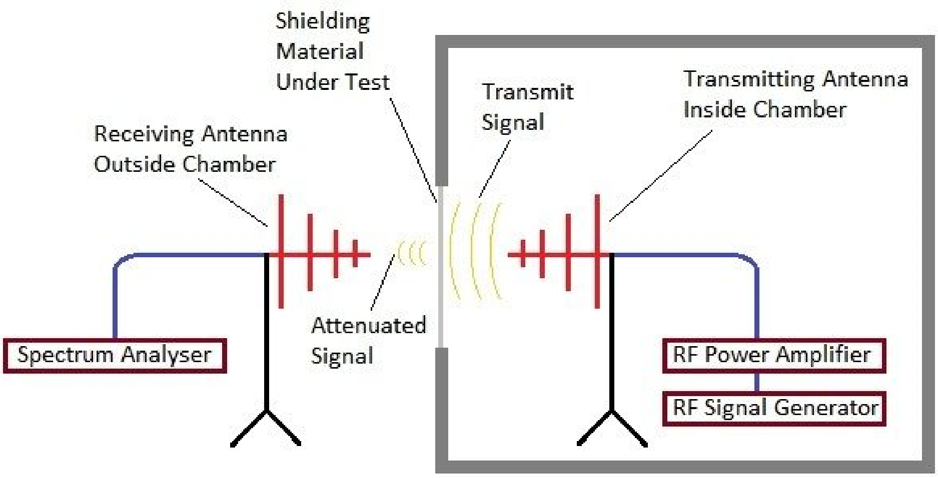
Shielding Effectiveness test Set-Up Guide.

The remainder of this page will address the shielding effectiveness testing process.
No matter the standard for shielding effectiveness, the general procedure for testing shielding effective compliance follows the same process.
First, two antennas are set up on opposite sides of the sample for the test. One antenna acts as a transmit antenna. It is connected to a signal generator to sweep through the required frequency range. The second antenna is a receive antenna. This antenna measures the received field strength.
This information is stored in data form.
This data represents the signal attenuation or loss of signal through the barrier.



As a verification of results, there is a step prior step to the actual measurement of the sample under test. This step requires a calculation of the dynamic range such that accurate results are being made. Therefore, two measurements must be made.

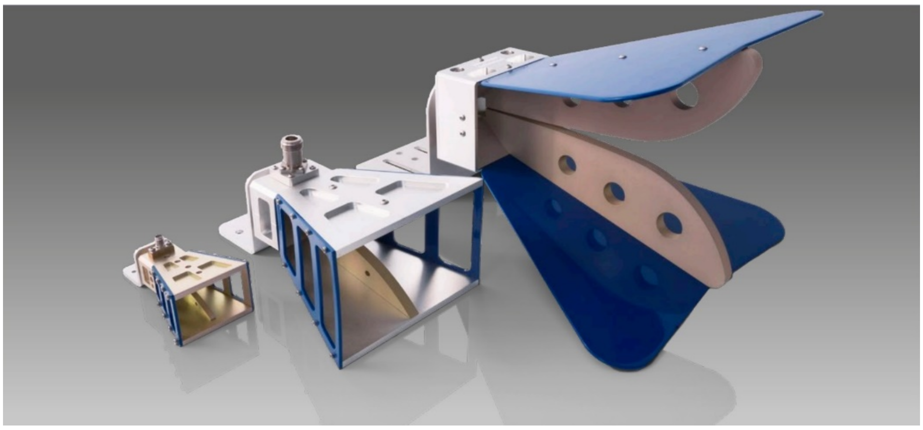
The first with no barrier. This means there is nothing between the transmitting and receiving antenna.
The second measurement is with a barrier. This is typically a metallic surface that is the best under materials used in shielding. The resulting signal should be the floor level noise of the antenna and receiver with an additional safety margin. This is usually 6 dB, to take into account for error.
Once these two verification measurements are taken, the dynamic range can be calculated.
This is simply the difference between the maximum and minimum signals. The amount of dynamic range must be greater than the amount of desired signal attenuation from the enclosure shielding from the sample.
Otherwise, the unit outperforms the test chamber, and thus concludes the sample shields better than the chamber, which should never be the case. It is important to always verify data, especially if the outcome appears to support this situation.

