more preferably also at frequencies in the range below 100 MHz, especially 50–100 MHz or 1–10 MHz, or ii) at EMI frequencies greater than 300 MHz, preferably also at frequencies greater than 500 MHz, more preferably also at frequencies greater than 1000 MHz.

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IMPROVED ELECTRICAL WIRING ASSEMBLY

This invention relates to a method of improving an electrical wiring assembly incorporating a twisted pair of wires or passive components such as filters, to the resulting improved wiring assembly, and to automotive electrical components, for example ABS sensors or actuators for automotive air bags or seat belt pre-tensioners, with such improved wiring assembly connected thereto for electrical actuation in use.

Twisted pairs of wires are traditionally used to reduce parasitic signals generated in those wires when exposed to electromagnetic interference (EMI).

Passive components such as filters are traditionally used to reduce transients such as electro static discharges being transmitted along wires.

Advantages of time and cost savings are obtained according to the present invention, especially in high-volume automotive wiring harness production lines, when the twisted pair and/or a passive component is replaced by an untwisted pair of wires, at least one of which untwisted wires is at least partly enclosed (preferably substantially completely enclosed) in

(a) an inner layer of a high-dielectric (above 4, preferably above 6, more preferably above 8, at 1 kHz frequency, and preferably above 6 at 1 MHz, above 5 at 10 MHz, and above 4 at 100 MHz) polymeric composition, with or without dielectric-raising inorganic fillers, preferably in direct contact with the wire conductor, the composition preferably comprising polyvinylidene fluoride (PVDF) or chlorosulphonated polyethylene, which may preferably be cross-linked by known means, which inner layer is enclosed in

(b) an overlying lossy layer at least partly composed of organic polymeric material, and which lossy layer is enclosed in

(c) an overlying electrically-insulating polymeric jacket layer,

wherein the layers are capable of acting as a parallel filter to attenuate by more than 20dB per metre (preferably at least 25dB per metre) parasitic signals

(i) at electrostatic discharge (ESD) frequencies of less than 300 MHz, preferably also at frequencies less than 200 MHz, more preferably also at frequencies in the range below

100 MHz, especially 50-100 MHz or 1 - 10 MHz, or
(ii) at EMI frequencies greater than 10 MHz, preferably also at frequencies greater than 100 MHz, more preferably also at frequencies greater than 1000 MHz.

The invention is especially useful in combatting parasitic signals caused by electrostatic discharge (ESD) at frequencies below 100 MHz, especially 50-100 MHz or 1 - 10 MHz, in which ranges lie many of the electrical events which may interfere with electrical sensors (e.g. ABS braking systems) or threaten accidental discharge of pyrotechnic actuators in vehicles.

It is often preferable that each wire of the said untwisted pair is at least partly enclosed as aforesaid. The inner layer (hereinafter referred to for convenience as the PVDF layer without necessarily excluding other suitably high-dielectric materials), the lossy layer, and the jacket layer may be formed by coatings extruded along the wire(s) by known wire-coating techniques. The presence of the PVDF layer has been found especially advantageous for the aforementioned automotive uses of the invention. The lossy layer is preferably a ferrite-filled polymeric material, for example a thermoplastic elastomer, preferably fluorinated, those available under the Trade Mark "Viton" being particularly preferred. The jacket layer may be made of any suitable polymeric material, for example cross-linked ethylene/tetrafluoroethylene (ETFE) copolymers, or preferably polyester for lower cost. A recommended form of such wires is available under the Trade Mark "Electroloss Filterline" from Raychem Corporation. Suitable lossy materials are described, for example, in US-A-3309633 and US-A-3191132, and high-frequency-attenuating wire and cable structures are described, for example, in EP-A-0053036 (MP0750), the disclosures of all of which are incorporated herein by reference.

It has been found that wiring assemblies from which twisted pairs of wires are eliminated according to the present invention can achieve attenuation of the parasitic signals to levels at least comparable with those achieved by the twisted pairs, without the cost and efficiency disadvantages associated with the additional wire twisting operation. It may also be possible to eliminate some or all of the known series-connected passive components such as filters and/or ferrite beads possibly used with the twisted pairs, while maintaining acceptable levels of attenuation in the lossy layers of the untwisted wires according to the present invention. The series filters and beads may in any case be less than desirably effective at frequencies above 100 MHz.

The invention is thus especially useful in wiring assemblies wherein the original twisted pairs of wires replaced by the untwisted pairs of wires according to the invention are connected in use to an automotive pyrotechnic device for actuation thereof, especially for use in automotive air bags or seat belt pre-tensioners. Protection of such pyrotechnic devices against parasitic currents caused by coupling of the wires with an ESD or the filelds generated by it, or possibly with EMI fields generated by mobile telephones or their roadside base stations, is especially desirable, the lossy wires preferably being at least 30 cm in length. At EMI frequencies in the 700 to 2000 MHz (preferably 900 to 1800 MHz) range, the untwisted lossy wires of the present invention are capable of attenuation levels ranging from 20dB/m up to more than 25 dB/m, more than 27dB/m, or even more than 30dB/m.

ESD in vehicles may occur for many reasons, such as wind friction or passenger contact with static-generating materials. The major source of RF energy inside the passenger compartment of a vehicle is the mobile phone, especially the hand portable with the antenna radiating inside the vehicle. Glass mounted antennae should produce a lower field inside the car than hand portable phones, but fields of greater than 30V/m inside one vehicle have been shown to be the result of transmissions from other vehicle(s). The types of phone may be fixed-installation or hand-portable, and analogue or digital. Frequency ranges for such phones include 890 MHz to 1000 MHz for DCS 900 ETACS; 1100 MHz to 1300 MHz for ORANGE; and 1710 MHz to 1785 MHz for DCS 1800. Power outputs of the phones vary, but GSM allows up to 20W to be used for Transmitters (43 dBm), and such phones use typically 8W for GSM 900 Class 2 (39 dBm); 2W for GSM 900 Class 4 handheld (33 dBm); 1W for DCS 1800 Handheld (30 dBm); and 500mW for Analogue Handheld (27 dBm). These figures exclude transmission from amateur transceivers that can be of the order of 70W (48 dBm) at 430 MHz and 144 MHz. These transmissions are not considered legitimate by the regulatory bodies in the EEC and do not form part of the directive for auto EMC.

The EEC directive for EMC in vehicles stipulates a field strength of 30V/m, at which all electronic systems must appear unaffected and operate normally. It has been demonstrated that a class 2 GSM 8W transceiver can produce a field of 33V/m inside a vehicle, 3V above the maximum allowed in the EEC directive. It is clear that higher-power GSM transceivers, if and when they are introduced, and amateur transceivers will produce fields well in excess of the limit.

A typical wiring harness as previously known for vehicle pyrotechnic actuators is constructed as follows:-

Length 1m; 2 cores multistrand black PVC believed to be 24 gauge; Load end terminated in two crimp terminals to accept pins from load; Load pins insulated with orange heatshrinkable tubing; Both wires assembled into a 5mm dia black PVC tube; 75 mm from one load pin is an in-line inductor measured as 8μH; Inductor believed to be Siemens type (Siemens Matsushita); A high-frequency filtering inductor is spliced into one wire and is covered by black heat shrink tubing. The Siemens Matsushita data sheets B82144, B78108-S and B78148-S show inductors of the above value (nominally 6.8μH) to be resonant at 80 MHz (LBC), 75 MHz (BC), and 40 MHz (SBC) where LBC is large bobbin core, BC is bobbin core and SBC is small bobbin core and are Siemens designations of the component used, the impedance above these frequencies dropping away dramatically (typically by two orders of magnitude per decade of frequency). This means that the inductors will have little effect in the higher (for example mobile phone) frequency bands. Ferrite beads only add 250nH of inductance per line per bead and a considerable number of beads would be required to approach ideal performance.

