SHIELDED ROOMS & ENCLOSURES

Introduction

An RF shielded enclosure is any container which is made up of continuously conducting walls and whose seams and openings are especially treated to minimize RF leakage. In the context of this paper, a shielded enclosure is an especially designed room in which man and equipment can be placed. It has an access door, ventilation openings, power entrance, and the RF environment inside is significantly different from that outside of the enclosure's walls.

Generally, a shielded room has four walls, a roof and a floor. Some designers try to eliminate the shield floor of rooms which are resting on earth by extending the walls into the earth. This is a very flakey practice, however, since the RF shielding effectiveness of the earth is, at best, variable depending upon the consistency of the soil. In a practical sense, it is better to include the shield floor than to go to the expense of an elaborate and untested design to eliminate it.

There are several types of shielded rooms. Most are semi-permanent structures designed so that they may be dismantled and moved to another location and reconstructed. Thus, they are either bolted together or welded in a way that the weld may be removed and then rewelded. The shielding which is built into the architectural structure of the building is, of course, fixed, and intended to be permanent in nature. There are also a large number of a third type of shielded rooms, that is, mobile shielded enclosures built into a van or truck such as that shown in Figure 1. Sometimes the entire van is built as a shielded enclosure.

Shielded rooms should not be confused with anechoic rooms. An anechoic chamber is made of microwave absorbing material designed to minimize internal reflections by simulating the impedance of free space in the direction of propagation and along the walls. Since an anechoic room will leak RF energy, it is often desirable to build an RF room around the chamber. There are many RF shielded anechoic chambers in existence today.

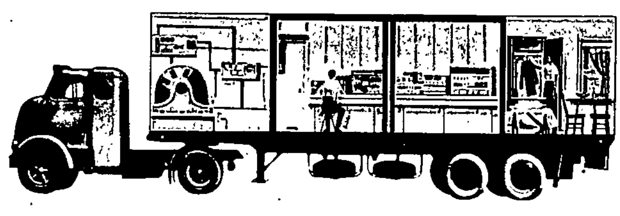


Figure 1: Mobile Shielded Enclosure

SHIELDED EFFECTIVENESS is the total capability of a given material to prevent propagation of electromagnetic energy, and it is represented schematically in Figures 2 & 3.

Expressed mathematically: $SE = R + A + B$ eq. (1)

where: SE = Total shielding effectiveness in (dB)

$R = R_1 + R_2$ = Reflection radiated power loss in (dB) (first and second boundary)

A = Absorption power loss (dB)

B = B–factor (dB) (omit if A is greater than 10 dB)

P_1 = Incident radiated power (dB)

P_2 = radiated power thru the shield (dB)

Expressing in terms of the law of conservation of energy:

$$P_2 = P_1 - (R_1 + A + R_2 + B)$$

$$P_1 - P_2 = R_1 + R_2 + A + B = R + A + B$$

$$SE = R + A + B = 10 \log \frac{P_1}{P_2}$$

These equations are expressed in terms of incident and emitted power. However, at low frequencies it is more convenient to work with electric or magnetic field intensities, thus the equation becomes:

$$SE = 20 \log \frac{E_1}{E_2} = 20 \log \frac{H_1}{H_2} \qquad \text{eq.(2)}$$

Reflection and absorption losses are a function of frequency, thickness of shielding material, resistivity, permeability and conductivity. Reflection loss is caused by a difference in characteristic impedance between the incident field and the shield and may also vary with distance. When the impedance of the incident field is much higher or lower than the impedance of the shield, the reflection loss is very high.

At all frequencies, magnetic fields are low impedance and electric fields are high impedance. Generally, for most materials, the impedance is low at low frequencies and high at high frequencies. Therefore, magnetic reflection loss R_h is small because there is a good match between the impedances of field and shield. For this reason, magnetic shielding depends primarily on absorption loss. For good shielding effectiveness ferromagnetic materials are the most suitable, and as the frequency increases, the impedance mismatch widens with the consequent increase of R_h.

Electric fields are readily stopped by metal shields because high reflection loss RE is easily obtained due to the mismatch between field and shield is always large.

