IMPLEMENTATION OF IEC 61196-1
SHIELDED SCREENING ATTENUATION TEST METHOD

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ABSTRACT

The physical design and electrical characteristics of coaxial cable screening attenuation (shield effectiveness) test fixtures, which meet the guidelines of IEC 61196-1[1] , are presented. Two test fixtures are considered: one for large diameter cable (for example RG-6 type CATV cable) with an upper frequency limit greater than 2 GHz and another for smaller diameter cable with an upper frequency limit greater than 4 GHz. The test procedure is reviewed. Advantages and limitations are discussed. Screening attenuation performance results for a selection of coaxial cable are presented.

INTRODUCTION

This paper describes a practical test fixture that has been developed for the measurement of shielded screening attenuation (also known as shield effectiveness) of coaxial cable. The theoretical basis of the fixture is contained in the draft Amendment 1[1] to International Electrotechnical Commission (IEC) Standard 61196-1 and the original German development publications[2].

A number of test methods and devices have been developed and used by industry to characterize the shielding performance of shielded cables in the RF and microwave bands. Among these are found the absorbing clamp, various shield effectiveness test fixtures, surface transfer impedance test fixtures, the mode stirred chamber, the TEM cell, and the open field antenna site. The shielded screening attenuation test is a new addition to this wealth of test methods.

The fixture uses commercially available transmission line hardware, is low in cost, and is easily assembled for utilization in a general laboratory or production environment.

TEST FIXTURE DESIGN

The test fixture housing is a metallic cylinder that forms a triaxial test configuration with the cable sample shield and center conductor. A breakdown drawing of the fixture showing dielectric supports and cable under test is shown in Figure 1.

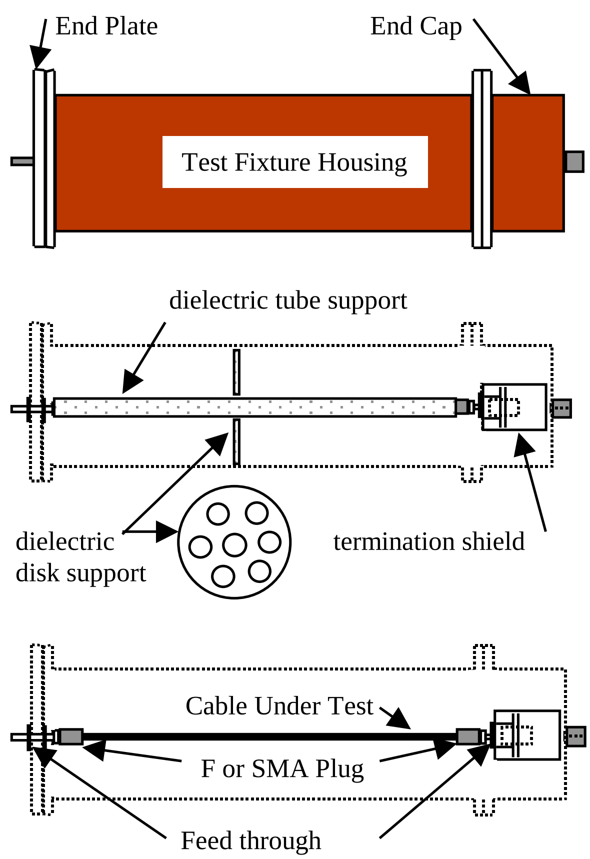


Figure 1. Test Fixture Construction Details

The test fixture housing is one or more sections of standard 50Ω rigid transmission line outer conductor fitted with coupling flanges at each end. Fixtures were constructed with 38.7mm and 76.5mm diameter lines. The 38.7mm fixture was 1.5m long and the 76.5 mm fixture was made in 1.5m, 3m and 6.7m lengths using cascaded sections.
The 38.7mm fixture was fitted with 50Ω SMA type feed-throughs and terminating resistive load. The 76.5mm fixture was fitted with 75Ω F type feed-throughs and terminating resistive load.