There are two kinds of measurements that can be taken regarding an electric or magnetic field.
The first is a far field electromagnetic wave.
The second is a near field electromagnetic field. When considering a far field electromagnetic wave measurement, this is when the electric and magnetic field are

orthogonal or perpendicular to each other. The normal, or along with, is the direction of the energy generation.
In the test setup, this would be the signal generator. For the opposite direction, this is just the opposite case. This is where there is no region where the electric and magnetic fields are related at all. In other words, considering the working of an antenna system, the near field is very close to the antenna, and far field means further away.

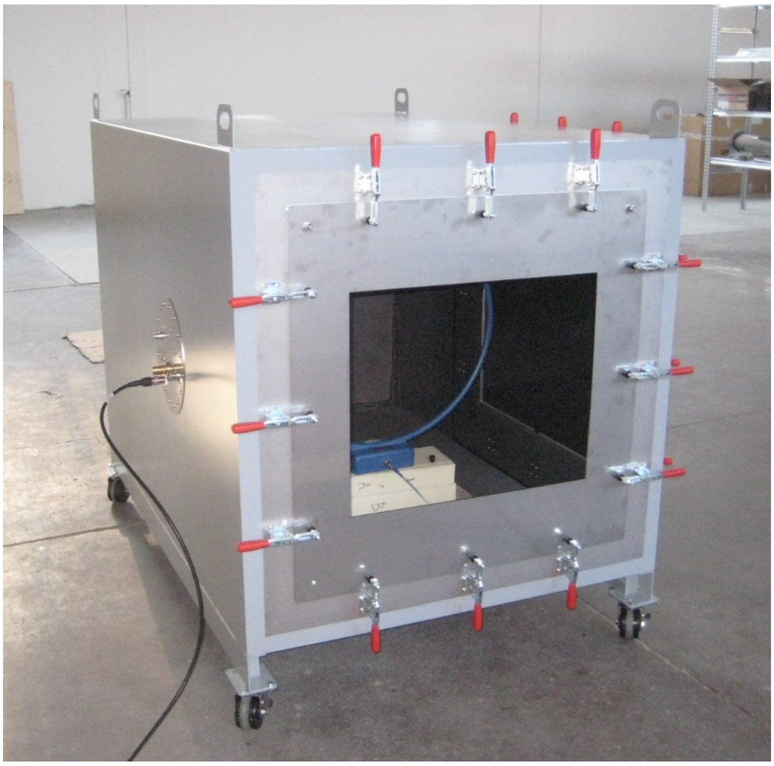
In addition to determining the shielding of materials, we can also access the shielding of cables. The shielding of cables can reduce the coupling of radio waves, electromagnetic fields and electrostatic fields. The amount of reduction can vary based on several factors.
For instance, the material used, its thickness, the size of the shielded volume and the frequency of the fields of interest can all have an impact. Also impacting the effectiveness of the shielding is the size, shape and orientation or apertures in a shield to an incident electromagnetic field.
Do not forget the perfect connection of the frame to the sample under test! It is required a way better than the screen level of the sample to avoid leackage and false measurements. To insure a perfect connection could be necessary apply on the border: silver paint, silver silicon glue, silver-metal PU glue, fingers strips, copper adhesive tape, aluminium tape and to end a bit of experience!…

LIMITS of Application
Due to the difficulties to have a repeatable test condition (mantain a far away field wave propagation) this test methos is generally applied from 0,7 to 40GHz by mean of broad band horn antennas



Instruments required for a full coverage 10KHz-18GHz (optional expansion to 40 GHz)

- Primary are necessary a **shielded box** at least 1mc. Volume lined with absorbers with a couple of ridge horn antennas according to the different frequency band (700MHz-18GHz),



