



AEROSPACE INFORMATION REPORT

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Design and Handling Guide Radio Frequency Absorptive
Type Wire and Cables (Filter Line, AS85485)

RATIONALE

This revision is purely for correcting editorial errors prior to stabilizing the document.

FOREWORD

Today's performance needs for military, avionics, and ordnance systems require increasingly sophisticated electronic equipment and greater use of composite structures. As operational requirements become more critical, the level of electromagnetic interference (EMI) protection for electrical equipment is increasing. Filter line interconnect systems provide a high degree of EMI protection while functioning as conventional electrical wiring systems.

In aircraft, most control and monitor signals operate at frequencies substantially below 50 MHz, whereas most interference sources operate in the high VHF, UHF, and SHF bands (e.g., radio, IFF, radar, EW, etc.). By effectively attenuating these sources of interference on susceptible control and monitor wiring, filter line wiring efficiently serves the dual roles of filtering and interconnection.

Filter line wiring can also be useful for non-aviation installations where the pass band and stop band characteristics fit the system needs.

Filter line interconnect systems consist of high-performance wire and cable and termination devices that, when used as specified, suppress conducted and radiated EMI above 100 MHz. It provides a reliable alternative to conventional discrete filters and filter-pin connectors. Filter line cables are flexible, lightweight, and can be used with most high-density connectors. Filter line wire and cable performance requirements and construction details are specified in AS85485 (formerly MIL-C-85485).

Proven filter line termination devices include back shell adapters, braid splicers, shield terminators, and shield splices. These components provide 360-degree, low-impedance terminations at connectors; a must for efficient EMI protection. They also permit easy repair of connectors without disconnecting shield terminations.

This design guide consists of three chapters:

- a. Introduction
- b. Designing with filter line
- c. Constructing harnesses with filter line

The purpose of this manual is to provide practical suggestions to both designers and end users in dealing with the applications and manufacturing of harnesses utilizing filter line wiring.

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1. SCOPE

This document presents design and application information which will allow optimized utilization of filter line wire and cable purchased to AS85485. Filter line wire is defined and design information is presented. The electrical and mechanical performance characteristics of the wire, along with recommended harnessing methods and techniques, are also presented.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (U.S. and Canada only) or +1 724-776-4970 (outside U.S. and Canada), www.sae.org.

AS5768	Tool, Stripper, Electrical Insulation, General Specification For
AS6173/1	Cutting Tool (Miniature) Electrical, Wire Cutting, Hand Actuated, Type 1, Wire Sizes 26 Through 16
AS6224/1	Repair Sleeve, Primary Wire Insulation Damage, Electric, Permanent, Environment Resistant, 150 °C Maximum Operating Temperature
AS22759/34	Wire, Electrical, Fluoropolymer-Insulated, Crosslinked Modified ETFE, Normal Weight, Tin-Coated, Copper, 150 °C, 600 Volt, ROHS
AS22759/35	Wire, Electrical, Fluoropolymer-Insulated, Cross-Linked Modified ETFE, Normal Weight, Silver-Coated, High Strength Copper Alloy, 200 °C, 600 Volt, ROHS
AS81044	Wire, Electrical, Crosslinked Polyalkene, Crosslinked Alkane-imide Polymer, or Polyarylene Insulated, Copper or Copper Alloy
AS81824/5	Splices, Electric, Permanent, Crimp/Solder Style, Copper, Insulated, Environment Resistant, Kit, Shielded Cable, 150 °C
AS83519/3	Shield Termination, Solder Style, Insulated, Heat-Shrinkable, Environment Resistant with Preinstalled Braid, Class 1, Non-ROHS
AS83519/4	Termination, Solder Style, Insulated, Heat-Shrinkable, Environment Resistant with Multiple Opening Sealant, 150 °C and 200 °C
AS83159/5	Shield Termination, Solder Style, Insulated, Heat-Shrinkable, Environment Resistant with Preinstalled Braid, Ni Plated, Class 1, ROHS
AS85049/93	Connector Accessories, Electrical, Termination, Shield Split Support Ring, Composite, Nonenvironmental, Straight, Category 7
AS85049/103	Connectors, Accessories, Composite, RFI/EMI, Electrical, Strain Relief, Straight, Self-Locking, Category 3C (for MIL-DTL-38999 Series III and IV Connectors)
AS85049/128	Shield Band, Connector Accessories, Electrical Backshell, Category 7 (for AS85048/82 - /90, /93, /109 - /117 Accessories)
AS85485	Cable, Electric, Filter Line, Radio Frequency Absorptive

2.2 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-DTL-38999 Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded or Breech Coupling), Environment Resistant with Crimp Removable Contacts or Hermetically Sealed with Fixed, Solderable Contacts, General Specification for

MIL-STD-464 Electromagnetic Environmental Effects Requirements for Systems

3. WHAT IS FILTER LINE?

Filter line wire looks and performs just like ordinary wire with one additional function: it will absorb high-frequency energy and allow it to dissipate as heat instead of conducting it.