A harness according to the present invention is constructed to the same dimensions as the above, but with the wire containing the inductor completely replaced with a one-metre length of Raychem's Electroloss Filterline wire, comprising a stranded metal conductor enclosed in successive layers of (a) radiation-cross-linked PVDF, (b) ferrite-filled lossy layer, and (c) radiation-cross-linked modified ETFE copolymer.

To best simulate the automotive application of such harnesses, it was decided to make measurements with the harness resting on a ground plane with interfering signal injected at the driving end of the harness. Measurements of the signal at the receiving/load end of the harness were made at both sides of the load and differential and common mode signals were calculated from these measurements. The detonator-actuating load was idealised as the circuit shown in Figs. A and B of the accompanying drawings, wherein the 4.7 ohm resistor represents the actuating bridgewire, the two 66 ohm resistors represent the resistance through the compound from the bridgewire to the metal case of the load and the 18pF capacitor represents the capacitance between the case of the load and the adjacent ground plane metalwork.

The measurements taken are the signal level at the load on the 'high' and 'low' sides of the load with respect to ground. As the load is a pure resistor, i.e. it has negligible inductance and capacitance, there is no phase change across the load from the signal and the resultant differential mode signal can be calculated from the two common mode measurements. The highest of the common mode signals can be taken as representing the largest common mode threat to the load, energy flow from the bridgewire through the compound and the capacitance to ground.

With reference to Figs. 1 to 4 of the drawings, it is clear that the inductor harness is resonant. It is therefore a little difficult to make comparisons as many of the portrayed attenuating areas are merely signal cancellation in the load. This might appear at first inspection as a desired effect but with small manipulation of the cable these attenuation troughs can appear as non attenuating peaks with changes in apparent attenuation level of as much as 60dB and the position of the peak/trough moving as much as 70 MHz. The Filterline harness provides a much more stable, consistent harness to measure. Figure 1 shows the attenuation provided by the harness to the signal injected at the drive end when the load is looked at as the receiving end. This is the level of attenuation to the differential mode signal arriving across the bridgewire at the load. The very peaky nature of the inductor harness can be explained by resonance of the harness and by the lack of effect of the inductor. The harness is 1 metre long and can be expected to have resonance's spaced at multiples of $\lambda/4$ i.e. 70 to 100 MHz range spacing. The impedance offered by the inductor over the range shown taken from the Siemens data sheet is less than 100 ohm and given that the typical characteristic impedance of the line is in the 100 to 300 ohm range the attenuation offered by the inductor is probably less than 3 dB. The attenuation shown for the inductor harness is largely as a result of signal cancellation and normal harness losses at these frequencies. The large dips in signal are due to cancellation of signal at the load. The Filterline wire example shows a much more controlled response over the frequency spectrum with the large majority of resonance damped out.

In the 900 MHz to 1000 MHz band the peaks of signal indicate that the inductor harness attenuates for much of the band by as little as 15 dB, whilst the Filterline wire is always better than 27dB, i.e. the Filterline wire reduces the signal through the load by a factor 16 times greater than the inductor harness. Further, in the 1200 to 1300 MHz band the inductor harness reduces the signal by the same amount as before, 15dB, whereas the Filterline wire harness is always better than 33dB. Unfortunately it is not possible to keep the deep troughs of resonant cancelling without the peaks of signal transmission, as they are part and parcel of the same process.

Figure 2 shows the net signal level in common mode at the load. The signal level for the Filterline wire can be seen to be significantly lower than that for the inductor harness. The effect of this signal level is that energy will flow from the bridgewire through the explosive to local ground plane. It is probable that this, or significantly less, energy flowing in this mode will cause a response from the explosive compound.

In the 900 MHz to 1000 MHz band, the Filterline wire reduces the power level by between 20 and 25dB, in comparison with the inductor harness generally reducing the power level by less than 20dB. Power levels in the 1200 to 1300 MHz band are reduced by the Filterline by at least 30dB. The inductor harness reduces the power level by a about 10dB. This indicates that the Filterline wire has an advantage in power reduction of at least two decades over the inductor solution.

Figure 3 and 4 show the same information for the DCS 1800 band of frequencies. Apart from the resonant cancellation of signal at 1700 MHz, the Filterline wire is clearly a better solution. The Filterline wire attenuation and the level of signal at the load in the Filterline harness was always below the noise floor of the measurement for this set-up. Accordingly, the attenuation of the differential mode signal (that which could operate the detonating bridgewire) is typically 25dB greater in the case of the Filterline wire, i.e. 300 times less signal across the bridgewire in this case.

Both harnesses reduce the actual power level at the load for this frequency range, but clearly the inductor harness is still resonant and it is impossible to say how much better the Filterline wire is as the power level is reduced below the noise floor for this experiment. In any case the Filterline wire is at least 5 to 10dB better than the inductor harness i.e. at least a factor of 4 better. Whereas the inductor harness is resonant and does not represent a controlled and predictable method of removing mobile phone RFI, the Filterline wire gives much improved and controllable performance.

A typical wiring harness used to connect ABS braking sensors incorporate twisted pairs of wires that reduce parasitic transients. An alternative wiring harness using the Filterline as described above can be shown to be equivalent or superior to the traditional twisted pair whilst having the manufacturing advantages of a pair of parallel wires. Results are shown in figs 5 – 8 that demonstrate the superior or equivalent performance of the Filterline construction. In fig 5 the attenuation of a typical ESD transient by both a standard twisted pair and the Filterline harness is shown. It can be seen that the total energy in the pulse is reduced to a tenth (20db power reduction). In fig 6 Bulk Cable Injection demonstrates the reduction of parasitic signals. In this test a high frequency transient is induced onto the cable under test and the resulting parasitic induced voltage is measured. Fig 6 shows that the induced current is less than that for the twisted pair. The level of an induced parasitic signal induced by a radiated field is shown in fig. 7. In this test the harnesses are radiated in a stripline at a field strength of 30 volts per meter as specified in many specifications such as the EC directive on EMC. The results shown in fig. 7 show that the induced voltage from the field is to some extent reduced at higher frequencies and that the performance of both systems is broadly equivalent. The final test measures the strength of the emissions radiated from the test wires conducting parasitic transients. If a high frequency parasitic signal is injected into the test cables then, if the cables reduce the parasitic signal, the radiated emission are also reduced. In fig. 8 the radiated emissions from both a twisted pair and a Filterline harness are shown and in general they can be considered equivalent demonstrating that the known performance of a twisted pair can be achieved with the Filterline harness.

The features of the present invention are further defined and illustrated as follows.

Effect of frequency on dielectric constant and permeability.

Dielectric Constant ε

The dielectric constant of plastic materials varies with the frequency. Materials with high dielectric constants are polar and have pairs of opposite charges. A pair of opposite charges separated by a small distance forms a dipole. This dipole is free to rotate to align itself with an alternating electric field. The response to the field will be of the relaxation type with the rotation of the dipole lagging further behind the phase of the applied field. Therefore as frequency increases the measured dielectric constant will fall. The situation is very complex due to the number of possible dipoles within a system and a frequency spectrum is usually obtained.