Test box L1xH1xW1,5m lined with flat anechoic absorbers

- A **double TEM cell** coupled to cover low frequencies from DC to 3GHz

(the picture represent only one TEM-3000 cell)

- RF signal or sweep generators (10KHz-20GHz)
- Receiver (or spectrum analyzer 9KHz-26GHz)
- Amplifiers (more than 1 depending from the frequency range up to 4-5W)
- Pre-Amplifiers (broadband 10KHz-20GHz 15dB)
- Coaxial cables (low loss, high quality!)
- Fixed attenuators 10-20-20-30dB
- Adaptors Kit N to SMA connectors

Reference Standards

Many are the standards about the Shielding Effectiveness, each one is specific for a kind and shape of materials, and frequency range. Here is a short view;

ASTM F3057-14 -Measuring the effectiveness of Electromagnetic Shielding of Glazing/Glasses

It is a new and the best method focuses on glazings/glasses or glazing configurations at a specified full range frequency from 100kHz to 20 GHz, and covers the determination of the electromagnetic shielding effectiveness.
This is a component test. It is not applicable to full systems such as walls, floors, ceilings, shielded racks, or window systems and it is used to standardize a measurement procedure for glazings or glazing configurations, with and without coatings, films, interlayers, or other enhancements, as single or insulating units at a standard size and when mounted in a standardized frame.

ASTM D 4935-10: -Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials

The ASTM D 4935-10 standard involves the measurement of shielding effectiveness of planar material (square) for plane far-field Electromagnetic wave. The samples under test must be electrically thin for a near field magnetic field (H) calculation. Electric field shielding effectiveness can be calculated for far-field as well, but applicability has yet to be established. Measurements are to be taken within a frequency range of 30 MHz – 1.5GHz.

ASTM D4935-18: -Measuring the Electromagnetic Shielding effectiveness of Planar Materials

Shielding effectiveness test following the Standard ASTM D4935-18: The Standard ASTM D4935-18 describes how measuring the electromagnetic (EM) shielding effectiveness (SE) of a planar material for a plane, far-field EM wave.
The measurement method is valid over a frequency range of 30 MHz to 1.5 GHz.
These limits are not exact, but are based on decreasing displacement current as a result of decreased capacitive coupling at lower frequencies and on overmoding (excitation of modes other than the transverse electromagnetic mode (TEM)) at higher frequencies for the size of specimen holder described in this test method.
This test method is not applicable to cables or connectors.

ASTM D 4935-99: Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials

The ASTM D 4935-99 standard involves the measurement of shielding effectiveness of planar material (square) for plane far-field Electromagnetic wave. The samples under test must be electrically thin for a near field magnetic field (H) calculation. Electric field shielding effectiveness can be calculated for far-field as well, but applicability has yet to be established. Measurements are to be taken within a frequency range of 30 MHz – 1.5GHz and follows the typical setup of shielding effectiveness.

IEEE 299-2006: Measuring The Effectiveness Of Electromagnetic Shielding Enclosures

It defines the uniform measurement procedures and techniques for determining the effectiveness of electromagnetic shielding enclosures, It defines the uniform measurement procedures and techniques for determining the effectiveness of electromagnetic shielding enclosures at frequencies from 9 kHz to 18 GHz (extendable to 50 Hz and 100 GHz, respectively) for enclosures having all dimensions greater than or equal to 2 meters.

The types of enclosures covered include, but are not limited to, single-shield or double-shield structures of various construction, such as bolted demountable, welded, or integral with a building; and made of materials such as steel plate, copper or aluminum sheet, screening, hardware cloth, metal foil, or shielding fabrics.

. It can be any classification of enclosure, but must serve a purpose to shield from exterior electric or magnetic fields, or in a similar fashion, protect the environment around itself from the effect of an interior electric or magnetic field.