An end plate closes the housing at one end, and an end cap encloses the other. A feed-through connector is mounted in the center of the end plate. The end cap is fitted with a 50-ohm type N feed-through connector. The center pin of the N feed-through connects into one end of an anchor connector. The sample termination shield consists of a split anchor connector that is mated to the end cap anchor connector. One side of the split anchor connector is fitted with a feed-through connector, and the mated pair encloses and shields the cable sample termination. This arrangement provides for terminating the cable sample under test with a shielded resistive load and for connecting the shield to the center pin of the N feed-through.

The cable sample under test is fitted with a plug type connector at each end and is connected between the feed-through connectors respectively located in the end plate and the split anchor connector. The cable sample under test is centered by PTFE dielectric tube and disk supports.

Electrical Characteristics

The test fixture is electrically composed of two regions: the test chamber, which is located between the cylindrical housing and the cable sample shield, and the cable sample.

Test chamber. The test chamber portion is viewed as a transmission line with center conductor (the cable sample shield) short circuited to the end plate at one end. At the other end is the 50Ω N feed-through connector. The chamber electrical characteristics depend on length, diameter, dielectric, and cable under test.

Table 1 gives the chamber cut-off frequency, nominal impedance, and percent velocity (%VP) characteristics for three cables that were tested in the fixtures. The cut-off frequency is the upper test frequency limit and is a function of the housing diameter, cable shield diameter, and chamber dielectric material. The nominal impedance is also a function of housing and cable shield diameters, the effective dielectric constant of the cable jacket, and PTFE support material.

Table 1.
Test Chamber Electrical Characteristics

Cable #	F_C - GHz	Z_o - Ohms	% VP
2	2.1	149	91
8	4.1	132	92
9	4.3	138	96

Figure 2 presents the chamber return loss (cable 2) measured at the end cap N connector of the 1.5m long 76.5mm diameter fixture. The theoretical cutoff frequency is about 2.1 GHz.

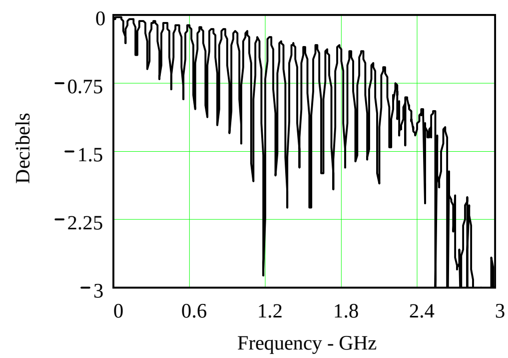


Figure 2. 76.5 mm chamber return loss.

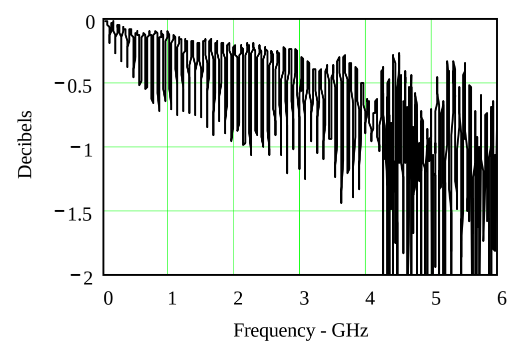


Figure 3. 38.7 mm chamber return loss.

A higher upper frequency limit is obtained with the smaller diameter fixture. Figure 3 presents the chamber return loss (cable 9) for the 1.5m long 38.7mm diameter fixture. The theoretical cutoff frequency is 4.3 GHz.

The input impedance to the chamber consists of resonant peaks corresponding to length and %VP, which are difficult to measure with a network analyzer. Figure 4 shows one such peak reaching an amplitude of some 50,000Ω. An equivalent frequency resolution of 5 kHz was required to properly capture the peak.