Filter line wire and cable are available in two basic constructions differentiated primarily by size and weight. AS85485/9 through /12 are smaller in size and lighter in weight than M85485/5 through /8. The information in Table 1 has been taken from Table 1 of AS85485/5, /6, /9, and /10. A list of AS85485 part number cross-references to the qualified manufacturer part numbers for /9 through /12 constructions is found in the qualified products list to AS85485 (QPL 85485).

Table 1 - Filter line wire (M85485) weight and diameter

	Finished Wire Diameter (inch)	Finished Wire Diameter (inch)	Weight (pounds/1000 feet) (max)	Weight (pounds/1000 feet) (max)
AWG	M85485/6	M85485/10	M85485/6	M85485/10
24	0.053 ± 0.003	0.045 ± 0.002	3.9	3.0
AWG	M85485/5	M85485/9	M85485/5	M85485/9
22	0.062 ± 0.004	0.051 ± 0.003	5.1	4.0
20	0.070 ± 0.004	0.059 ± 0.003	7.0	5.8
18	0.080 ± 0.004	0.070 ± 0.003	9.7	8.7
16	0.086 ± 0.004	0.078 ± 0.004	11.7	11.2
14	0.100 ± 0.004	0.095 ± 0.004	16.6	16.1
12	0.127 ± 0.004	0.112 ± 0.004	26.1	24.0
10	0.151 ± 0.005	0.136 ± 0.006	39.1	37.0

For additional physical, environmental, and electrical requirements, refer to the appropriate detail sheets of AS85485.

Differing in construction to that of ordinary wire, M85485/9 and /10 filter line has a thin layer of radiation-crosslinked, polyvinylidene fluoride, PVF₂, (M85485/5 through /8 uses radiation-crosslinked, modified ethylene-tetrafluoroethylene [ETFE]), and a specially compounded absorptive material surrounding the conductor. This thin layer is in turn covered with a layer of radiation-crosslinked, modified ETFE insulation. See Figure 1 for diagrams of the primary and shielded/jacketed cable constructions.

