UNDERSTANDING AND APPLYING SHIELDING SPECIFICATIONS FOR WIRE AND CABLE

When attempting to select or design a shielded cable the cable specifier or cable designer is often met with a confusing array of contradicting or almost unintelligible specifications. Should the cable meet VDE specs, FCC docket 20780, TEMPEST, or MIL-STD-461B? Some of these requirements may be overkill for the type of application that is envisioned for the particular cable. However, economies of stocking and ordering may well dictate the use of an overspecified cable in some applications, or a cable that will meet more than one set of specifications.

This article shows how the various specifications for shielding relate to one another and how they may be interpreted in terms of certain sample type cables. The first section of this article shows a correlation between the basic specifications that are available today for shielding of cables. The second section will deal with how design and measurements made for one specification may be correlated to those taken for another specification—for example, how field strength relates to field intensity and transfer impedance.

Comparison of Various Shielding Specifications

All cable shielding specifications are measurements of how well a shield applied over a given cable will isolate that cable from the environment. Whether the specification is written to determine how much the signal in a cable will affect the environment around it, or how much the noise signals in the surrounding environment will affect signals in the cable, is of very small consequence to the construction of a proper shield. The entire frequency range of all the specifications that we will consider will be examined.

Listed below are the frequency ranges applicable to each of the various specifications that we shall study (see Figure 1 for details). As one may see from Figure 1, shielding specifications cover nearly the entire radio frequency spectrum. There is a considerable overlap with these specifications. For example, the frequency band of FCC Docket 20780 is also covered by VDE and MIL-STD-461B. Nearly all shielding specifications include both specifications for radiated emissions and susceptibility as well as conducted emissions and susceptibility. These conducted emissions are noise or interference signals which are propagated down the power line from the unit to the local in-house power lines, or from the power lines into the unit. These conducted emissions will not be covered. For the purpose of this article, we will make the following definitions:

1. Electromagnetic compatibility (EMC) is the ability of an electronic system or subsystem (cable) to viably operate in its intended electromagnetic environment without either responding to electrical noise or generating unwanted electrical noise.
2. Electromagnetic interference (EMI) is the impairment of the performance of an electronic system or subsystem (cable) by an unwanted electromagnetic disturbance.

Most of the specifications that we will be dealing with are only concerned with EMI, whereby the cable may be an EMI emitter. However, in some cases, such as MIL-STD-461B, this specification is concerned with both electromagnetic interference emitted by the cable and the electromagnetic susceptibility of the cable to outside interference.

Specification		Frequency Range
FCC Docket	20780	
	Class A	30 mHz-1 GHz
	Class B	30 mHz-1 GHz
TEMPEST		
	Black	1 kHz-1 GHz
	Red	1 kHz-1 GHz
VDE/DIN	0871/6.78	10 kHz-18 GHz
	0875/6.77	150 kHz-300 mHz
CISPR		10 kHz-1 GHz
MIL-STD-461B	RE 01	0.02-50 kHz
	RE 02	14 kHz-10 GHz
	RS 01	0.02-50 kHz
	RS 03	14 kHz-40 GHz
MDS-201-004		200 kHz-1 GHz

Figure 1. Frequency Ranges of Various Shielding Specifications (Radiated Emissions).

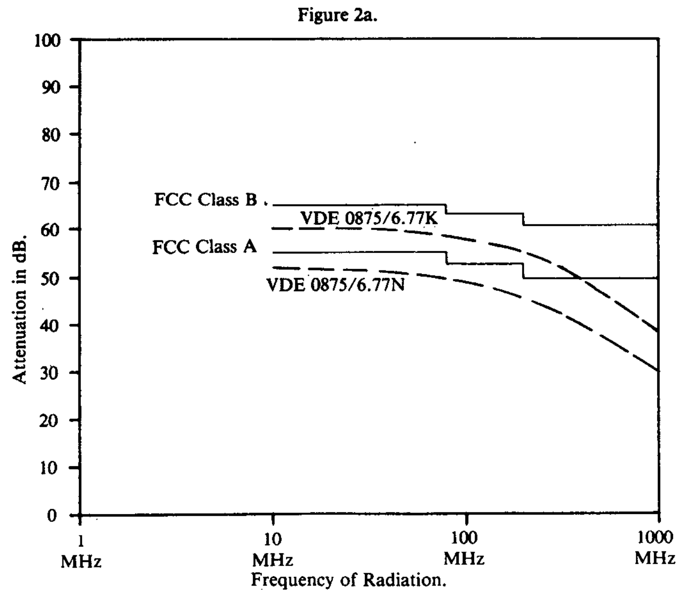
FCC Docket 20780 is concerned with computing devices and is broken into two separate parts, Class A and Class B. A Class A computing device is defined as a computing device that is marketed for use in a commercial, industrial or business environment, excluding devices which are marketed for use by the general public or which are intended to be used in the home.