Usually, the enclosure is constructed of metal with guidelines for continuous electrical contact between joining panels (i.e., doors). Examples for specific enclosures include: single-shield or double-shield structures of various construction (i.e., bolted demountable, welded, or integral with a building) or made of materials (e.g., steel plates, copper / aluminum sheets, screening, hardware cloth, metal foil, or shielding fabrics).

MIL-DTL-83528C: General Specification For Gasketing Material, Conducting Shielding Gasket, Electronic, Elastomer, EMI / RFI

The MIL-DTL-83528C standard involves the measurement of shielding effectiveness of gasketing material, specifically of elastomeric shielding gaskets. The following material of which these gaskets are made of type qualifies under this standard:

1. **Silver-plated copper-filled silicone** rated for shielding effectiveness of a 110-dB plane wave at 10 GHz
2. **Silver-plated aluminum-filled silicone** rated for shielding effectiveness of a 110-dB plane wave at 10 GHz
3. **Silver-plated copper-filled flurosilicone** rated for shielding effectiveness of a 110-dB plane wave at 10 GHz
4. **Silver-plated aluminum-filled silicone** rated for shielding effectiveness of a 90-dB plane wave at 10 GHz
5. **Medium pure silver-filled silicone durometer** rated for shielding effectiveness of a 110-dB plane wave at 10 GHz
6. **Pure silver-filled flurosilicone** rated for shielding effectiveness of a 110-dB plane wave at 10 GHz
7. **Silver-plated copper-filled silicone** rated for shielding effectiveness of a 110-dB plane wave at 10 GHz
8. **Pure silver-filled high durometer silicone** rated for shielding effectiveness of a 110-dB plane wave at 10 GHz

9. **Pure silver-filled low durometer silicone** rated for shielding effectiveness of an 80-dB plane wave at 10 GHz
10. **Copper-filled silver-plated high durometer** rated for shielding effectiveness of a 110-dB plane wave at 10 GHz
11. **Nickel-filled silver-plated silicone** rated for shielding effectiveness of a 100-dB plane wave at 10 GHz
12. **Glass-filled silver-plated silicone** rated for shielding effectiveness of a 100-dB plane wave at 10 GHz

Measurements are made using the plane wave shielding effectiveness method. The gasket will be determined by its ability to electrically bond a test cover panel to an enclosure flange so the radiated RF plane wave will attenuate through a 24-by-24-inch opening. The enclosure needs to be large enough so no part of the transmitting antenna is within one meter of any enclosure surface.

MIL-G-83528B: General Specification for Gasketing Material, Conducting Shielding Gasket Electronic, Elastomer, EMI / RFI

This standard precedes the MIL-DTL-83528B standard.
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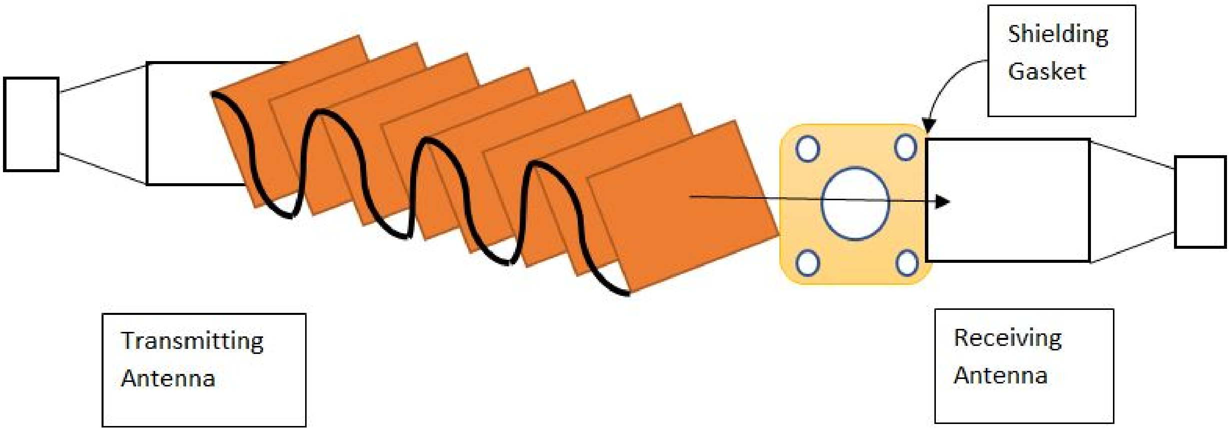