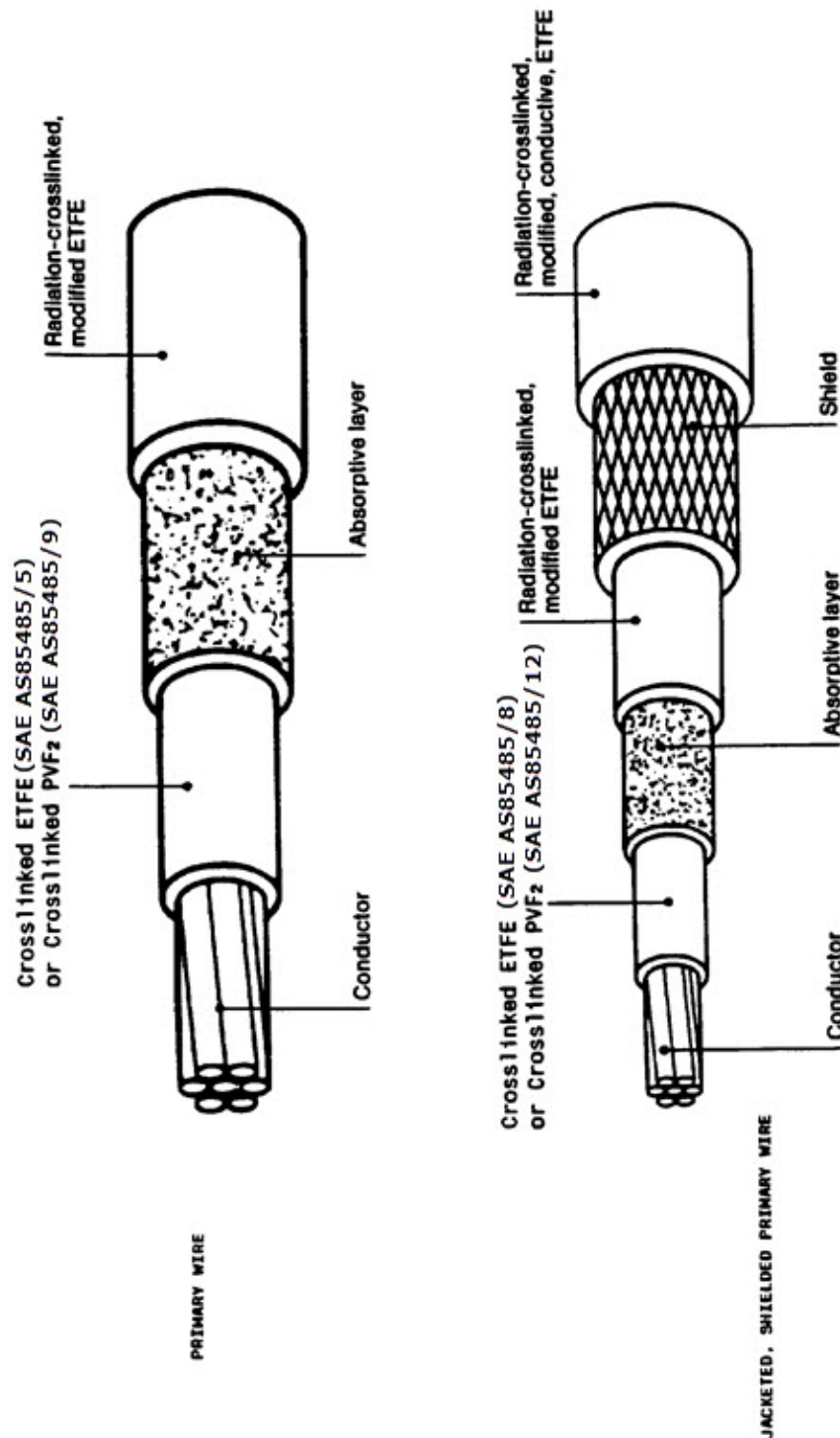


Figure 1 - Filter line wire and cable constructions

3.1 Principle of Operation

The principle by which this high-frequency absorption mechanism takes place is best analyzed at the atomic level. Associated with the electrons of an atom, there are magnetic dipoles resulting from the electron spin. In some substances, including ferrites, these spins align within small regions called magnetic domains. Filter line works by the interaction of the magnetic fields caused by current flowing on the conductor with these magnetic dipoles. Energy is absorbed from the magnetic field and causes domain rotation or domain wall movement. The absorbed energy is then dissipated by the ferrite crystal lattice via lattice vibrations or photons. This vibration manifests itself as heat.

This absorption mechanism can be characterized by the following features:

- a. Energy contained in the oscillating magnetic field caused by a signal current on the conductor is ultimately absorbed by the ferrite lattice as heat.

NOTE: The amount of heat absorbed is much less than 1 mW/ft.

- b. The power absorbed (rate of energy absorption) is dependent on the volume of the ferrite. For filter line, this means that for a given construction, the power absorbed (the attenuation) is proportional to the length of the line.
- c. The power absorbed increases strongly with frequency. Thus, energy of a lower frequency traveling on the conductor is virtually unaffected. The filter line thus acts as a very efficient low pass filter.

Filter line does not depend upon an impedance mismatch to attenuate EMI as do standard filtering devices. Furthermore, filter line has an inherent reliability that does not depend upon a collection of resistors, inductors, and capacitors as do conventional passive filters nor upon the solid state operational amplifier elements associated with modern active filters. Rather, it depends upon the mere presence of its special absorptive layer.

In order for filter line wire to be effective, the high-frequency energy field surrounding the conductor must be confined so that the absorptive layer can absorb this energy. This requires a metallic shield surrounding the filter line wire to act as a field confining member. In principle, the more closely the metallic shield surrounds the filter line, the more concentrated the field and the more efficiently the absorptive layer behaves. Therefore, filter line wire is most efficient (on a decibel per running foot basis) in shielded and jacketed constructions, having from one to four conductors within the closely fitted shield, as shown in Figure 2.