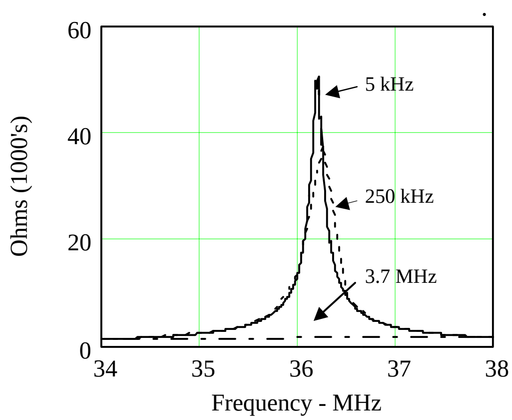


Figure 4. Chamber input impedance resonance peak variation with frequency resolution

The cable sample jacket is part of the dielectric material present in the test chamber. Figure 5 indicates that at least to a frequency of 3 GHz the PVC jacket material causes less than one decibel loss.

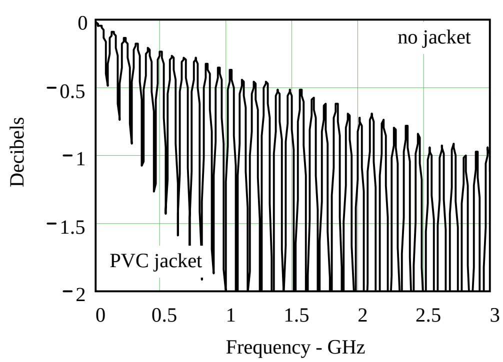


Figure 5. 38.7 mm chamber return loss effect of PVC jacket.

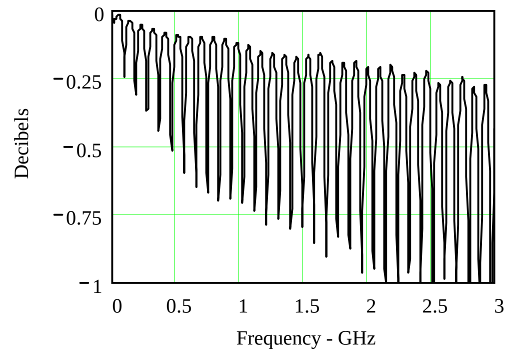


Figure 6. 38.7 mm chamber return loss. Effect of dielectric support.

Another factor in the test chamber is the dielectric tube and disk PTFE support material. Figure 6 compares chamber return loss for cable 9 measured with one disk support versus two disks and tube support. There is minimal amplitude change due to the low loss nature of PTFE, but the phase and hence the %VP is significantly affected. With only two disks (dotted line plot) the %VP is about 99%. Addition of the tube (solid line plot) reduces the %VP to about 96 % at 1.5 GHz.

The test chamber diameter ratio determines the upper frequency test limit, and the length of the cable sample determines the lower frequency limit. The sensitivity of the test method is limited by contact resistance where the cable sample shield forms a short circuit with the cylindrical test fixture end plate and by leakage from the cable sample termination, which is located within the fixture test chamber. These factors have been minimized to achieve a measurement capability greater than 140dB over the 1-3000 MHz frequency range.

Cable sample. The cable sample portion is a transmission line terminated in a resistive load closely matching its characteristic impedance.

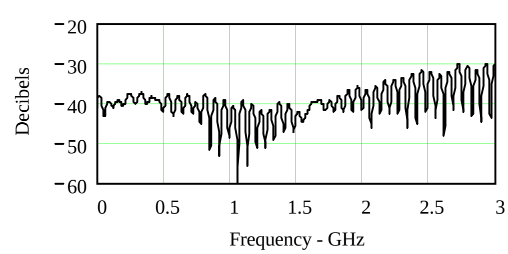


Figure 7. Cable sample return loss.

The cable sample return loss (cable 9) measured as installed in the test fixture housing is given in Figure 7. The results include the effect of end plate and anchor connector feed-throughs, the resistive load, and the cable itself.

Figures 8 and 9 give the magnitude and phase of the sample input impedance measured at the end plate feed-through. Impedance amplitude and phase of the resistive termination are also plotted. Small impedance mismatches in the connection hardware and the cable cause the ringing in Figures 8 and 9.