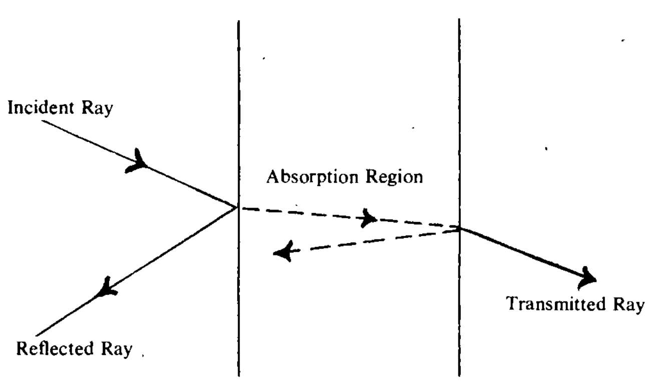


Figure 2: Reflection and Attenuation

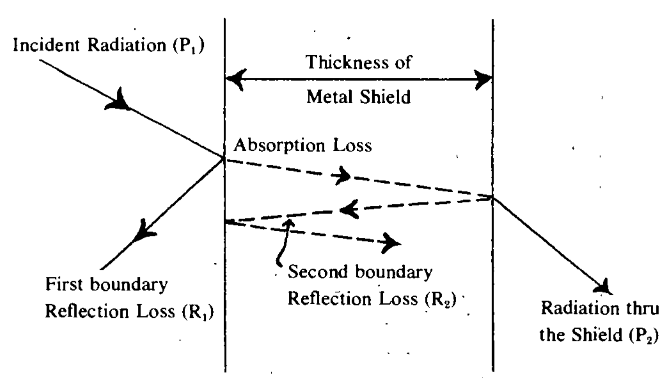


Figure 3: Factors Contributing to Total Shielding Effectiveness

The total reduction in field intensity is caused by reflection and absorption losses, therefore the shielding effectiveness of an enclosure is the sum of reflection and absorption losses. Reflection takes place at the surface of the shield while absorption is the dissipation of the signal as it passes through the body of the shield. (see figures 2 & 3).

In any a-c circuit there are two vectors: the electric field vector associated with the voltage and the magnetic vector associated with the current. If the field varies with time, the electric and magnetic components occur simultaneously. A field may be predominantly electric or magnetic if most of the energy is stored in the dominant component and will generally occur close to the generating source (within one wavelength). The ratio of the electric to the magnetic field is defined as the characteristic impedance. For a plane wave in free space the characteristic impedance is 377 ohms, for a magnetic field the impedance is less than 377 ohms and for an electric field it is greater than 377 ohms.

Basic Shielding Design Equations

The following equations are presented in a simplified form as an aid in designing RF shielded enclosures. All terms used are defined:

SE = Shielding effectiveness, representing reduction of electromagnetic energy in (dB). Measurements are made in power, voltage or current ratios.
R = Total reflection loss in (dB) from both surfaces of the shield.
A = Absorption loss inside the shield.
B = Positive or negative correction factor in (dB) (omit when A is more than 10 dB).
Z_s = Intrinsic impedance of the shield.
Z_w = Wave impedance of incident wave in space.
μ = Relative magnetic permeability referred to free space: 1 for copper, 1 for ferrous metals at microwave frequencies, and 200 to 1000 for ferrous metals at low frequencies.
μ_o = Permeability of free space = 1.26×10^{-6} henrys/meter.
ξ = Permittivity of free space = 8.85×10^{-12} farads/meter.
G = Relative conductivity referred to copper (1 for copper, 0.61 for aluminum, 0.17 for iron).
V = Speed of light in free space = 3×10^8 meters/second.
f = Frequency in hertz/second.
λ = Wavelength in meters/hertz.
β = $2\pi/\lambda$
ω = $2\pi/f$
r = Distance from source to shield in meters.
r_1 = Distance from source from shield in inches.
t = Thickness of shield in mils.
T = Thickness of shield in meters.
E = Electric field component in volts/meter.
H = Magnetic field component in amperes/meter.
p = Plane wave.
α = Attenuation coefficient of metal in nepers/meter.

$\sqrt{\frac{\mu_o}{\xi_o}}$ = Impedance of plane waves in free space = 377.6 ohms, approximately 120π.

To compute R:

$$R = 20 \log_{10} \left[\frac{(Z_s + Z_w)^2}{4 Z_s Z_w} \right] \text{dB} \qquad \text{eq.(3)}$$

$$Z_s = \sqrt{\frac{\mu f}{G}} \times 3.69 \times 10^{-7}$$

Values of R may be zero, positive or negative. In all cases R is positive at frequencies above 1 Khz. SE is always positive and in all cases greater than zero.