A Class B computing device is defined as a computing device that is marketed for use in a residential environment, not withstanding use in a commercial, industrial or business environment. Examples of such devices include, but are not limited to, electronic games, personal computers, and calculators.

These computing devices are defined as any electronic device or system that generates and uses timing signals or pulses at a rate in excess of 10,000 pulses or cycles per second, and uses digital techniques or any device or system that generates and utilizes RF energy for the purpose of performing data processing functions, such as electronic computations, operations transformations, recording, filing, sorting, storage, retrieval or transfer. Radio transmitters, receivers, ESM equipment or any other RF devices which are specifically subject to an emination requirement elsewhere in Chapter 15 of the FCC requirements are excluded from this definition.

The FCC recognized the fact that a Class B device may be used in an area where there are many commercially manufactured items, such as television sets, which are susceptible to the emitted radiations from this device. With this in mind, they have set regulations of Class B computing devices which are stricter than those regulations on Class A computing devices.

The radiation limits specified by the FCC under Docket 20780 are intended to be tested in an open field, a test site which is in an area of quiet radio frequency energy.



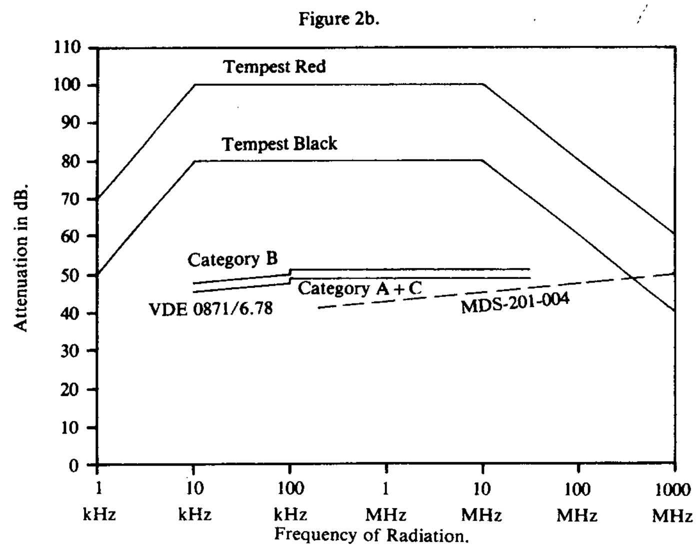


Figure 2. Specification Limits for Shielding Effectiveness (assumed is a TTL signal and a power dissipation in the cable of 25 × 10-3 watts).

To further complicate the situation with the FCC Docket, the two types, Class A and Class B, are intended to be tested at different distances. The Class A computing device radiation is specified at a distance of 30 meters from the radiating item. The radiation is specified in field strength of microvolts per meter. Class B computing devices are measured at a distance of 3 meters from the radiating device and the radiation is likewise measured as a field strength in microvolts per meter. Thus, correlating between Class A and Class B devices requires some thought and some calculation. Essentially, the measurements that are taken are made by a spectrum analyzer receiver that is set up with a dipole antenna of a specified size at the distance required in the specification. The equipment is operated normally to its limits and readings are made of the signals received at the antenna. If these signals exceed those specified in Docket 20780, the equipment is rejected (see Figure 2a).

TEMPEST is an activity developed over recent years concerned with the measurement and control of unintended compromising electromagnetic radiation.For purposes of specification and measurement, TEMPEST is divided into two color classifications defined as follows:

1. Black wire lines, components and systems handling unclassified signals and areas with no classified signals. Also considered black are encrypted classified signals.
2. Red spaces within limited exclusion areas carrying power lines and signals with classified plain language information.