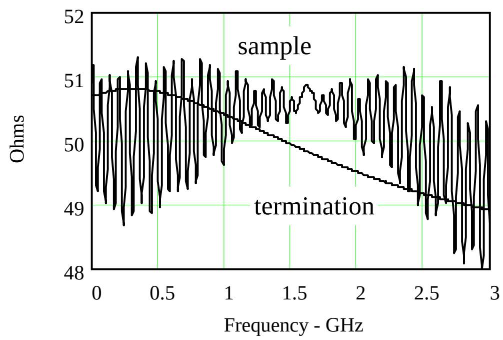


Figure 8. Cable sample input impedance magnitude.

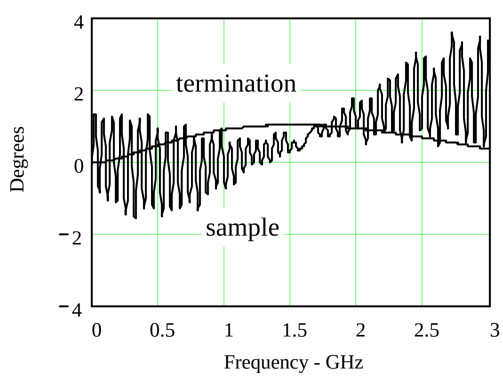


Figure 9. Cable sample input impedance phase angle.

TEST PROCEDURE

The shielded screening attenuation test is closely related to the absorbing clamp test. With both of these methods, the sample under test is energized and a signal which is proportional to the resulting leakage field is measured. However, with the shielded screening attenuation method, the leakage field is contained or shielded within a cylindrical metallic tube. Screening attenuation is derived from the difference in power levels (insertion loss) between the end plate (energized sample) and the end cap (chamber).

The equipment setup is given in Figure 10, and the equipment is listed in table 2. Normally, the sample under test is powered, and leakage is measured from the chamber. However, due to reciprocity, the direction of power flow may be reversed and practically the same insertion loss is measured. This is useful when the resistive termination is limited to a low power rating.

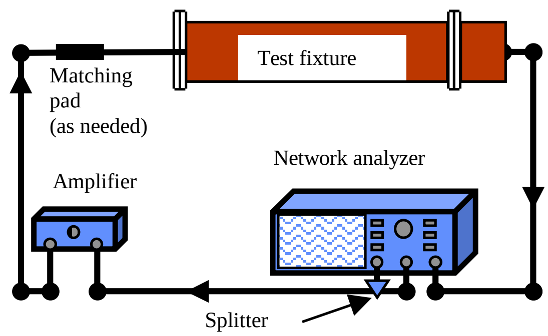


Figure 10. Test Equipment Setup

Table 2.
Screening Attenuation Measurement
Test Equipment

Network Analyzer: HP8753B, +10dBm output, 10 Hz res. bandwidth HP 8510B
Power Splitter: HP11850C, 9.5 dB loss nominal, DC-3 GHz
Matching pad: HP11852B, 5.7dB loss nominal, DC-2 GHz, 50Ω-75Ω, type N connectors
Power Amplifier: HP8347A, 25 dB gain nominal, 100 kHz-3 GHz HP8447D, 27 dB gain nominal, 100 kHz-1.3 GHz
Resistive Termination in Anchor Connector: 75Ω type F for CATV fixture 50Ω SMA for microwave fixture

DESCRIPTION OF SAMPLES TESTED

Several constructions of RG-6 type and RG-59 type 75 ohm coaxial cable[3] were tested in the 76.5mm fixture and are designated 1-6. (1 is RG-59 type and 2-6 are RG-6 type cables). Smaller 50 ohm samples were tested in the 38.7mm fixture and are designated 7-9. (7 is RG 58 type, 8 is RG-223, and 9 is RG-402 type cable) The construction details for the samples are shown in Tables 3 and 4.