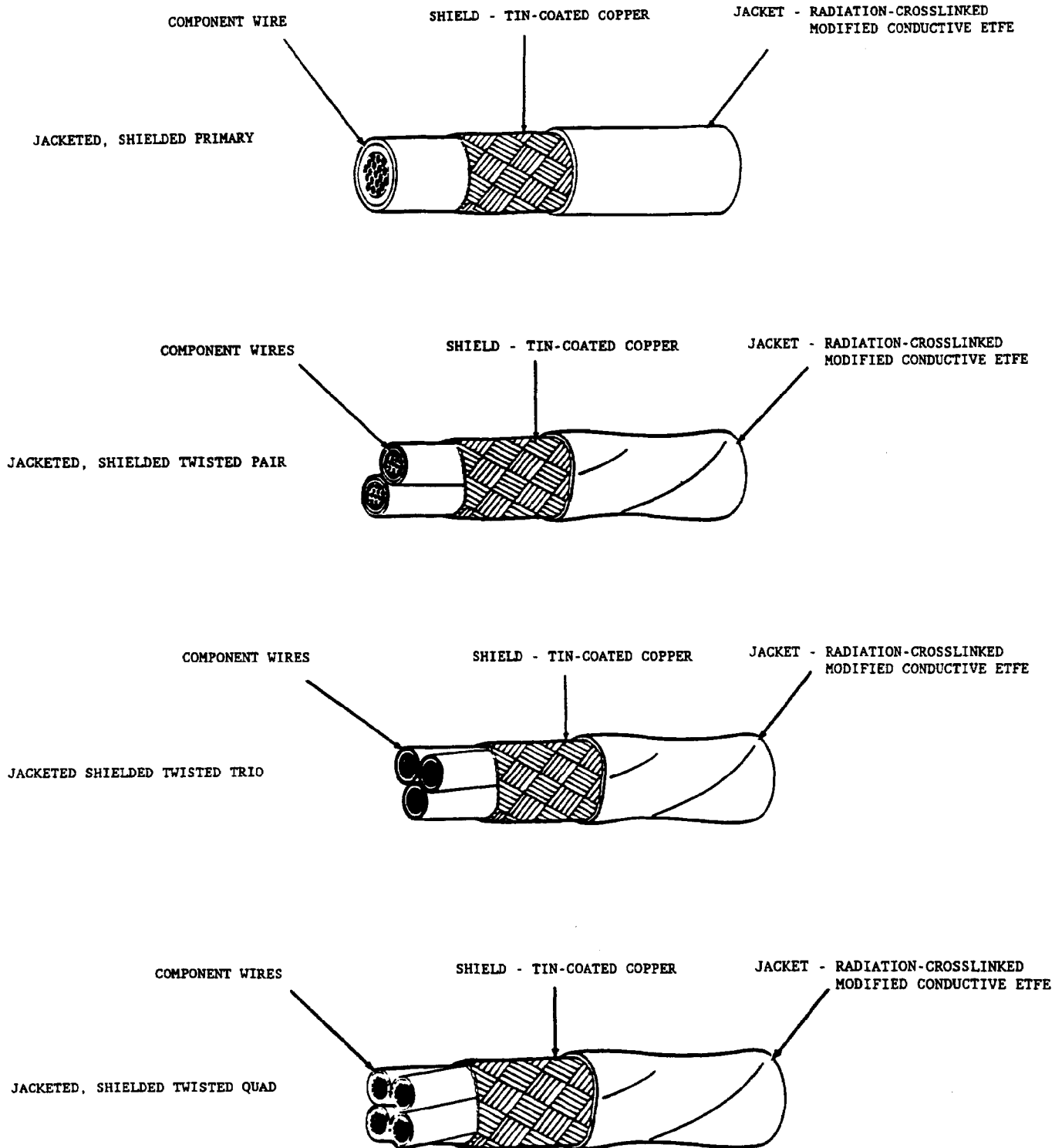


Figure 2 - Jacketed, shielded constructions

Alternatively, a single metallic shield can act as a common field confining member for a large number of filter line wires grouped together and surrounded by the shield, as in a gross (overall) shielded harness branch or cable. Such a construction is shown in Figure 3. Here, the bundle consists of a large number of individual filter line wires grouped together forming several concentric "layers" of filter line. In this configuration, the absorption efficiency of the filter line wires is diminished on a decibel per running foot basis. For design purposes, the efficiency of filter line wires configured in this manner can conservatively be considered as 70% of that of an individually shielded and jacketed filter line wire on a decibel per running foot basis.

3.1.1 Design Rule

Filter line wires must have a metallic shield surrounding them in order for the expected filtering action to occur.

Since filter line is employed in a system to protect against conducted EMI, it is reasonable to expect that such a system would also have provision for protection against radiated EMI in the form of braided EMI shields on the cable, etc.

In the remainder of this design guide, we shall show the employment of filter line in interconnect systems that have EMI shields of various conventional configurations.

It is fortuitous that these EMI shields can also serve as the field confining member needed for filter line.

3.2 Applications

The high-frequency attenuation performance of filter line protected interconnect systems has been successfully demonstrated in an array of applications involving ordnance, weapon systems, aircraft, and helicopter interconnect wiring. The common thread that links these applications together is the increasing susceptibility of EMI in electronic systems due to the greater use of EMI/RFI transparent composite structures and highly sophisticated but sensitive electronic equipment in the aircraft industry.

Historically, filter line wire and cables have been used in areas of vehicles that are constructed of composite materials or areas that are extremities, such as wings on an aircraft. These areas are prone to receive more direct high-frequency energy from radar and microwave communication systems which will interfere with the onboard systems. Filter line cables will attenuate this unwanted energy, thus prohibiting disruption of the primary system.