$Z_w = \frac{E}{H} = \frac{1}{V\xi} = 376.7$ ohms for high impedance electric fields, when $r > \lambda$ eq. (4)

$Z_w = -\frac{E}{H} = V\mu_o = 276.7$ ohms for low impedance magnetic fields, where $r > \lambda$ eq. (5)

To compute R for magnetic fields the given formula reduces to:

$$R_{(H)} = 20 \log_{10} \left[\frac{0.462}{r_1} \sqrt{\frac{\mu}{Gf}} + 0.136\, r_1 \times \sqrt{\frac{Gf}{\mu}} + 0.354 \right] \text{dB} \qquad \text{eq. (6)}$$

To compute R for Electric fields the given formula reduces to:

$$R_{(E)} = 353.6 + 10 \log_{10} \left[\frac{G}{f^3\, \mu\, r_1^2} \right] \text{dB} \qquad \text{eq. (7)}$$

To compute R for plane waves, where $r > \lambda$ the given formulas reduce to:

$$R = 108.2 + 10 \log_{10} \frac{G \times 10^6}{\mu\, f} \quad \text{dB} \qquad \text{eq. (8)}$$

To compute A:

$$A = 3.338 \times 10^{-3} \times t \sqrt{Gf\mu} \quad \text{dB} \qquad \text{eq. (9)}$$

To compute B:

$$B = 20 \log_{10} \left\{ 1 - \left[\frac{Z_s - Z_w}{Z_s + Z_w} \right]^2 \times 10^{-A/10} \times \left(\text{Cos. } 7.68 \times 10^{-4}\, t \sqrt{Gf\mu} - j \text{ Sin } 7.68 \times 10^{-4}\, t \sqrt{Gf\mu} \right) \right\} \text{dB} \qquad \text{eq. (10)}$$

NOTE: If A is more than 10 dB, B is neglected.

FREQUENCY	IRON		COPPER		ALUM.	
	G	μ_a	G	μ	G	μ
60 Hz	0.17	1000	1	1	0.61	1
1 KHz	0.17	1000	1	1	0.61	1
10 KHz	0.17	1000	1	1	0.61	1
10 KHz	0.17	1000	1	1	0.61	1
150 KHz	0.17	1000	1	1	0.61	1
1 MHz	0.17	700	1	1	0.61	1
3 MHz	0.17	600	1	1	0.61	1
10 MHz	0.17	500	1	1	0.61	1
15 MHz	0.17	400	1	1	0.61	1
100 MHz	0.17	100	1	1	0.61	1
1 GHz	0.17	50	1	1	0.61	1
1.5 GHz	0.17	10	1	1	0.61	1
10 GHz	0.17	1	1	1	0.61	1

Grounding

After RF shielding, proper grounding is of outmost importance for two main reasons. First, improper grounding will cause electrical hazards whch are a danger to life and property. Second, improperly grounded RF shielded enclosures can result in loss or degradation of RF integrity, or excessive radiations within the enclosure that could raise the electromagnetic ambient to an intolerable level. The hazards are comprised of potential voltages which may exist between the enclosure and ground. When an enclosure is installed with multiple grounds, or partial grounds such as pipes, ducts, hangers from overhead structure, anchors, etc. in addition to the ground stud, then circulating ground currents will result.

The ground impedances at the various contact points are totally unpredictable and the obvious result will be ground loops between the multiple grounding points. When the currents circulate through the enclosure skin, the induced voltages will radiate both inside and outside the enclosure. If the impinging voltages stem from outside sources, the energy, in circulating through the enclosure walls could be transmitted inside, or viceversa. Either way, the RF integrity could be compromised.

It is recommended therefore, that a single point ground be used and that the grounding connection be made only at the ground stud provided for this purpose. Pipe penetrations, hangers, etc. should be isolated by means of dielectric fittings. Electrical conduit feeding the power line filters should also be isolated by means on non-conductive fittings. Use canvas boots or non-conductive flexible connections for ducts to or from the enclosure. The entire floor of the enclosure must also be insulated from the building slab.

The result of single point ground is that all equipment and instrumentation will be at the same potential within the enclosure and electrical hazards will be non-existent. During construction, a relay operating ohmmeter or a suitable monitoring device can be continually attached to insure against inadvertent grounding. After completion of the installation, the single point ground is connected before power hook-up.