Table 3.
Test Sample Construction

#	Foil (inner)	Braid / Angle	Foil	Braid/Angle (outer)
1		95% b. c. /23°		
2	a	40% Al /38°		
3	a	60% Al 27°		
4	a	80% Al /27°	b	
5	a	95% Al /42°	b	
6	a	60% Al /27°	a	40% Al /20°
7		95% t. c. /23°		
8		95% Ag-Cu /28°		95% Ag-Cu /40°
9	.0122mm polyester/ .0178 mm Cu	92.5% t. c. Tin Dipped 64°		

Table 4.
Aluminum Foil Description

	Layer Thickness (mm)			
Foil Type	Al Foil	Polyester	Al Foil	Width (mm)
a	.00889	.02286	.00889	19.05
b	.0254	.02286		25.4

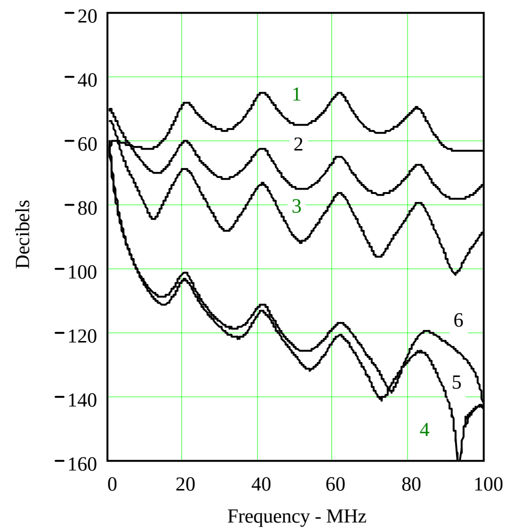


Figure 11. Screening attenuation results 6.7 m fixture.

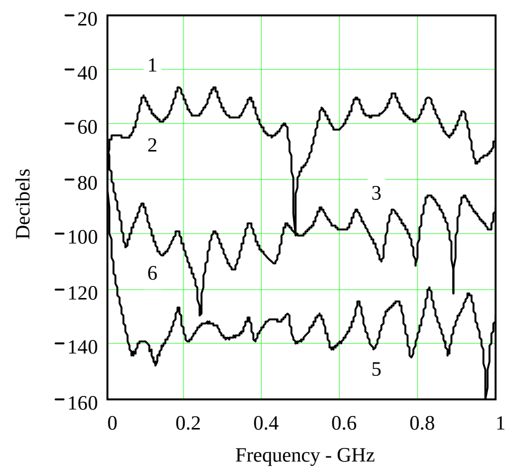


Figure 12. Screening attenuation results 1.5 m fixture.

TEST RESULTS

Cables 1-6 were tested in the 76.5mm fixture with a length of 6.7m. The results are plotted in Figure 11 with an upper frequency of 100 MHz. The first resonance peak in the response is near 20 MHz and subsequent peaks are spaced at about 20 MHz intervals. The screening attenuation is found from an envelope curve (not shown) formed by the peaks. Peak frequencies depend on sample length and %VP.

Figure 12 plots results measured in the 1.5m long 76.5mm fixture. The upper frequency is 1 GHz, and the first peak resonance frequency is about 100 MHz. Note the peaks have not been connected by envelope curves for clarity. The 1.5m fixture is not long enough to resolve screening attenuation below 100 MHz.

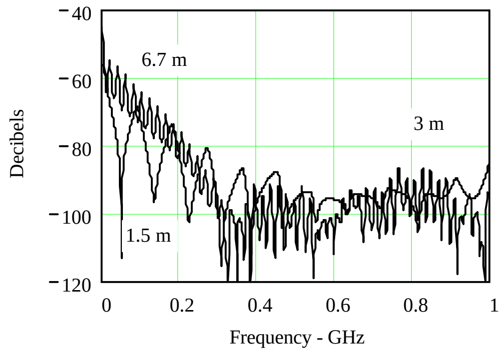


Figure 13. Screening attenuation, cable 2;
76.5 mm fixture, 3 lengths.

Figure 13 plots results for 1.5m, 3m and 6.7m long fixtures. The 6.7m fixture gives better resolution below about 400 MHz. Above 400 MHz the 6.7m and 1.5m fixtures give similar performance. The 3m fixture gives slightly more pessimistic results. This is thought to be due to sample variance.