Values for Kynar (Trade Mark) PVDF given in the literature are as follows at the indicated frequencies: 1kHz 8.1, 10kHz 8.0, 100kHz 7.8, 1MHz 6.8, 10MHz 5.8. We have additionally measured 4.5 at 100MHz and 2.5 at 1GHz.

Data for plastics filled with ferrites also show a strong dependency on frequency.

Permeability μ

This also is strongly dependent on frequency since magnetic dipoles and domains in the ferrite cannot rotate quickly enough to keep in phase with the applied magnetic field. Permeability rapidly falls off at frequencies above 10MHz. It should be realised that the highly-permeable layer alone cannot greatly attenuate signals at frequencies of 1 GHz, where the permeability and dielectric constants for the materials are quite low. The real structure of Filterline wire enables it to work as a distributed transmission line filter rather than as a lumped filter element.

Values for the PVDF layer.

Since the frequencies we are most interested in are in the 1 to 10 MHz range, where ESD and other threats lie, we are less interested in values in the GHz region. Further, the measurement of both permeability and dielectric constants is greatly complicated by the need to consider the "real" and "imaginary" portions of those terms. For simplicity, we will now concentrate on values measured at low frequency, where the imaginary part is small. Typically, measurements are made in the 1kHz frequency, and the higher the dielectric constant the better. It should be most preferably greater than 8, preferably achieved with PVDF plus inorganic fillers. Better than 6.0 may be acceptable, which would include unfilled PVDF and CSPE. Better than 4, which would include PVC, may be acceptable as a minimum in some cases. In some compositions it may be preferable to use a small amount of fillers such as barium titanate or other similar fillers to increase the dielectric constant of PVC or other polymer systems. Very high loadings, above 50% by weight, are needed to move the dielectric constant above 10, which loadings may be impracticable for processing, but the use of lower levels of the inorganic fillers to raise the value higher than that of the base polymer is often beneficial.

The Effect of Construction on the Performance of Low Susceptibility Wire.

Raychem's Filterline low susceptibility wire is a unique three-layer construction that provides the necessary electrical properties to act as a low-pass-band distributive filter. Unlike other products, the Raychem wire has an inner layer made from a high-dielectric-constant material, preferably polyvinylidene fluoride. The second layer is preferably a rubber material filled with 80%, by weight of the whole layer, of a ferrite material with very high initial permeability at low frequencies (<50 MHz). The outer layer provides the wire with a tough outer insulating jacket. With this construction adequate performance can be obtained without the use of an additional screening layer.

The three-layer combination provides a lower operating frequency than constructions with just one active layer that is filled with a ferrite. This is because the inner layer provides the capacitance term of the wire that can be considered as a distributive filter. The second layer is filled with a ferrite whose high initial permeability at low frequencies combined with low resistivity provides the inductive term. This unique combination ensures that the wire is effective at attenuating high speed pulses such as those caused by electro static discharges whose energy is concentrated in the 30MHz region. The outer layer provides the insulating layer.

Ferrites are magnetic ceramic materials consisting mainly of iron oxide that is blended with other metallic oxides. The choice of these other metals determines the permeability and the operating frequency of the ferrite layer. A second variable is that of the shape of the ferrite particle to ensure maximum coupling to the magnetic field. Raychem has selected a ferrite whose magnetic properties and shape factor combine to give the highest values of permeability and permittivity for the second layer of its low-susceptibility wire at low frequencies.

The outer layer can be made of any suitable polymeric material, preferably of either fluorinated ethylene propylene (FEP) for high temperature uses (>200°C) or polyesters such as poly butylene terephthalate for intermediate temperatures such as 150°C. These materials have little, if any, influence on the magnitude of any currents flowing down the central conductor the wire, firstly because they have dielectric constants of only between 3 and 4, and secondly because they are not sufficiently close to the conductor. The outer layer thus provides a means for protecting and insulating the two-layer structure of the high-permittivity and high-permeability materials.

These constructions have been tested to the threats associated with automobile applications and described in GMI 12559R the specification used by General Motors to control EMC in automobiles . Given the complex nature of these threats it is not possible to determine the suitability of the performance of materials to this specification merely by studying attenuation-with-frequency data. These show almost no attenuation until frequencies of greater than 100 MHz is reached. The actual effect of coating a wire with a high permittivity and a high permeability layer is to increase the electrical length by slowing down the propagating wave and to decrease the bandwidth of the wire. Hence high frequency pulses such as ESD are significantly slowed and attenuated so as to reduce the threat they pose to systems. The wire also acts as a poor antenna and receiver hence reducing its emissions and susceptibility to high frequency radiation.

EXAMPLES

QUALIFICATION OF THE T300 CABLE ASSEMBLY AND SEAT BELT PRETENSIONER ASSEMBLY TO THE REQUIREMENTS FOR ELECTROMAGNETIC COMPATIBILITY AS SPECIFIED IN THE GM INTERNATIONAL STANDARD GM1 12559R

Summary

A seat belt Pretensioner system has been tested in the EMC laboratories in Swindon to the requirements of the GM International Specification GM1 12559R. Two designs were tested, the first with a ferrite chock spliced into the interconnection cable and the second using Raychem ElectroLoss wire.

The GM specification GM1 01301 gives the requirements of the Seat Belt Buckle Pretensioner and in this document the only EMC test is for ESD. In a further specification GME 12 550 that covers the requirements for Squibs for Airbags again only ESD is specified. However, the general EMC specification GMI 12559 covers all systems and subsystems and is the master specification for the requirements of EMC. This specification covers all aspects of EMC in the car and its systems and not all parts are applicable to the seat belt pretensioner system. An study was made of the specification to select the relevant sections applicable and the rational for these are given in this report. The specifications do not, however, specify the test levels and these have been chosen from the requirements of the new Automotive EMC Directive 72/245 and from similar specifications from other OEMs.

A full range of EMC tests were carried out on the assemblies including radiated susceptibility, bulk cable injection, transient pulse injection and ESD withstand. Both systems tested met the requirements of the specification.

SELECTION CRITERIA FOR THE RELEVANT PARTS OF GM1 12559 R

This specification is general and covers all aspects of the EMC performance of an automobile. Only parts of it are applicable to the system under test and the criteria and rational for the selection of the tests is given below for each section.

5. Electromagnetic Immunity

5.1 Electromagnetic immunity, off vehicle radiation source, vehicle requirement.
This section covers the radiation testing of the whole vehicle to the requirements of the relevant EC directive and as such has to be carried out on the complete vehicle with the seat belt pretensioner installed and is hence outside the scope of this qualification.

5.2 Electromagnetic immunity, on board transmitter simulation, vehicle requirement.
The same comments apply to this as for 5.1 and this section is outside the scope of this qualification.

5.3 Electromagnetic immunity, direct radiation, absorber lined chamber, component test.

This test measures the immunity of a system to high frequency radiated fields. The frequency range is above that that can be achieved with the stripline test. No levels or frequency ranges are given in the specification but in the EC 75/245 a test level of 30 Volts/meter is specified and a normal frequency range is 30MHz to 1GHz.

Tests were therefore carried out at 50V/m to provide a safety margin between 30MHz and 1GHz in the Raychem screened room using a bipolar antenna at 1 meter for the frequency range 30MHz to 210 MHz and a log periodic antenna from 210MHz to 1GHz.

5.4 Electromagnetic immunity, bulk cable injection (BCI), component test.
This test is widely used to evaluate the immunity of systems to the effects of radiated fields. The test is not specified in the standard, however, the test is limited by injection coils to between 200kHz and 450MHz. The injected current level is specified in the EC 75/245 at 60milliamps , however, most OEM specifications use 100milliamps over a frequency range 1MHz to 450 MHz and that was used in this qualification.