Measurement for TEMPEST activities are concerned with determining the reduction in signal levels due to shielding, and not, as in the case of the FCC Docket 20780, measurement of absolute field strength (see Figure 2b).

The VDE (Verband Deutscher Electrotechniker) association of German Electrical Engineers has two standards, VDE 0871/6.78 and 0875/6.77, which are in close agreement with recommendations of the International Special Committee on Radio Interference (CISPR). Hence, only the VDE specifications will be addressed here. Under VDE 0871/6.78 there are three sets of classifications: Classes A, B, and C. The VDE classes A, B, & C specifications are predicted upon an interference amplitude of dBμV. However, the category C equipment listed under VDE is not applicable to mass produced equipment of the type normally dealt with, since it requires an emission test at each installation site. Therefore, only the VDE classes A and B will be dealt with here. VDE is a much stiffer specification than the FCC spec VDE 0875/6.77 (covering Unintentional R.F. generators, such as equipment for household use). The VDE specification has three letter-designated limits on radiation:

N—normal limit;
G—coarse limit applicable for industrial areas; and
K—small limit applicable for remote areas or radio receiver installations

Interference levels are measured in dBμV with an antenna at a distance of 10 meters from the radiation source.

MIL-STD-461B is broken into several parts. Part 1 defines the scope and general requirements of the standard. Part 2 covers equipment and subsystems installed aboard aircraft, including associated ground support systems. Part 3 addresses equipment and subsystems installed aboard space craft and launch vehicles, including associated ground support equipment (Class A-2). Part 4 discusses equipment and subsystems in ground facilities fixed in mobile including track and wheel vehicles (Class A-3). Part 5 explains equipment and subsystems installed in surface ships (Class A-4). Part 6 describes equipment and subsystems installed in surface ships (Class A-4). Part 7 covers support equipment and subsystems installed in non-critical ground areas (Class-B).

Of the specifications that we have dealt with so far, MIL-STD-461B is the only specification that deals with both radiated emissions and susceptibility to radiation. Specifications are broken down by narrow band emissions and broad band emissions and are measured in db microvolts for the narrow band emissions and db microvolts per megahertz for the broad band emissions. The susceptibility is measured as a susceptibility to a certain electrical field in volts per meter at the anticipated location of the subsystem equipment. MIL-STD-461B is meant to cover the gamut of cables or equipment operating in military or space environment, and is generally not applied to commercial equipment.

Figure 3. Specification Limits Emitted Radiations (dBμV). All figures are reduced to 30 meters measuring distance, assumed to a TTL signal, and a power dissipation in the cable of 25×10^{-3} watts).

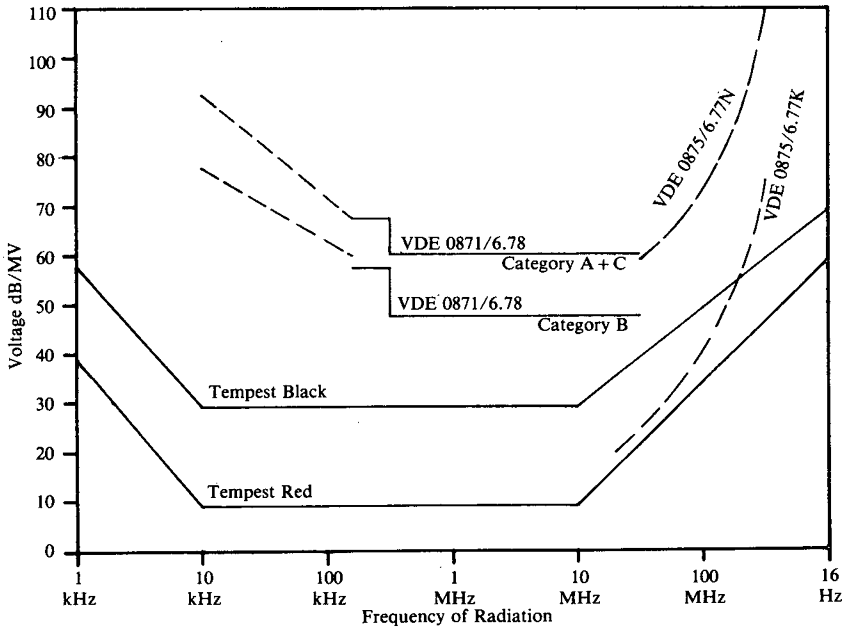


Figure 3a.