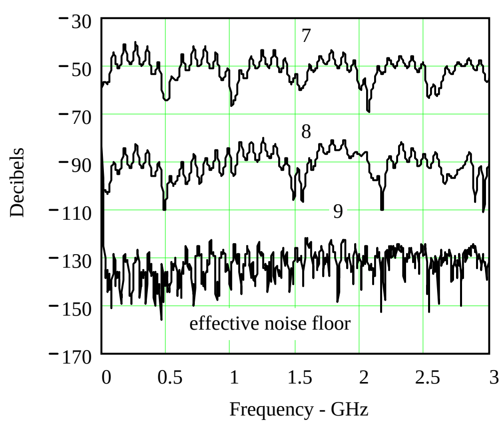


Figure 14. Screening attenuation;
38.7 mm fixture.

Cables 7-9 were tested in the 38.7mm fixture with a length of 1.5m. The results are plotted in Figure 14. The effective noise floor is due to the analyzer noise floor in combination with the amplifier(s) used to increase the measurement range.

CONCLUSION

The new test method has characteristics that make it very attractive. These advantages are however accompanied by certain disadvantages.

Advantages

Low cost: Required hardware can be purchased and assembled for an estimated US$1000.
Results are expressed in decibels.
Covers a wide frequency range (20 MHz - 4 GHz).
Cable and connector can be tested together.
Cable shields with non-metallic outer layers can be tested.
Test is shielded and enclosed: This makes it feasible for general laboratory or even production environments and the possibility of a greater range of shielding effectiveness.
The method is being standardized by the IEC.

Disadvantages

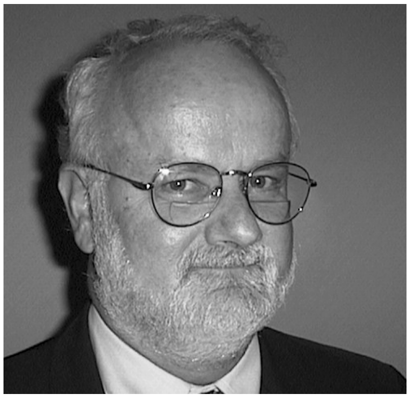
Length of fixture required to cover frequencies as low as 20 MHz.
Some variability may result in interpreting the position of the screening attenuation envelope and assigning values of performance.

References

1. IEC 61196-1 Generic Standard for Coaxial Cable. IEC Committee Draft for Vote: 46A/320/CDV, closing date for voting 6/30/98.

2. Breitenbach, O; Hahner, T; Mund, B: “Screening of Cables in the MHz to GHz Frequency Range Extended Application of a Simple Measuring Method”, ”, IEE Colloquium on Screening Effectiveness Measurements, Savoy Place, London, May 6, 1998.

3. Kincaid, J; Dole, C; “Test Fixture Design and Shielded Screening Attenuation Performance of CATV Coaxial Cable”, IEE Colloquium on Screening Effectiveness Measurements, Savoy Place, London, May 6, 1998.



John Kincaid

John is a Senior Product Engineer at the Belden Engineering Center. He holds BSEE and MSEE degrees from the University of Oklahoma and has over 25 years experience with Belden. His experience encompasses engineering management and product development positions in the USA as well as in Europe. He holds nine patents. John is a member of the IEEE and is active in IEC and TIA cable standardization activities. He is the US Technical Advisor to IEC SC 46A on coaxial cables, and is Convenor of IEC SC 46A/WG3 on data and CATV cable. He is also an expert on working groups 5 and 7 dealing with shielding and premises cabling issues.

Carl Dole

Carl is a Product Engineer and has been with the Belden Engineering Center of Belden Electronics Division since 1990. He currently holds one U.S. patent. His academic achievements include a B.S. degree in Electrical Engineering Technology ("With Highest Distinction") from Purdue University. Prior to joining Belden, Carl worked 10 years in television broadcast engineering. He is a Certified Senior Broadcast Engineer and has a lifetime FCC General Class Radiotelephone License. His areas of responsibility include developing improved electrical test methodologies, writing technical papers, and working on new product development. He is a member of SMPTE, IEEE, and SBE.

John W. Kincaid originally presented this paper on November 19, 1998 at IWCS 1998, Philadelphia, PA, USA.