U.S. Naval ship-based aircraft must be able to perform in extreme electromagnetic fields created by the ship's radar, communication, and tracking equipment.

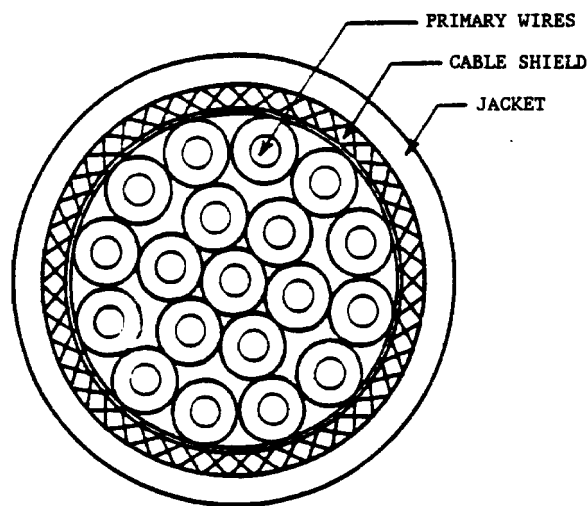


Figure 3A - Jacketed, shielded 19 member bundle

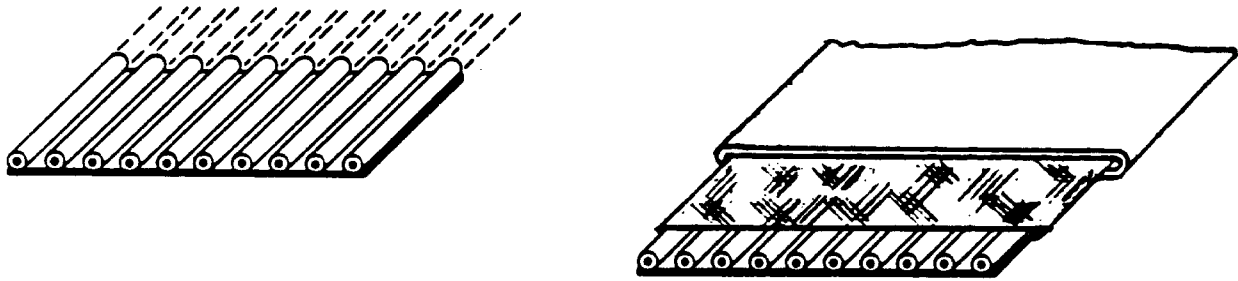


Figure 3B - Planar-arrayed (ribbonized or film-bonded) filter line cables (primaries and shielded and jacketed)

Figure 3 - Filter line wires

During its full-scale development design phase, the Navy LAMPS helicopter required the application of EMI filtering techniques. The filter line interconnect system, installed for initial field testing, was proven highly successful in eliminating electronic instrument problems associated with EMI at the Patuxent River test facility in 1982. Filter line was specified, thus minimizing EMI concerns, and has been used for the helicopter wiring since that time.

Filter line in this program and other similar aerospace and ground vehicle applications eliminates the need for connector filter pins and discrete filters. Additionally, its use reduces the amount of metallic shielding normally required on NEMA WC27500 cables otherwise used to gain equivalent EMI protection.

Planar arrayed (flat) filter line cables meet the growing demand of the electrical interconnect industry. The placement of specified wires within flat cables can be organized so that EMI sources are isolated from potentially susceptible circuits in a consistent, repeatable manner, providing a major advantage over randomly placed wires in round wire bundles enhancing an EMI compatible design. Applications such as a harness for drawer or rack mounted instrumentation usually require increased flexibility in one cable plane, while no flexibility is needed in the perpendicular plane. Due to the geometric shape of planar cable harnesses, these cables often have the advantage over round wire bundles in that they gain maximum use of available space and predictable conductor-to-conductor spacing. Flat cables can be stacked several layers thick without adverse effects on performance.

The use of filter line primary wires arranged in a planar format and used as part of an integrated, modular system offers tremendous advantages through weight savings, load sharing, organized wiring, and the reduction of cable bundle size requirements. See Figure 3B. Typical applications include areas of high-density wiring with EMI protection requirements and areas on aircraft such as pylons and various weapon rails.

Integrated modular systems bring together attributes of the flat, low profile of a ribbonized construction, maintaining the primaries in an organized fashion, EMI/EMP protection, rectangular mass termination, and robotics capabilities in manufacturing. An integrated wiring systems approach based on modularity guarantees minimum weight, smallest size, increased reliability, enhanced maintainability, extended life, and performance of the total interconnect system.