Measurements are made using the plane wave shielding effectiveness method. The gasket will be determined by its ability to electrically bond a test cover panel to an enclosure flange so the radiated RF plane wave will attenuate through a 24-by-24-inch opening. The enclosure needs to be large enough so no part of the transmitting antenna is within one meter of any enclosure surface.

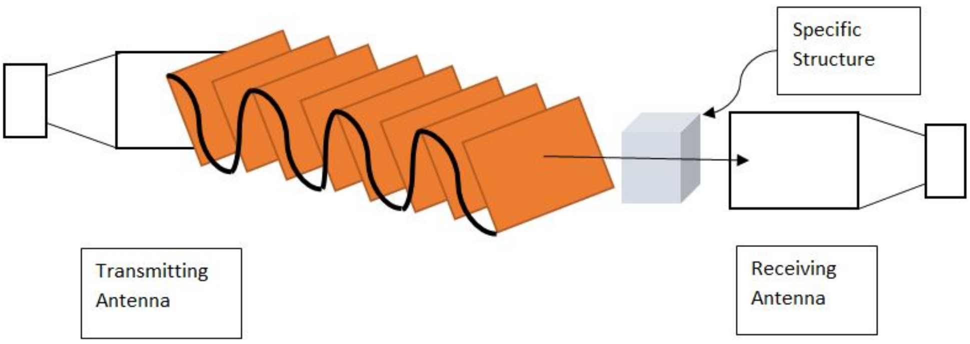
MIL-STD 1377: Measurement And Effectiveness Of Cable, Connector, And Weapon Enclosure Shielding And Filters In Precluding Hazards Of Electromagnetic Radiation To Ordnance

The MIL-STD-1377 specification is specifically for a weapon developer or designer with shielding effectiveness test methods. The actual methods of the shielding effectiveness test are for weapon enclosures, cables, and cable connectors. The weapon enclosure can involve an enclosure that surrounds the weapon circuit, the cable is wiring that starts outside of the enclosure and enters inside and connected to circuits inside the weapon enclosure, and cable connectors are simply what connects everything together for the overall system. The test is performed over a frequency range of 100 kilohertz (kHz) up to 30 megahertz (MHz), then from 1 gigahertz (GHz) to 10 gigahertz (GHz).

As depicted in the figure, test setup is the same as other shielding effectiveness, with the determination of the dynamic range and the actual measurement of the signal for the sample in question. If the system involves a weapon enclosure, all internal components need removed such that only the enclosure is being tested.

MIL-STD-188-125-1: High-Altitude Electromagnetic Pulse (HEMP) Protection For Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions (Transportable Systems)

MIL-STD 188-125-1 details the minimum performance requirements for low-risk protection from mission-aborting damage due to HEMP attacks. The description of these threats are defined in MIL-STD-2169. MIL-STD-188-125-1 also addresses minimum testing requirements for demonstrating that prescribed performance has been achieved and for verifying that the installed protection subsystem provides the operationally required hardness for the completed facility.
The MIL-STD-188-125-1 test specification defines the design and testing criteria for specifically designated fixed ground-based facilities in HEMP-hardened, critical, time-urgent C4I networks. Facilities include subscriber terminals and data processing centers, transmitting and receiving communications stations, and relay facilities. MIL-STD-188-125-1 applies to both new construction and the retrofit of existing facilities. Although only local portions of facility interconnects are addressed, it is assumed that survivable long-haul communications paths, fiber optic links, or other hardened interconnects between facilities will be provided as required for mission accomplishment. MIL-STD-188-125-1 can also be used for HEMP protection of other ground-based communications-electronics facilities that require HEMP hardening.
Keystone Compliance has completed numerous site surveys to determine the level of protection against HEMP attacks. Our team diligently completes the assessments and provides valuable feedback on any weaknesses that should be addressed. This feedback often includes suggestions for remediating any aperture points of entry (POE) and conductive points of entry. Our experience provides insight on improving protection as well as in determining specific locations within the facility that be more likely to serve as a point of entry.