We will deal with four of the basic requirements for MIL-STD-461B—RE-01 and RE-02 for radiated emissions, and RS-01 and RS-03 for susceptibility to radiation. Once again, measurements are mostly antenna-driven. Finally we will concern ourselves briefly with MDS-201-004, entitled, "Electromagnetic Compatibility Standard for Medical Devices," which is the EMC standard for the FDA. The primary purpose of this standard is to establish a reasonable level of assurance that medical devices will operate safely and effectively in the expected electromagnetic environments. This specification also covers the areas of electromagnetic emission as well as susceptibility.

In order that a comparison of these shielding specifications may be meaningful, a method of comparing them must be deduced. A plot of specification limits for shielding effectiveness will serve as a graphic example of a specifications comparison. Plots of emitted radiation for each of the specifications discussed are also presented in Figures 3a and 3b. The charts show that there is indeed correlation between the various specifications for shielding, and allow the opportunity to decide how much more shielding or how many specifications any one cable can reasonably meet without becoming prohibitively expensive.

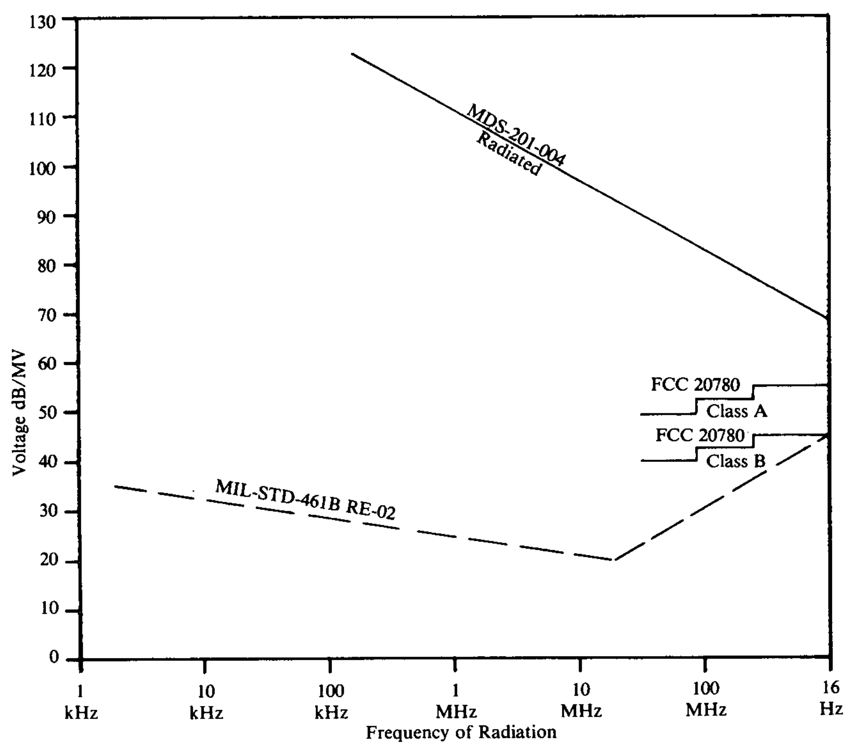


Figure 3b.

Shielding Specification Correlations

This section will examine shielding effectiveness of four sample cables. Those cables will be: a 25/conductor RS232 type with a foil shield; a 25/conductor cable with a foil shield which has the folds internally shorted; a 25/conductor cable which has an internally shorted foil shield and overall 95% braid shield; and, finally; a 25 conductor cable which has a foil shield plus 2 95% braid shields. The braid shields are at a 45° braid angle with a 36 AWG braid. Shielding efficiency will be measured in the following ways:

- as a reduction in emissions or susceptibility in db, as well as the transfer impedance of the shields; and
- as the radiation emitted from these sample cables under assumed input usage levels.

The power consumption in the cable may easily be calculated from Ohms' E = IR.