Like any other component of a system, there must be a sure method of testing the filtering performance of filter line wire and the EMI susceptibility of shield terminations used for filter line harnesses. The filtering performance is evaluated by means of attenuation measurements. The shielding effectiveness against EMI of cable shield terminations, braid configurations, back shell adapters, and connectors as part of a harness assembly is evaluated by means of the surface transfer impedance technique. Further explanation of these tests can be found in Section 5.

4. DESIGNING A SYSTEM WITH FILTER LINE

4.1 Penetration of an EMI Protected Enclosure

An EMI protected "black box" communicates with the outside world through an I/O connector, which is mated to a cable connector terminated to the end of the appropriate wiring harness.

It is important to remember that EMI can potentially be conducted through the I/O connector via any electrical line or contact. Therefore, all wires feeding through the I/O connector should be filter line if all paths for conducted EMI are to be addressed. Furthermore, the overall filtering effect of a group of filter lines entering a protected black box will be characterized predominantly by the filter line(s) having the lowest EMI attenuation.

Figure 4 shows the results of mixing filter line and regular wires at the penetration into a protected black box. Filter lines A and B are functional, but their effect is largely masked because line C provides a direct path for conducted EMI to enter the box. The attenuating effect of the filter lines is greatly diminished by the use of a nonfilter line primary passing through the I/O connector.

In Figure 5, all wires in the I/O cable are filter line. However, any EMI that is present on the individual shield of the twisted pair can pass into the black box via the shield termination line C. It is important that the subject unit be adequately protected with an EMI-proof enclosure that is electrically bonded to the airframe structure. The attenuation of EMI realized by filter line can be negated as a result of direct radiation of EMI into components and wiring within unprotected enclosures.

- a. Design rule: All lines entering a protected black box through an I/O connector must be filter line. See 5.1.1 for details.
- b. Design rule: Individual shields of cables in a bundle with an overall shield should not be carried through the I/O connector of a protected black box.