5.5 Electromagnetic immunity, stripline, component test.

This test is used to evaluate the immunity of a system to radiated fields in the range 1 to 200 MHz. The specification provides no details, however the EC 75/245 would use 60 V/m and normal field strengths from most OEMs is 100V/m. Tests were carried out at 100 V/m over the frequency range 1 to 200 MHz.

6. Radio Frequency Interference (RFI)

6.1 RFI, far field radiated emissions tests, vehicle requirements.

Test measures radiated RFI from the vehicle and is not relevant to the passive components of the seat belt pretensioner unit and its harness and as such this test was eliminated from the test schedule.

6.2 RFI, radiated emissions test, protection of on-board receivers, vehicle requirements.

6.3 RFI, broadband emissions test, component test.

6.4 RFI, narrowband emissions test, component test.

The same comments apply to these sections as to 6.1.

7. Conducted Emissions and Conducted Immunity.

7.1 Conducted Emissions.

There are no emissions from a passive system such as the seat belt pretensioner and its harness and as such no tests were carried out.

7.2 Conducted Immunity

The test pulses are specified in ISO 7637-1 and cover a total of 5 pulse types. These cover all the likely transients that can occur in a vehicle and a study of their causes and sources is required to select the relevant pulses to use. Some of the transient pulses have more energy in them than the pulse used to fire the squib. It has been assumed that the seat belt pretensioner is isolated from the battery power supply and that transients associated with load dumps and battery changes are not applicable especially since the transients are above the power levels required to fire the squib.

ISO 7637 Test Pulse No. 1 simulates the disturbance caused by the disconnection of the inductive load supply and is a double exponential pulse of 2 ms width 100 volts and 10 amps. This pulse fires the squib and is not applicable to this qualification since the total system has to be isolated by design from this transient.

ISO 7637 Test Pulse No. 2 simulates the disturbance caused by a sudden interruption of current in an inductance in series and is a double exponential pulse of 50us width 100 volts and 10 amps

This pulse fires the squib and is not applicable to this qualification since the total system has to be isolated by design from this transient.

ISO 7637 Test Pulse No 3 simulates the transients caused by switching, due to capacitances and inductances along the wiring harness. This transient is a double exponential 100ns in width, 150 volts and 3 amps. This is the typical transient that occurs on vehicle harnesses and is relevant to this qualification. Section 10.4 species that the most severe level is -150 volts, however, it does not specify the number of pulses. The usual number is 10,000 at a repetition rate of 10Hz to represent the life of the vehicle. A pulse of opposite polarity is also specified but at +100 volts and again the number of pulses applied was 10,000.

ISO Test Pulse No 4 and the deviations specified again simulate transient due to sudden load dumps and have sufficient energy to cause the squib to fire and these transients are not applicable to this qualification since the total system has to isolated by design from these transients.

7.3 Coupled immunity

This test is not applicable to a passive system and was not carried out for this qualification.

7.4 Electrostatic discharge, vehicle test.

This test is more specifically detailed in the relevant part of the air bag and seat belt pretensioner specifications.. The test as detailed in GME 12 550 refers to ISO TR 10 605 and specifies 4 modes using 15000 volts and a 330 pF capacitor. The qualification was carried out using the procedure specified in this specification as it was considered more relevant than that specified in the GMI 12559R

SAMPLE IDENTIFICATION

Two termination systems were evaluated, one (Previously-known System) with a ferrite choke in series with the squib and the second (The Invention) with the input line to the squib being of Raychem Filterline ElectroLoss (Trade Mark) 55FA0511-22-7L wire. The samples were supplied to Raychem by AlliedSignal as completed assemblies marked 673-1L,2L & 3L for those using the ferrite choke and 673-1R,2R & 3R for those using the ElectroLoss cable.

SAMPLE TERMINATION

The plastic connector was removed from the end of the T300 harness and the two wires terminated in a BNC coaxial connector to facilitate testing.

Since the object was to generate the maximum current in the loop made up of the two wires to the squib these were usually terminated in a short. During tests to determine the level of interference during radiated testing the two wires were terminated in 50 ohms.

TEST SEQUENCE

Each sample was tested in the following sequence radiated field, strip line, BCI, Voltage transient and ESD since this was considered a sequence of increasing severity.

TEST MEASUREMENTS

Before each test the DC resistance between the two wires was measured. At the end of each test the resistance was again measured and of the squib fired this would be recorded.

TEST RESULTS

5.3 Electromagnetic immunity, direct radiation, absorber lined chamber.

The sample under test was supported 5cms above a ground plane in the screened room and radiated from 1metre. The applied field strength was measured using a field probe. The samples were terminated in a short between the input and output wires. The sample was radiated using a bi-conical antenna from 30 MHz to 210 MHz in steps of 5Mhz with the power to the antenna being increased until the field strength was 50 volts/meter. For the frequency range 210 MHz to 1GHz the frequency steps were 10MHz.

Test Results

SAMPLE	Initial Resistance Ω	Final resistance Ω	Squib Fire
673-1L	2.6	2.6	NO
673-2L	2.7	2.6	NO
673-3L	2.6	2.5	NO
673-1R	2.8	2.7	NO
673-2R	2.5	2.5	NO
673-3R	2.6	2.6	NO

5.4 Electromagnetic immunity, stripline

The samples were supported 5cms above the return of the strip line which was 1 meter long with a height of 50 cms and a width of 40 cms. Again a field probe was used to measure and control the field strength to 100 Volts per meter. The test was carried out between 1 and 200 MHz using increment steps of 1 MHz from 1 to 20 MHz, MHz from 20 to 200 MHz. Two tests were carried out, the first with the input and output wires short circuited to maximize the circulating current and the connected to the input of a spectrum analyzer to measure the voltage generated into 50 ohms.

Test Results

SAMPLE	Initial Resistance Ω	Final resistance Ω	Squib Fire
673-1L	2.6	2.5	NO
673-2L	2.5	2.6	NO
673-3L	2.6	2.5	NO
673-1R	2.8	2.7	NO
673-2R	2.5	2.5	NO
673-3R	2.6	2.4	NO

Typical voltages compared to a control sample are shown in fig. 9.

5.5 Electromagnetic immunity Bulk Cable Injection

During this test the injection coils are calibrated by determining the power required to drive 100 milli amps into a 50 ohms calibration jig. This power is then used to inject current onto the input wire to the squib with both the input and output shorted together to from a loop. The induced current on the wires is monitored with a second coil. **A typical result for a harness and a control sample is shown in fig. 10.**

Test Result

SAMPLE	Initial Resistance Ω	Final resistance Ω	Squib Fire
673-1L	2.6	2.6	NO
673-2L	2.4	2.6	NO
673-3L	2.6	2.7	NO
673-1R	2.5	2.7	NO
673-2R	2.5	2.5	NO
673-3R	2.6	2.5	NO

7.2 Conducted Immunity

A pulse generator was connected to the input line of the sample under test and the specified pulse injected into the harness at a repetition rate of 10 Hz. The wave form was monitored using an oscilloscope across the input terminals.