Many installations require isolated power and in addition may require a ground detection system to monitor failure of the ungrounded circuits. Since all power line filters utilize large values of capacitance, approximately 40 microfarrads or higher between the lines and the gounded case, a certain amount of leakage current will exist which is sufficient to set off the alarm in the ground detector device. The solution to this problem is readily met by installing the isolation transformer within the shielded enclosure, thus isolating the wiring from ground after the filter. In other words, filter the primary, not the secondary of the transformer. The shielded enclosure still must be grounded regardless of isolated power within.

The material on Basic Shielding Theory and Grounding has been prepared by Jose Solis, Sales Manager, Ray Proof Corp., Div. of Keene Corp. Reprinted by permission.

SELECTING AN ENCLOSURE

With the electromagnetic frequency spectrum becoming more and more crowded, electronic engineers are increasingly called upon to design equipment that does not cause electromagnetic interference. To do this, an interference-free environment is essential to allow the engineer to conduct various tests to evaluate his designs. An interference-free environment is brought into the laboratory by using a shielded enclosure. Often the electronic engineer is called upon to specify the type of enclosure required.

Shielded enclosures are of varied construction and materials. Various parameters have a bearing on the attenuation afforded by the enclosure. Knowledge of them is essential in evaluation of an enclosure. These parameters are: (1) frequency range through which the tests will be made; (2) ambient levels of interference present and their frequency range; (3) possible future sources of interference with estimates of frequency and intensity; (4) practical materials available for shielded enclosures; (5) power requirements; (6) various signal and metering input circuits; and (7) ventilation and lighting requirements.

INTERFERENCE SURVEY

An EMC consultant is extremely valuable in determining the first three parameters, for he has both the equipment and experience for providing an intelligent answer. A radio-frequency interference survey is normally performed at the proposed shielded-room site between the frequencies of 0.014 and 1000 MHz. Normal sources of radio-frequency interference include radio broadcast stations, radio beacon signals, ignition interference, oscillations from adjacent test equipment, and any other r-f source which can interfere with measurements being made on the equipment under test. Specific equipment in the plant, such as dielectric heaters, induction furnaces, transmitting equipment, and other sources of high-powered r-f interference should be energized and the field strength measured at the shielded-room site. Should any electrical or electronic equipment capable of producing r-f energy intentionally or unintentionally be planned for future installation, estimates of its interference capabilities should be considered. The survey determines the minimum attenuation required of a shielded enclosure to permit operation of a low-level r-f test.

CONSTRUCTION

Once a frequency range and attenuation level are determined, examination of the types of construction and materials available is next. The three popular types of construction (each successive type normally having increased shielding with a given material) follow:

1. single-layer shielding
2. cell-type shielding
3. double-layer insulated shielding

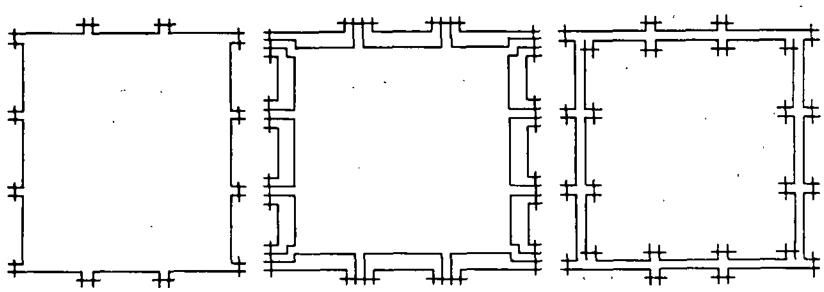
Commercial enclosures are generally made in sections so that they can be shipped easily and also moved should the occasion arise. Cross sections of the three types are shown in Figure 4.

PRACTICAL MATERIAL

Materials which provide sufficient effectiveness at various frequencies are copper, bronze and galvanized sheed iron. Copper and bronze screening are available, but a mesh less than 18 x 20 should not be used and wire diameter should be a minimum of 0.011 in. The lowest frequencies at which a given shielding effectiveness is required normally determine the type of material to be used. Ferrous materials produce more shielding effectiveness at low frequencies are netic and co-netic materials, while galvanized sheet iron has medium shielding effectiveness at the lower power frequencies. The accompanying table shows shielding effectiveness of a given material at a given frequency.