$E = 30$ volts

$$R = (14.74 \text{ Ohms}/1000') \frac{30 \text{ ft}}{1000 \text{ ft}} = 0.44 \text{ Ohms}$$

The total voltage drop in the cable, assuming each wire subject to an average of 3 TTL unit loads of 16 ma each (TTL low) or a total of 48 milliamperes per leg, is given by

Voltage drop = .048 AMP × .44 Ohms = 0.021 volts

Therefore the power consumption for each line is

$P_S = 0.021\text{V} \times .048 \text{ A} = .001$ Watts

For the total 25 lines, the power consumed in the cable is .025 watts ($= 25 \times 10^{-3}$ watts). For the worst case condition, we must assume the entire energy loss is able to be radiated from the cable and must be shielded.

Basic shielding effectiveness of the four cable types is plotted in Figure 4. See Figure 5 for a graphic description of the four cables.

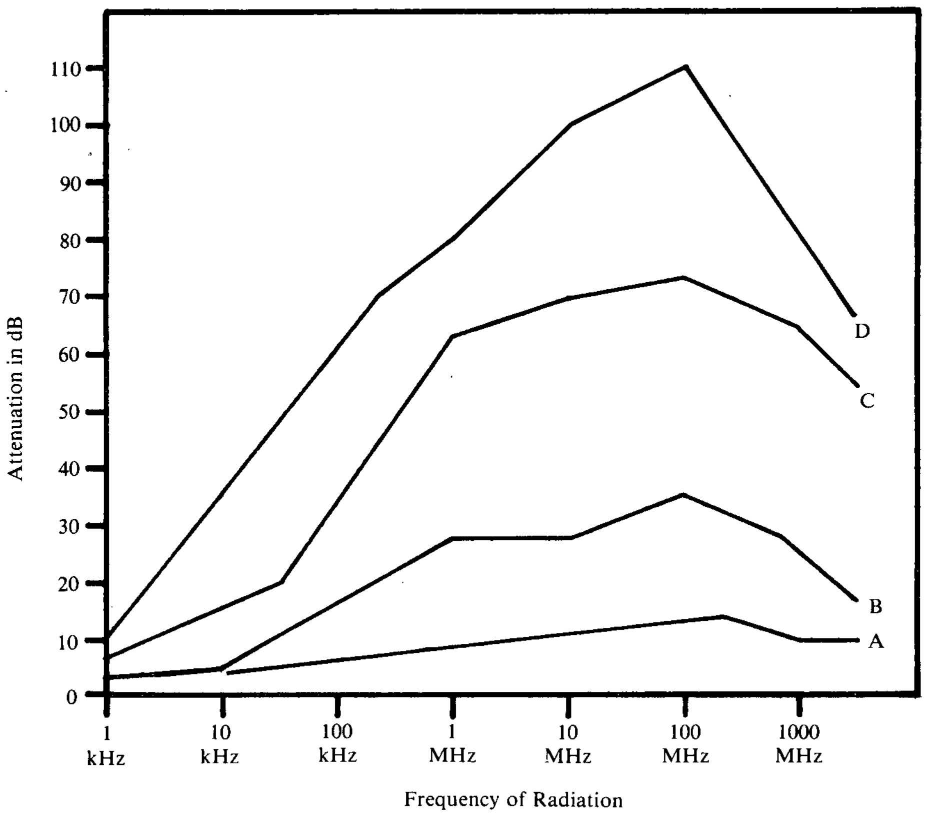


Figure 4. Cable Shielding Effectiveness. The curves are as follows: A. Aluminum/Polyester shield. B. Aluminum/Polyester shield with shorting fold C. Alumnium/Polyester shield with shorting fold and 95% braid shield D. Aluminum/Polyester shield with shorting fold and 2-95% braid shield (one in-one out).