Test Results

SAMPLE	Initial Resistance Ω		Final resistance Ω		Squib Fire	
Pulse	-150V	100V	-150V	100V	-150V	100V
673-1L	2.6	2.7	2.6	2.5	NO	NO
673-2L	2.7	2.6	2.6	2.4	NO	NO
673-3L	2.6	2.7	2.5	2.6	NO	NO
673-1R	2.8	2.5	2.7	2.4	NO	NO
673-2R	2.5	2.7	2.5	2.5	NO	NO
673-3R	2.6	2.7	2.6	2.4	NO	NO

7.4 Electrostatic Discharge

The pulse was applied in 4 modes:-

Mode a) Shorted pins to case; Mode b) Right pin to case; Mode c) Left pin to case; Mode d) Pin to pin

A total of 10 pulses at the specified level was applied by direct contact of each polarity.

Test Result

SAMPLE	Initial Resistance Ω	Final resistance Ω	Squib Fire
673-1L	2.6	2.6	NO
673-2L	2.4	2.6	NO
673-3L	2.4	2.4	NO
673-1R	2.8	2.7	NO
673-2R	2.5	2.5	NO
673-3R	2.4	2.5	NO

CONCLUSIONS

Both the termination systems meet the requirements of the GMI 12559R specification at the levels of threat tested for the parts of the specification that was considered relevant. None of the tests at the specified level caused any noticeable degradation of the resistance of the squib. In no cases at the levels tested did the squib fire.

CLAIMS

1. A method of improving an electrical wiring assembly incorporating a twisted pair of wires to reduce parasitic signals in those wires, which method comprises replacing the twisted pair of wires by an untwisted pair of wires, at least one of which untwisted wires is at least partly enclosed (preferably substantially completely enclosed) in

(a) an inner layer of a high-dielectric polymeric composition, which inner layer is least partly enclosed (preferably substantially completely enclosed) in

(b) an overlying lossy layer at least partly composed of organic polymeric material, and which lossy layer is least partly enclosed (preferably substantially completely enclosed) in

(c) an overlying electrically-insulating polymeric jacket layer,

wherein the layers are capable of acting as a parallel filter to attenuate (preferably by more than 20dB per metre, more preferably at least 25dB per metre) parasitic signals

(i) at electrostatic discharge frequencies of less than 300 MHz, preferably also at frequencies less than 200 MHz, more preferably also at frequencies in the range below 100 MHz, especially 50-100 MHz or 1 - 10 MHz, or

(ii) at EMI frequencies greater than 300 MHz, preferably also at frequencies greater than 500 MHz, more preferably also at frequencies greater than 1000 MHz.

2. A method according to claim 1, wherein the inner layer includes dielectric-raising inorganic fillers.

3. A method according to claim 1 or 2, wherein the inner layer is in direct contact with the wire conductor.

4. A method according to any preceding claim, wherein the inner layer composition comprises polyvinylidene fluoride (PVDF) or chlorosulphonated polyethylene, which may preferably be cross-linked by known means.

5. A method according to any preceding claim, wherein the inner layer composition has a dielectric constant above 4, preferably above 6, more preferably above 8, at 1 kHz, and preferably above 6 at 1 MHz, above 5 at 10 MHz, and above 4 at 100 MHz frequency.

6. A method of improving an electrical wiring assembly incorporating a twisted pair of wires to reduce parasitic signals generated in those wires when exposed to electromagnetic interference (EMI), wherein the twisted pair is replaced by an untwisted pair of wires, at least one of which untwisted wires is at least partly enclosed (preferably substantially completely enclosed) in (a) a layer of (preferably cross-linked) polyvinylidene fluoride (PVDF), preferably in direct contact with the wire conductor, which PVDF layer is enclosed in (b) an overlying lossy layer at least partly composed of organic polymeric material, and which lossy layer is enclosed in (c) an overlying electrically-insulating polymeric jacket layer, the arrangement being such that the wire is capable of acting as a parallel filter to attenuate by more than 20dB per metre (preferably at least 25dB per metre) the said parasitic signals at EMI frequencies greater than 100 MHz, preferably also at frequencies greater than 500 MHz, more preferably also at frequencies greater than 1000 MHz.

7. A method according to any preceding claim, wherein each wire of the said untwisted pair is at least partly enclosed in the said layers.

8. A method according to any preceding claim, wherein the said layers are formed by a coating extruded along the wire.

9. A method according to any preceding claim, wherein the wire(s) carrying the said layers is (are) at least 30 cm in length.

10. A method according to any preceding claim, wherein the said untwisted pair of wires is connected in use to a pyrotechnic device for actuation of an automotive air bag or seat belt pre-tensioner, or to an ABS sensor or other automotive sensor.

11. A method according to any preceding claim, wherein the wiring assembly is for use in commercial (non-military) land vehicles.

12. A method according to any preceding claim, wherein the said untwisted pair of

wires is used in conjunction with filters connected in series with the wires and/or in conjunction with ferrite beads, some or preferably all of which filters and/or beads are also replaced by the said untwisted pair of wires.

13. A method according to any preceding claim, wherein the jacket layer comprises (preferably cross-linked) ETFE or polyester.

14. A method according to any preceding claim, wherein the lossy layer comprises thermoplastic elastomer (preferably fluorinated) and/or ferrite filler.

15. A pyrotechnic device for actuation of an automotive air bag or seat belt pre-tensioner, or an automotive sensor device, the device having connected thereto an untwisted pair of wires as defined in any preceding claim for electrical actuation in use of the device.

16. An automotive air bag assembly or seat belt pre-tensioner assembly incorporating a pyrotechnic actuator device according to claim 10.

17. Use, in an automotive wiring harness production line, of an untwisted pair of wires as defined in any of claims 1 to 14.

****

Fig.A.

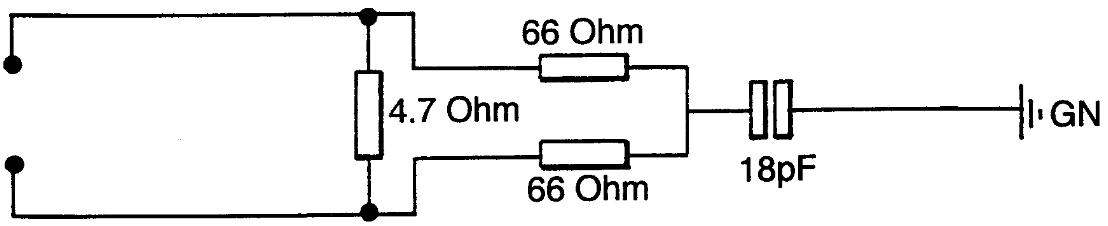

66 Ohm
4.7 Ohm
66 Ohm
18pF
GN

FIG.B.

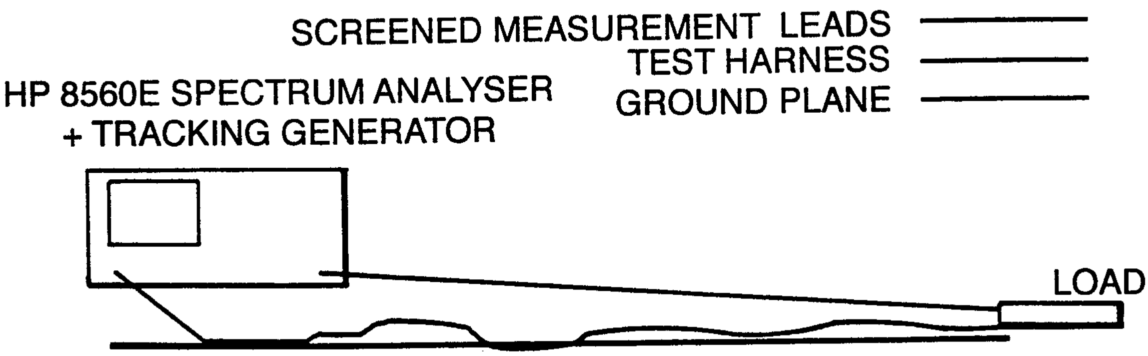

SCREENED MEASUREMENT LEADS
TEST HARNESS
GROUND PLANE
HP 8560E SPECTRUM ANALYSER
+ TRACKING GENERATOR
LOAD

Fig.1.