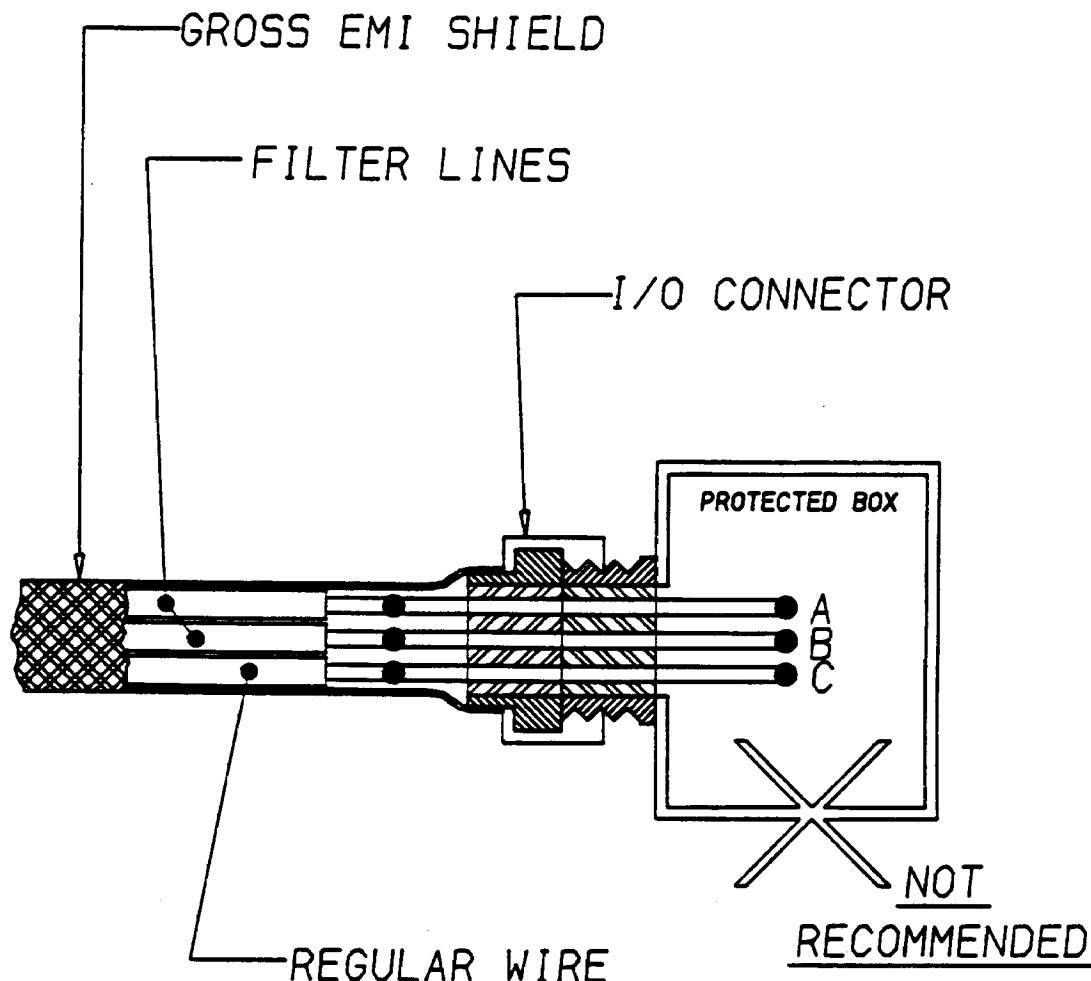


Figure 4 - Filter line primaries mixed with regular primary wire

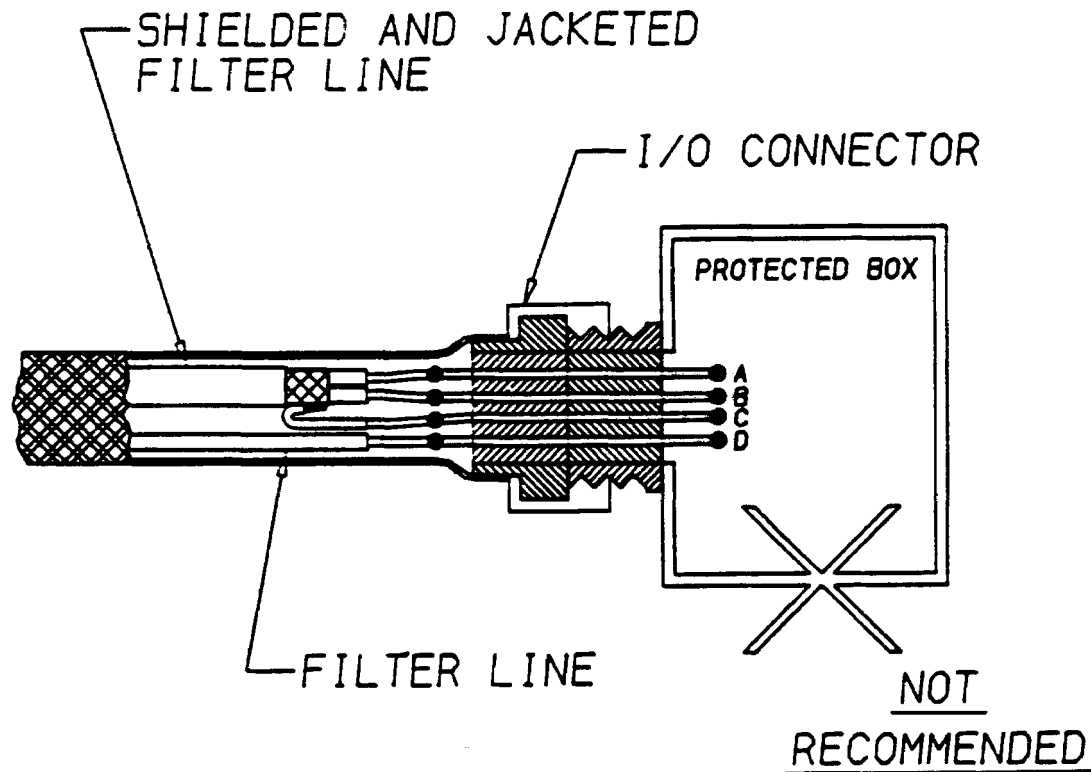


Figure 5 - Filter line primary wire and cable with gross shield terminated to an I/O connector contact

4.2 Bundling and Cabling

In 3.1, the bundling together of several filter lines in a common “shield” was introduced. In many harnesses, it is desirable to use a gross (overall) EMI shield configuration and at the same time include both regular wire and filter line in the same bundle. Figure 6 illustrates such a configuration. Box A is fed by both regular wires and filter line. Since all of the lines going into the box are not filter line, box A is not a “protected” box. Box C is fed by regular wire and is therefore not a “protected” box. Box B is fed exclusively by filter line and can therefore be considered a “protected” box. The entire interconnect harness joining boxes A, B, and C is covered with a continuous gross EMI shield.

In that portion of the harness where regular wire and filter line are commingled, the filtering effect of the filter line will be partially defeated. The regular wire can act as a path for conducted high-frequency EMI. This energy can then couple onto the filter line. The overall result is a diminished filtering effectiveness along that portion of the filter line. In that portion of the harness where the filter line is segregated from the regular wire (length L), the filter line will perform at its expected level. For design purposes, the filter lines feeding a protected box are segregated for a length (immediately prior to entering the protected box) sufficient to provide the desired amount of attenuation.