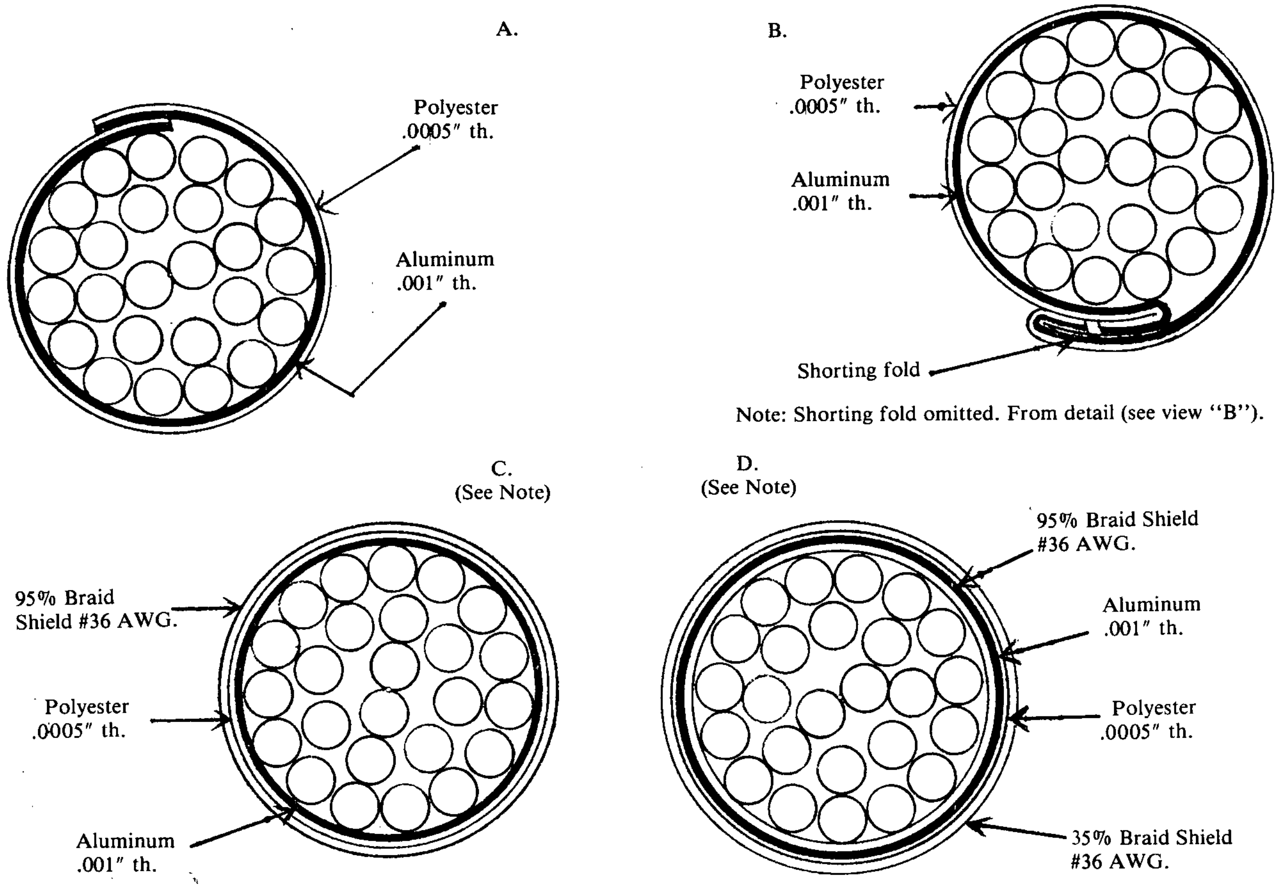


Figure 5. Cable Types. 25C #24 AWG. (7×32) tinned; copper—.010″ PVC insulation.

Figure 6 shows the transfer impedance for these same cables. Transfer impedance is defined as follows: If a current is caused to flow along the shield (the word "shield" as used in the definition includes all conducting layers where more than one exists) of a cable, with its return path outside that cable, then the longitudinal voltage along an incremental length which results on the inside surface of the shield is related to that current by the surface transfer impedance, and has units of impedance per unit length. The curves indicate that as the transfer impedance increases (at frequencies above 1 mHz), shielding effectiveness decreases. This dramatically illustrates that the lower the surface impedance at the point of contact between the cable and the backshell and backshell to connector the better the shielding.

In order to determine whether a certain shield will allow a cable to meet the required specification, the following must be considered:

1. A radiation level of .025 watts represents 109 dB/μV/M at a distance of 3 meters.
2. The radiation field intensity would be 0.289V/M for the same signal.

One can, therefore, calculate from the figures whether the shielding envisioned for a cable is proper for the application. Caution must be exercised, however, since these charts are based upon specific braid shields.