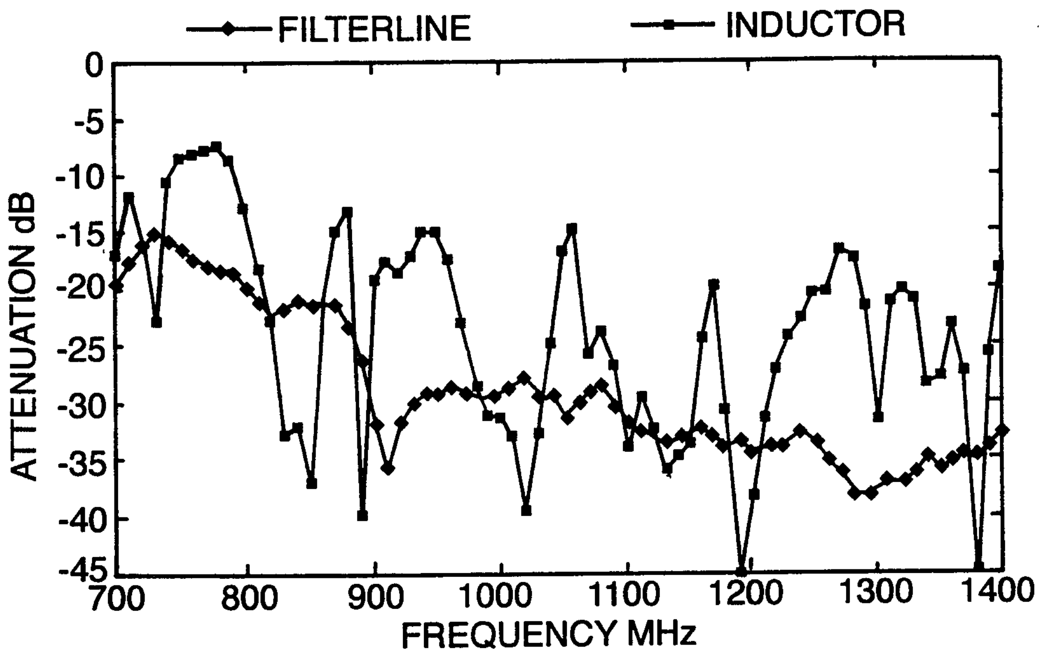

FILTERLINE
INDUCTOR
ATTENUATION dB
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
700
800
900
1000
1100
1200
1300
1400
FREQUENCY MHz

Fig.2.

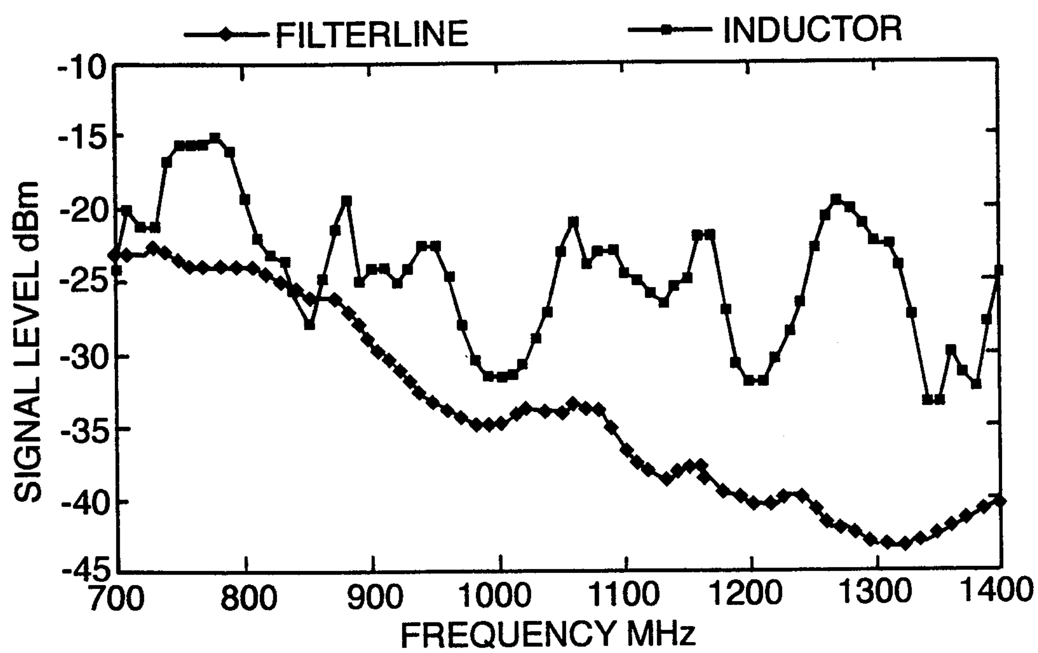

FILTERLINE
INDUCTOR
SIGNAL LEVEL dBm
-10
-15
-20
-25
-30
-35
-40
-45
700
800
900
1000
1100
1200
1300
1400
FREQUENCY MHz

Fig.3.

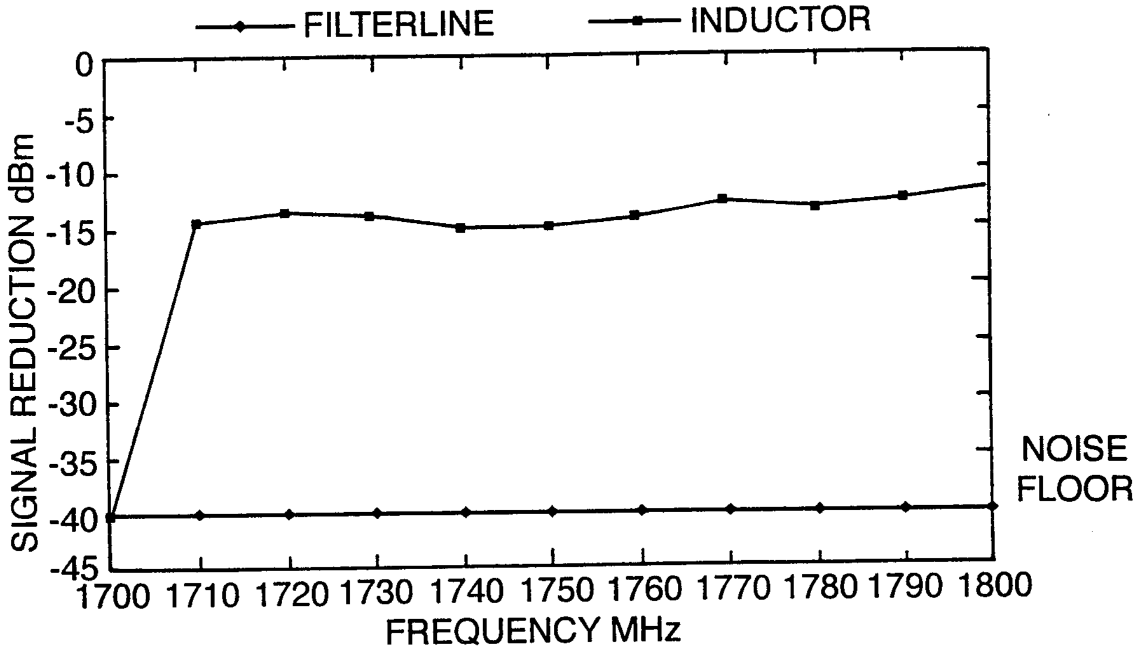

FILTERLINE
INDUCTOR
SIGNAL REDUCTION dBm
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
1700 1710 1720 1730 1740 1750 1760 1770 1780 1790 1800
FREQUENCY MHz
NOISE FLOOR

Fig.4.