MIL-STD-188-125-2: High-Altitude Electromagnetic Pulse (HEMP) Protection For Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions (Transportable Systems)

The MIL-STD-188-125-2 standard creates the requirements and objectives for design regarding a systems ability to comply with high-altitude electromagnetic pulse (abbr. HEMP) hardening (resistive) of transportable ground-based systems with features of time-urgent command, control, communications, computer, and intelligence (abbr. C^4I) missions. Specifically, this is a series with a companion specification of MIL-STD-188-125-1, with the only difference that for this specification, this addresses only transportable systems, whereas MIL-STD-188-125-1 addresses fixed facilities. In other words, this addresses the minimum requirements for showing a predetermined performance has been achieved and for verifying installed protection measures provide operationally required HEMP for the completed system.

System examples include, and are not limited to, subscriber terminals and data processing centers, transmitting and receiving communications stations, and relay systems under the assumption that long-haul communications paths, fiber optic links, or other hardened interconnects between systems are provided as required as such in the field. These are specifically itemized out in the specification under Section 5: Detailed Requirements. These relate to transportable systems such electrical shielding enclosures or fixed rooms in buildings (or the building itself), as long as the unit fulfills the sole purpose of the specification: the owner will determine if the observed event is mission aborting (passing criteria).

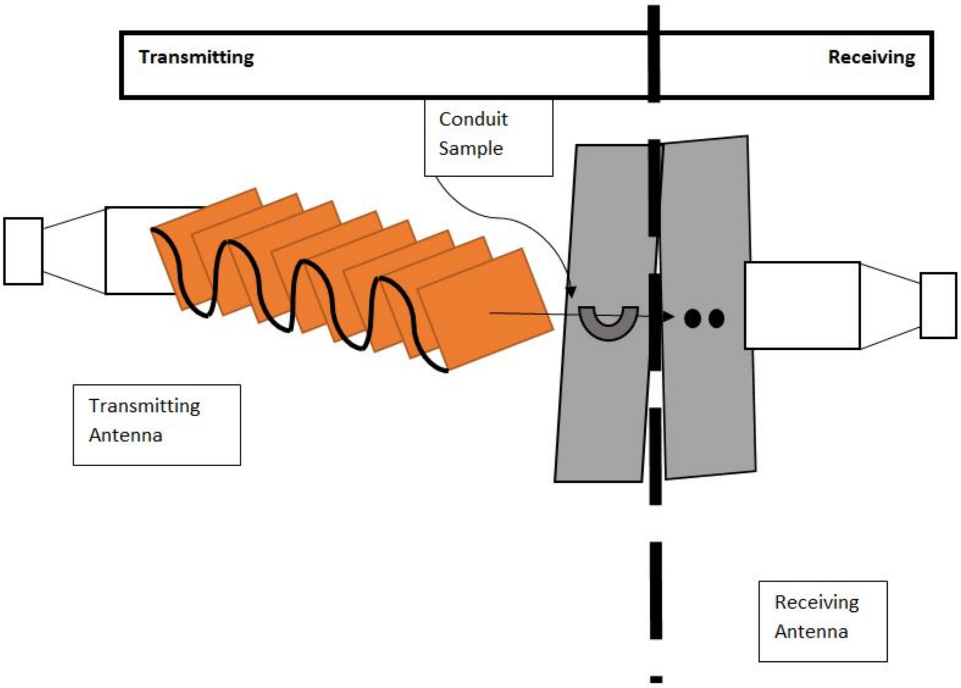
The test setup is the same as other shielding effectiveness, with the determination of the dynamic range and the actual measurement of the signal for the sample in question. If the system involves a weapon enclosure, all internal components need removed such that only the enclosure is being tested.
Keystone Compliance has the capabilities to test any size of enclosure to MIL-STD-188-125-2. We have tested large items such as entire on-site installation buildings and small items that can be easily transported to our lab.