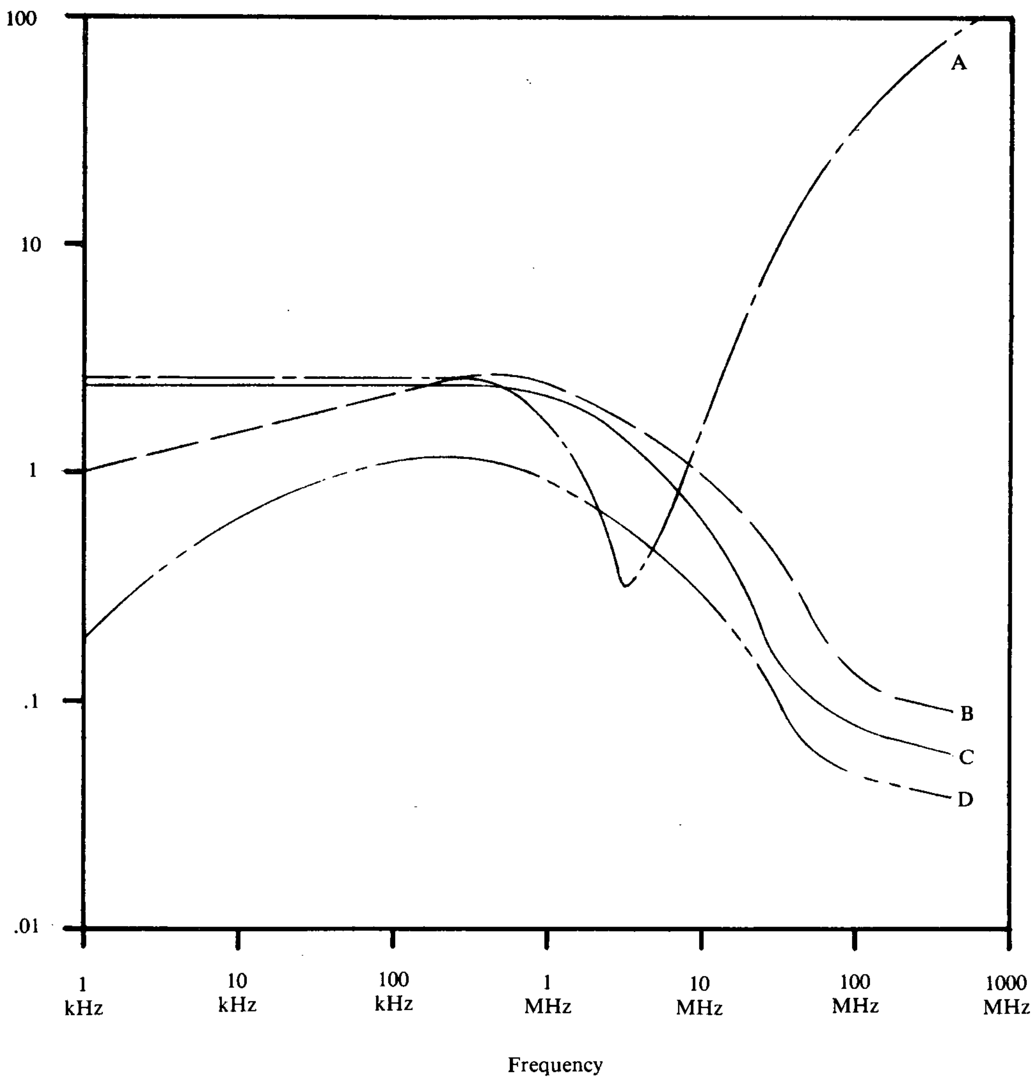


Figure 6. Surface Transfer Impedance.

For most cables in general use the four types of shielding discussed (or some variation on these types) will usually suffice. However should these shields not be sufficient, additional shielding may be determined based on the following:

- The best shield is one which is thick, solid, has high conductivity and permeability.
- Second best is braided cable shield.
- Poorest is a spiral-wrapped shield.
- When using well-shielded cables, it is also important to use well-shielded cable connectors. This means that the backshell of the connector should make good peripheral contact with both the cable shield and with the box or other connector to which it is attached.

Although many shielding specifications differ in their presentation, common ground can be found. Parallels may be drawn between TEMPEST, MIL-STD-461B, FCC 20780 VDE and MDS-201-004 specifications. Transfer impedance, shielding effectiveness and field strength all relate to the one basic requirement of making a cable an effective radiation barrier, able to meet the required specification.

This article was written for ITEM by Darrell Fernald, Mercury Wire Products, Inc., Spencer, MA.