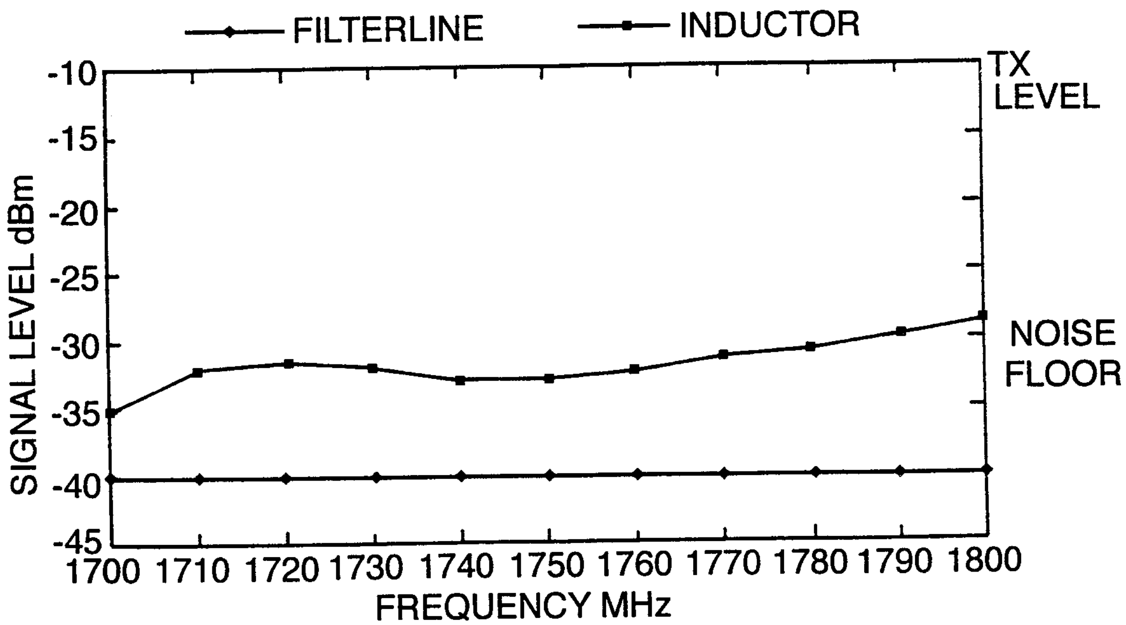
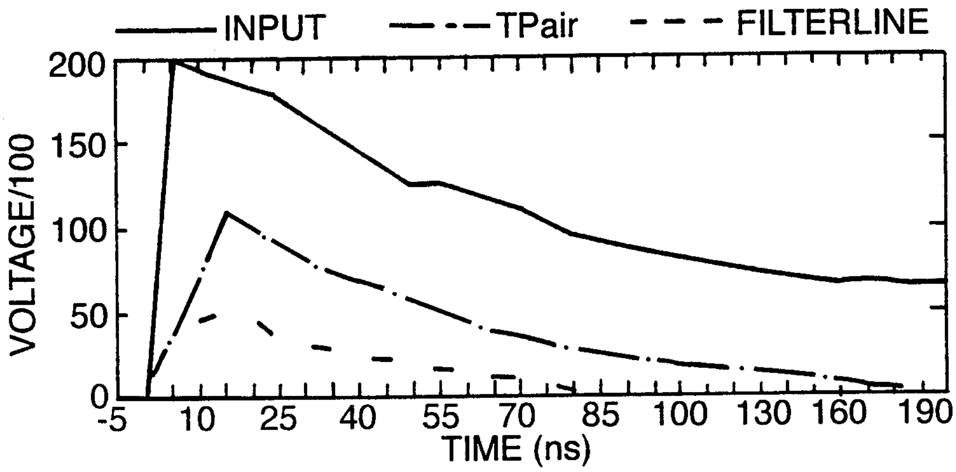
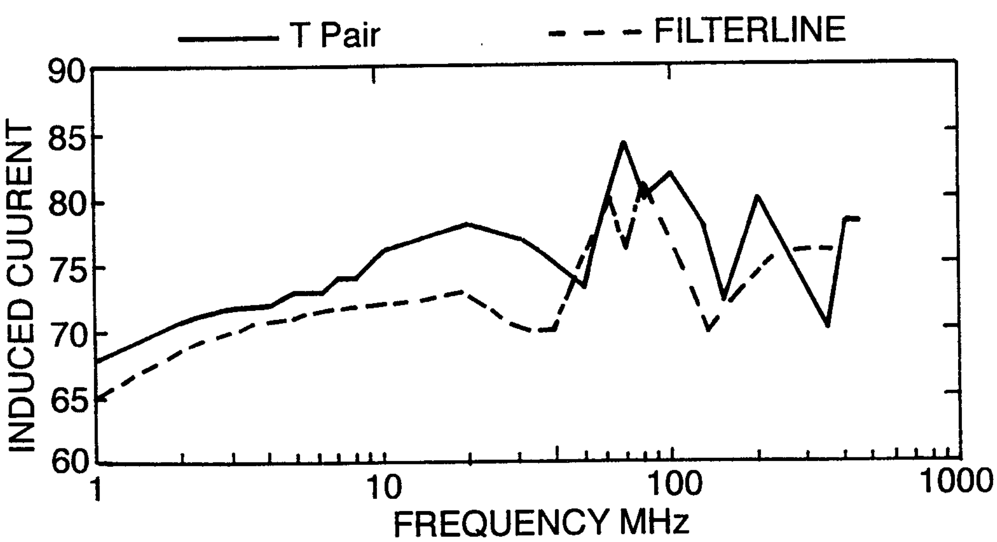

FILTERLINE
INDUCTOR
SIGNAL LEVEL dBm
-10
-15
-20
-25
-30
-35
-40
-45
1700 1710 1720 1730 1740 1750 1760 1770 1780 1790 1800
FREQUENCY MHz
TX LEVEL
NOISE FLOOR

Fig.5.



CABLE 1m LONG TERMINATED IN 50 Ohms, VOLTAGE ACROSS TERMINATION

Fig.6.



100ma BCI MEASURED CURRENT SHOWN, SAMPLES 1m TERMINATED IN 50 Ohms,

Fig.7.