- a. Design rule: Filter line that is commingled with regular wire within a gross EMI shield must be segregated for a sufficient length at the input of a protected box.

In filter line harnesses with gross shields, it may be necessary to include some individually shielded and jacketed filter lines for purposes of cross talk isolation between lines within the bundle, as shown in the example of Figure 7.

For best results, the shielded and jacketed (S&J) cables with semiconductive jackets should make contact with the gross shield (like “A”). If they are not in contact with the gross shield (like “D”), a transmission line between the cable shield and the gross shield is created, allowing EMI to “bypass” the filtering medium of the filter wire.

- b. Design rule: S&J filter line cables contained within a gross shield should be positioned such that their semiconductive jackets are in electrical contact with the gross shield.

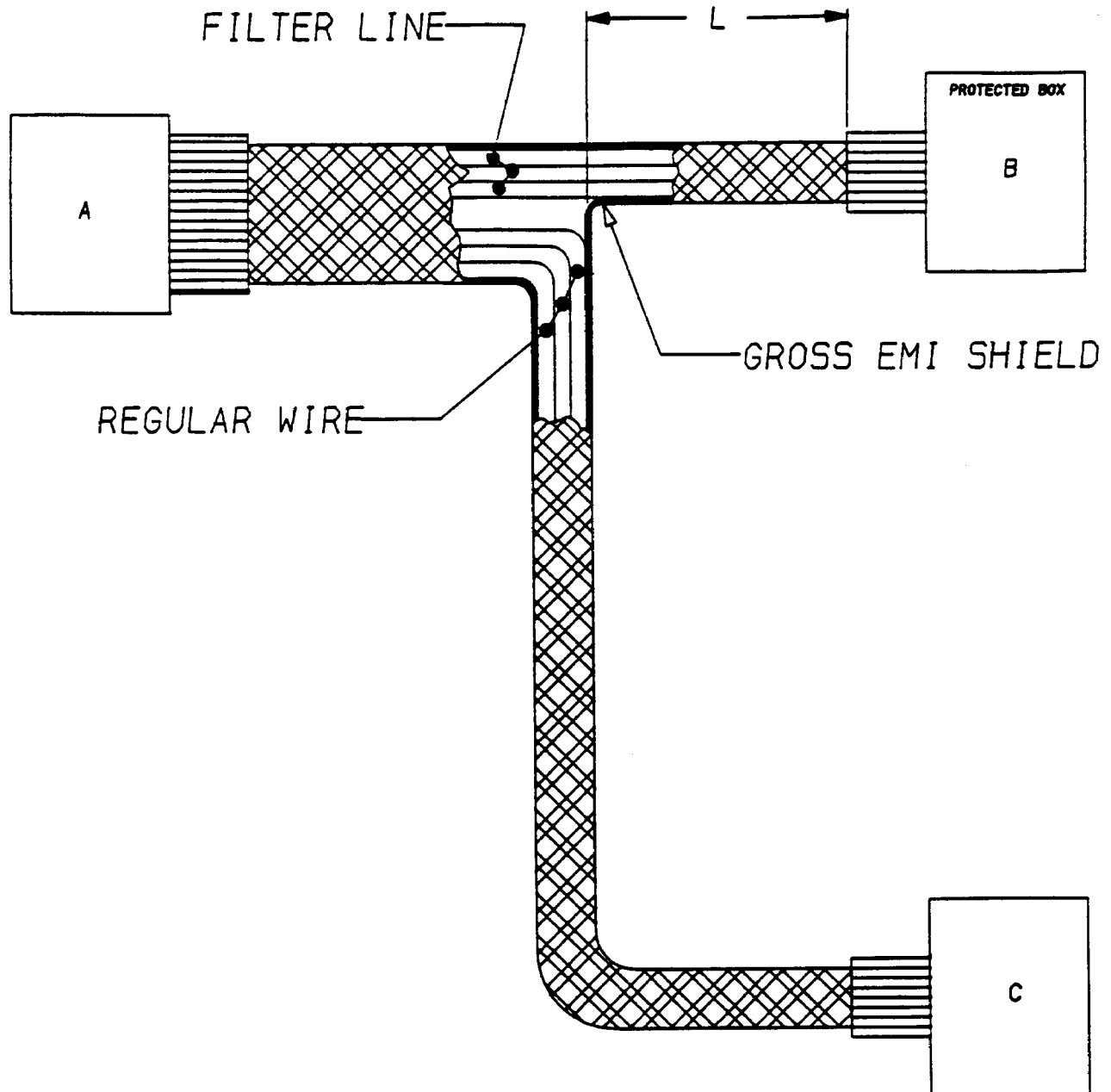


Figure 6 - Standard primary wire mixed with filter line wire in an overall shielded harness connecting multiple black boxes