## Conclusions

It is important that the test engineer be able to quickly and conveniently design and assemble low and high-pass filters over a wide range of cut-off frequencies. The pre-calculated 50-ohm filter designs presented in this article provide a wide selection of designs for virtually any cut-off frequency between 1 and 10 MHz.

By using these designs, the likelihood of calculation error is eliminated, and the filter construction is simplified because each design requires only standard-value capacitors. Although the designs are based on equal 50-ohm terminations in the 1 to 10 MHz range, designs for other termination resistances and other frequency ranges are easily calculated with simple scaling procedures while the advantage of standard-value capacitors is included in the new design.

Because most of the pre-calculated designs have a reflection coefficient less than four percent, the filter terminal impedance is relatively constant across the passband. This means that the lowpass and highpass filters can be cascaded to achieve a bandpass response with no difficulty as long as the passband is not less than one octave wide.

The design procedures discussed in this article should be useful to those responsible for performing TEMPEST testing, or for designing and constructing filters. Any comments, suggestions, or criticisms will be appreciated, and they should be addressed to the author, Ed Wetherhold, Honeywell Inc., POB 391, Annapolis, MD 21404.

**References**

1. E. Wetherhold, "Selected Chebyshev Filters for Narrowband Non-tunable TEMPEST Testing," *Interference Technology Engineers' Master (ITEM)*, pp. 86-106, 1980.
2. E. Wetherhold, "7-Element 50-ohm Chebyshev Filters Using Standard-Value Capacitors," *R.F. Design*, Vol. 3, No. 2, pp. 26-38, February 1980.
3. E. Wetherhold, "Lowpass Chebshev filters use standard-value capacitors," *Electronics*, Engineer's Notebook, pp. 160-161, June 19, 1980.
4. E. Wetherhold, "Design 7-element lowpass filters using standard-value capacitors," *EDN*, Vol. 28, No. 27, January 7, 1981.
5. R. Saal, *The Design of Filters Using the Catalog of Normalized Lowpass Filters*, Telefunken GmbH, Backnang, Western Germany, 1966.
6. A. Zverev, *Handbook of Filter Synthesis*, John Wiley & Sons, New York, 1967.
7. E. Wetherhold, "Butterworth Lowpass Filters for Broadband Non-Tunable TEMPEST Testing," pp. 112-126, *ITEM* 1979.
8. E. Wetherhold, "Component Selection and Test Procedures for LC Filters," Home Study Course 71, *Measurements and Control*, Pittsburgh, PA, October 1978.
9. P. Geffe, *Simplified Modern Filter Design*, John F. Rider, New York, 1964.
10. E. Wetherhold, "A Narrowband Non-tunable Detection System for TEMPEST Testing," pp. 68-71, *ITEM* 1975.

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# LOSSYLINE FLEXIBLE FILTER WIRE AND CABLE

## INTRODUCTION

*LOSSYLINE* cable is a single conductor flexible wire which possesses the properties of a magnetically and electrically shielded low-pass line filter in its ability to remove electromagnetic interference. The *LOSSYLINE* wire or cable solves a number of problems in interference filtering. These include leakage and coupling through shielding, avoidance of standing waves in long lines, suppression of transient spikes and ringing, and effective EMI filtering and suppression above 10 MHz.

The evolution of the *LOSSYLINE* cable occurred in two stages. The first stage was the development of a short, rigid element possessing the desired characteristics of a low-pass, high-frequency dissipative/absorptive lossy electromagnetic unit. The second stage of evolution was to incorporate these filtering principles and characteristics into single conductor type wire and cable.

## APPLICATIONS

Many existing devices which are subject to electromagnetic interference could be retrofitted with filters. However, the cost of such retrofitting is usually high, or else there is no available space for a conventional filter box. A less expensive, space-saving approach is to replace existing wiring with *LOSSYLINE* interference dissipative wire or cable. A cost reduction is effected because of the ease of installation of the cable.

Conventional wiring, though possessing state-of-the-art shielding, will pick up some radiated interference. For this reason, filters usually are placed in close proximity to the system components to be protected, and may be required at both ends. With filters, there still may be a problem of leakage or radiation of high frequencies from the conductor to other conductors. Shielding may prove unreliable or impractical. Replacement of the conductor with *LOSSYLINE* is a solution.

Leakage or pick-up by conductors may be prohibitive when they span considerable distances. It may not be practical or feasible to install sufficient filters along a great length. The use of *LOSSYLINE* cable may be the answer. It is flexible and also will provide magnetic dissipative isolation.

*LOSSYLINE* filters dissipate waveforms in proportion to their rise time. This provides the opportunity to remove individual spikes which might pass through a simple rejective filter and ring between reflective points. Shields may provide current paths through planes of contact between dissimilar metals or through minute perforations. The RF dissipative approach is a neater more direct solution.

Long conductors with and without filters possess inductive and capacitive reactance which requires matching for the passage of alternating current. Excessive standing wave voltages may appear along their length. Since it provides small reactance in the pass-band, and dissipation for higher frequencies, the RF dissipative approach provides a solution to the matching and standing wave problems.