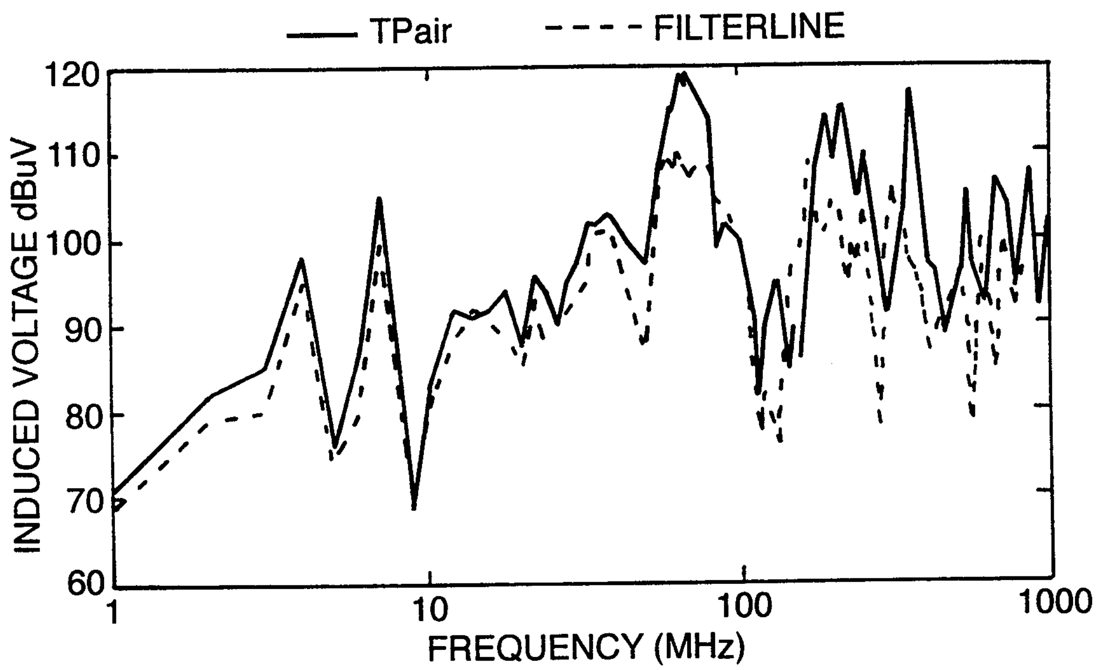

TPair
FILTERLINE
INDUCED VOLTAGE dBuV
120
110
100
90
80
70
60
1
10
100
1000
FREQUENCY (MHz)

Fig.8.

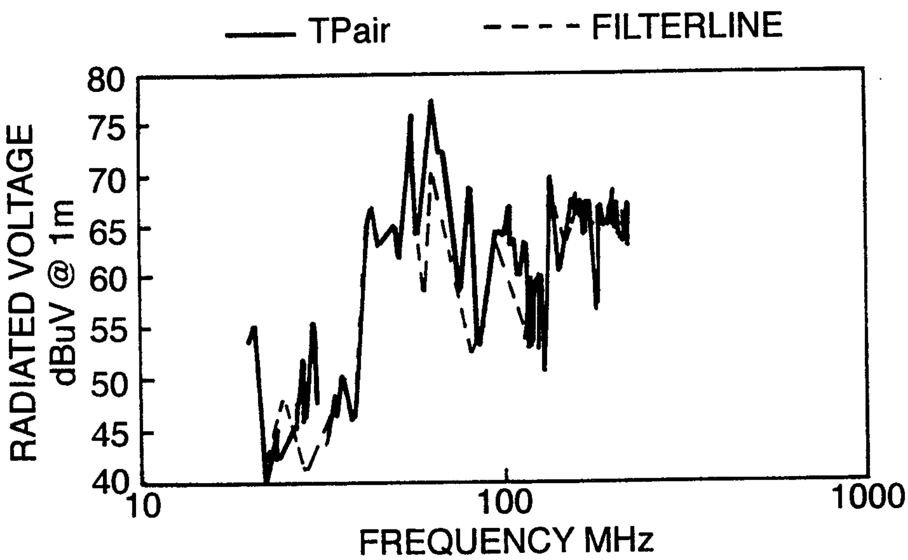

TPair
FILTERLINE
RADIATED VOLTAGE dBuV @ 1m
80
75
70
65
60
55
50
45
40
10
100
1000
FREQUENCY MHz

Fig.9.

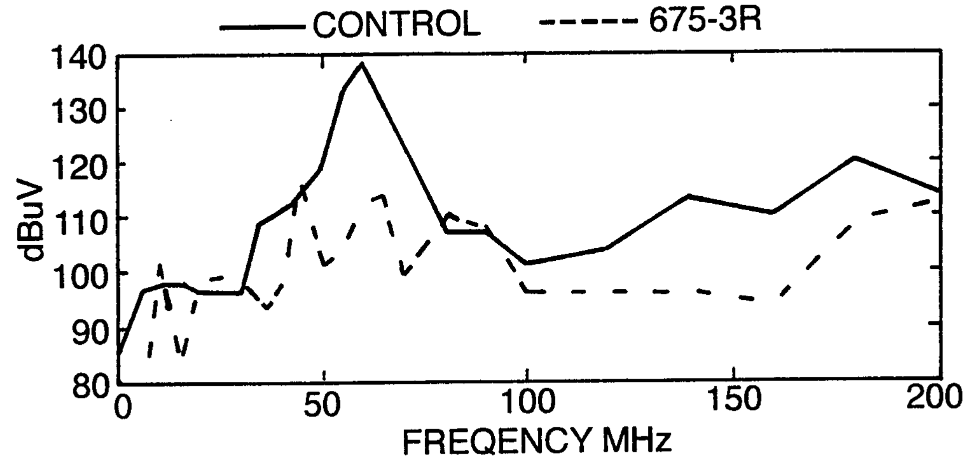
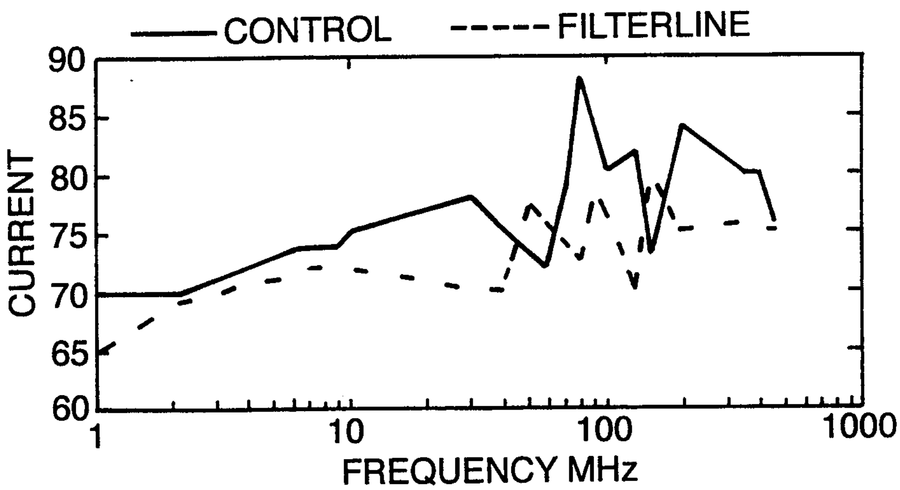


Fig.10.



100ma BCI WITH MEASURED CURRENT SHOWN, SAMPLES 1m TERMINATED IN 50 Ohms

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/00908

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01B11/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 371 742 A (MANLY) 1 February 1983 see column 6, line 62 - column 7, line 35; figure 2	1,6
A	EP 0 061 247 A (ELTRA) 29 September 1982 see page 11, line 12 - page 12, line 30; figure 1	1,6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 July 1998	14/07/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Demolder, J

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte ...ional Application No
PCT/GB 98/00908

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4371742 A	01-02-1983	DE 2855134 A	21-06-1979
EP 061247 A	29-09-1982	US 4413469 A CA 1190389 A JP 57170407 A	08-11-1983 16-07-1985 20-10-1982