MIL-STD-285: Military Standard For Attenuation Measurements For Enclosures.

The MIL-STD-285 standard actually replaced by IEEE-299. describes uniform procedures for measuring SE for enclosures at frequencies from 9 kHz to 18 GHz (extendable down to 50 Hz and up to 100 GHz), although the smallest linear dimension of the enclosure is assumed to be at least 2 m; the selection of 2 m as the smallest linear dimension was originally based upon being able to fit a typical bicone-style antenna inside an enclosure to perform plane-wave testing down to the range from 30 to 50 MHz.
The standard does not give any limits for pass/fail, leaving to the owner of the shielding enclosure to provide these limits.
In addition, although the standard suggests a range of test frequencies that can provide confidence in the effectiveness of the shield, it is clearly stated that the actual test frequencies must be chosen according to a test plan approved by the shield owner, the tester, and the shielding provider/vendor.
The measurement range in this method is divided into three subranges and in each subregion, some sub groups of testing frequencies are suggested:

1. A low-frequency range, from 9 kHz (50 Hz) to 20 MHz (a single frequency is suggested within 9–16 kHz, 140–160 kHz, and 14–16 MHz) where the SE is defined in terms of magnetic-field performance.
2. A resonant range, from 20 to 300 MHz, where the SE is expressed in terms of either electric field or power.
3. A high-frequency range from 300 MHz to 18 GHz (100 GHz) (a single frequency is suggested within 300–600 MHz, 600–1000 MHz, 1–2 GHz, 2–4 GHz, 4–8 GHz, and 8–18 GHz) where the shielding performance of the enclosure is expressed in power terms.

All samples that qualify for this testing must be a) some kind of enclosure; b) must be applied as a shield. Some examples of the enclosure vary greatly as there is a vast range of enclosures available. These can include, and are not limited, glass windows, conduit, even nanomaterials such as carbon nanotubes. As long as it will house some kind of material in some capacity, such as a conduit with wire sent through, then the sample would qualify. See the figure below showing an example with conduit. On the transmitting side, the conduit is connected to the test chamber bulk head (access panel) and has a signal being transmitted through it; on the receiving end is the opening of the conduit where the signal is measured to see the signal loss (attenuation) for the overall shielding effectiveness of the sample.



The test setup is the same as other shielding effectiveness, first determining the dynamic range of the unit/sample and the actual measurement of the signal for the sample in question.

MIL-STD-907B: Engineering, Design, And Shielding Effectiveness Criteria For Expandable and Non-Expandable Shelters

The single purpose for the MIL-STD-907B standard is for the development and design with rigid walled shelters. A few examples include a Radio Room, Antenna Tower Base Shelter, Power Shelter, Electrical Equipment Shelters, Instrument Shelter – Meteorological, among others. Three lines of criteria must be used in the design and engineering stage such that there will be effective shielding effectiveness:

1. Achieve required performance and versatility by shelters.
2. Minimize personnel man-hours to strike mobile shelters.
3. Establish design standards of tactical shelters within the Agencies and Departments for the Department of Defense.

It is essential that these considerations are taken seriously when designing and engineering, because if a failure occurs, the Department of Defense would fail, and remove one from consideration.

According to the Department of Defense, there are five classes of shelters that would be categorized for applying this standard. The five categories are given a specific class, and are the following:

1. Class 1: Non-Expandable Shelters. These are shelters that have equivalent size and shape in any form of transportation necessary.
2. Class 2: Expandable shelters. These are shelters than can expand in size and shape (can be made larger). However, they must fulfil an expansion ratio of 3-1, or less. Different shapes are also applicable.
3. Class 3: Highly Expandable Shelters. These have expansion ratios larger than 3-1 to the transport size.
4. Class 4: Knockdown shelters. Shelters that are reduced in height with exact items included inside for transportation.
5. Class 5: Large Area Shelters. Shelters that are disassembled and packed in dedicated or general-purpose containers for shipment.