With the greater use of frequencies above 10 MHz, the fall-off of attenuation with an increase of frequency cannot be disregarded. A purely dissipative filter, providing no leakage path as the wavelength becomes shorter is particularly helpful in the microwave region.

## GENERAL DESCRIPTION

The *LOSSYLINE* wire or cable is a flexible, single-conductor radio-frequency dissipative filter, comprising the following elements: (Ref. Figure 1)

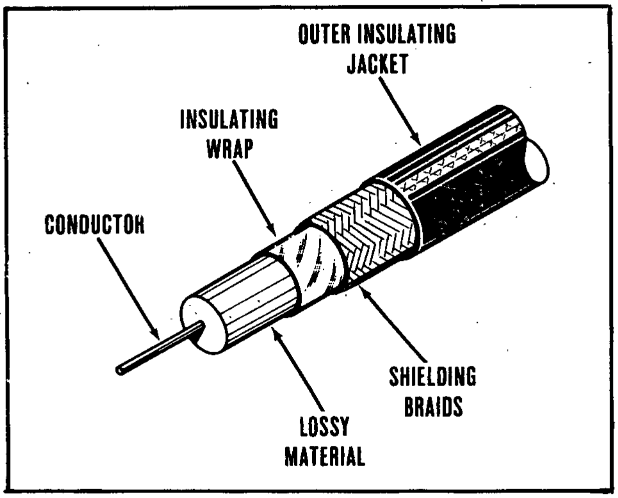


**Fig. 1 Basic Construction Features of Single Conductor *LOSSYLINE* Cable**

1. Low-Loss Conductor
   The low-loss pass-band conductor conforms to Specification MIL-W-3861. It may be solid or stranded. It may be straight, located at the longitudinal axis, or helical, concentric with the longitudinal axis. A helical conductor is completely embedded in a cylindrical extrusion of lossy material, then insulated and shielded. The helical conductor usually is provided in small wire diameters.
2. High-Loss Conductor
   The high-loss conductor is a radio-frequency dissipative/absorptive conductive solid dielectric, loaded with lossy pigments and compounds making conductive conductive contact with the low-pass conductor. The dielectric material consists of a flexible vulcanizable material.
3. Dielectric Insulating Wrap
   The dielectric is a thin layer, insulating the high-loss conductor from the shield of the cable. It consists of the electric grade of at least one of the following:

   polyester
   polyolefin
   teflon
   mica-seal
4. Shield
   The shield is braided or solid tubular bendable.

   Braided Shields
   Strands are interwoven and without splices. The braid is applied without breaks or discontinuities and conforms tightly to the dielectric insulating layer. The following types are employed:

   Single braid, #32-#38 tinned copper, 90% minimum coverage

   Single braid, #32-#38 silver plated copper, 93% minimum coverage

   Double braid, #32-#38 tinned copper, 98% minimum coverage

   Double braid, #32-#38 silver plated copper, 98% minimum coverage

   Tubular Solid Metal Shields
   The tubular shield is bendable, and conforms tightly to the dielectric insulating layer. It may be brass, copper or other metal, tinned or plated as specified.
5. Moisture Seal and Jacket
   The moisture seal and jacket conforms tightly to the shield.

## DESIGN INFORMATION

Specific design information can be obtained by contacting the author. Attenuation curves are shown below in Figures 2 and 3 for typical straight conductor and helix wound conductor *LOSSYLINE* cable.

**Typical Attenuation Curves**

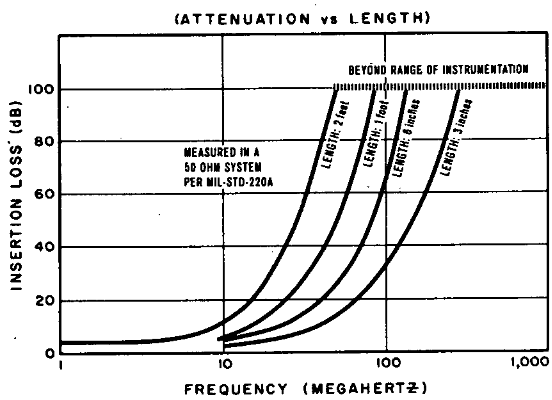


**FIGURE 2. HELIX WOUND CONDUCTOR**

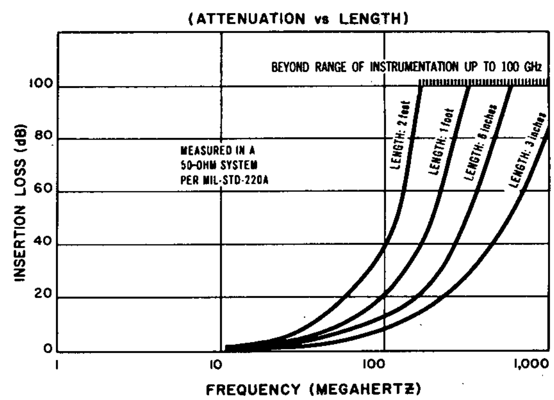


**FIGURE 3. STRAIGHT CONDUCTOR**

**Note: Attenuation characteristics vary slightly with different voltage ratings and shielding.**

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