MIL-STD-907B follows the MIL-STD-285 standard, only with the following exceptions regarding test frequencies and test point locations:

- Magnetic Field Frequencies: 150 kHz
- Electric Field Frequencies: 200 kHz, 1 MHz, 18 MHz, 300 MHz
- Plane Wave: 400 MHz, 1 GHz, 10 GHz
- Test Point Locations: Following the MIL-STD-285 standard, one location per panel at the mid-point, and one location per vertical corners.

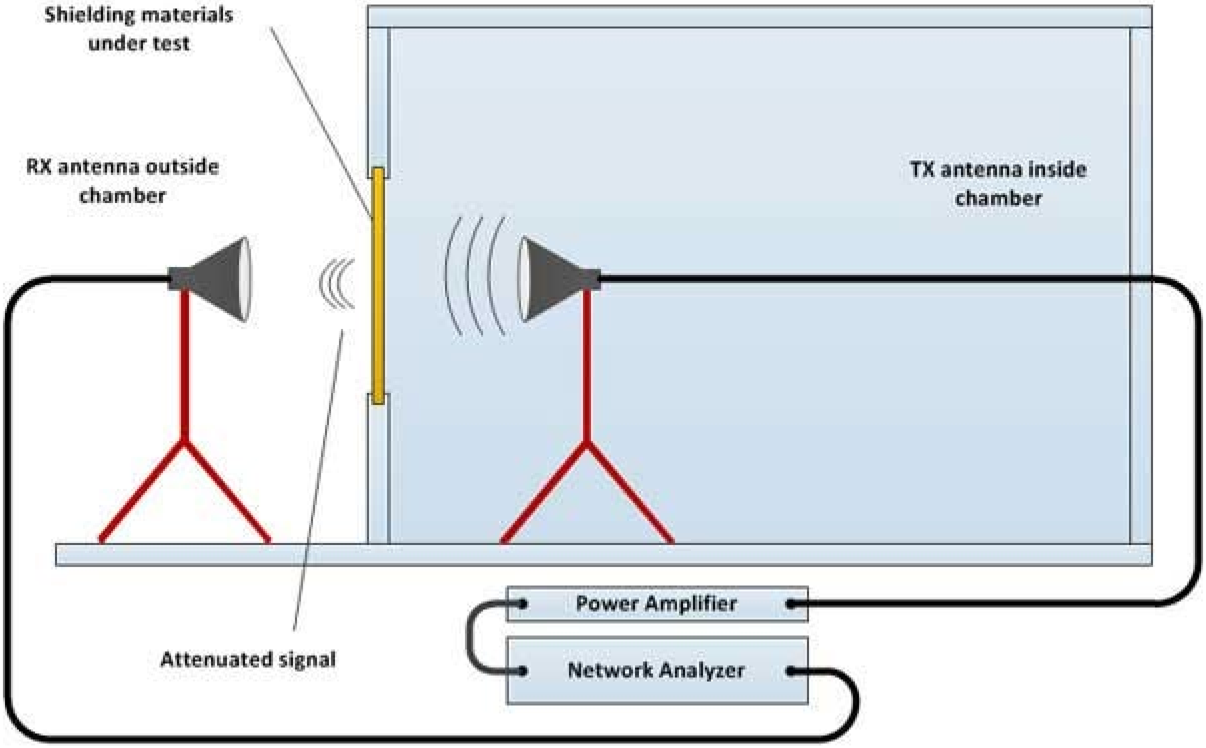
NSA 94-106

NSA 65-6

EN IEC 50147-1

EN IEC 61587-3

ANSI/SCTE 48-3



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