Non-ferrous materials are used to attenuate magnetic fields at higher frequencies. Here, shielding effectiveness is dependent upon thickness and must be related to the frequency.(1)

When a given material is decided upon, an increase in shielding effectiveness may be had by increasing the thickness of the material. However, doubling thickness will only increase shielding effectiveness by 6 dB. To increase shielding effectiveness and still not materially increase thickness of the material required, multiple-shielded enclosures are used. If, instead of doubling thickness of the single shield, another shield of the same thick-



(a) (b) (c)

Fig. 4—Three types of shielded enclosures used to provide an interference-free test environment: (a) single-layer shielding; (b) cell-type shielding; (c) double-layer insulated shielding.

ness, as the first is placed around the second, with a spacing of approximately 2 in. and isolated electrically from the first, shielding effectiveness of the room should theoretically be increased by the same amount as the shielding effectiveness of the first shield. Distance between the two shields and discontinuities in the shield will decrease total shielding effectiveness slightly. Magnetic field test results of single and double electrically isolated enclosures of copper screening and 3-oz. copper foil are shown in Figure 5. Placing both layers of this material one on top of the other would have resulted in only a 6-dB increase in shielding effectiveness.

POWER REQUIREMENTS

When bringing a-c power into a shielded enclosure, a line filter must be employed which will allow power frequencies to enter but attenuate all other undesirable frequencies. Standard commercial line filters are available with attenuation on the order of 100 dB. These filters are normally placed outside the shielded enclosure. At times, 100-dB attenuation is insufficient to remove the unwanted signals from the power line. These line filters are divided into two sections. One section is used outside the enclosure and the second section inside. Each filter section has a minimum attenuation of 80 dB through its effective frequency range. Placing both filter sections in series gives a theoretical attenuation of 160 dB or more (Figure 6). Filters made in this manner can be used on all types of enclosures. When line filters are to be used at frequencies of 400 Hertz or more, an investigation should be made into the

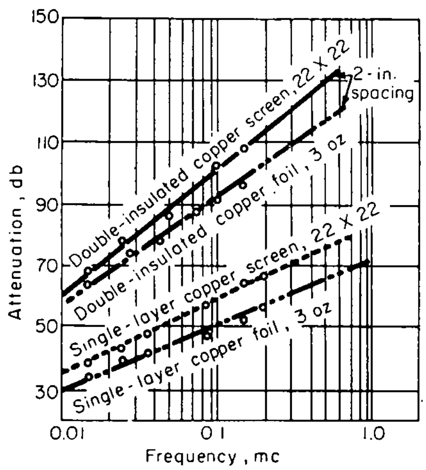


Fig. 5—Results of magnetic-field tests on materials for electromagnetic shielding.

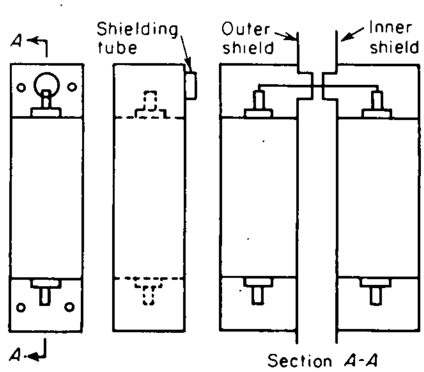


Fig. 6—Double-section r-f line filter for shielded test enclosure. A small tube is connected to each of the filters, as they enter the shielded enclosure, to prevent radiation from leaking around the filter. In the double electrically insulated enclosure, the tube prevents multiple conducting paths which tend to reduce enclosure shielding effectiveness.

amount of reactive power drawn by the filter. Many filters may draw more current than the 400 Hertz generator can handle. Power factor correction coils should be used to prevent problems of this type.

METERING AND INPUT CIRCUITS

Another shielding discontinuity is introduced by insertion of an r-f feed-through. An important requirement of the feed-through connector is that it must allow a specific r-f current, if required for testing, to enter or leave the shielded enclosure with minimum loss.

The UG-30/U Type N feed-through adapter exhibits a nominal impedance of 50 ohms and can be used as a feed-through connector. This feed-through is ideal for single-shield bulkhead mounting. When multiple shields are used, a special panel must be installed to provide a single shield at the point of r-f connector entry. In double electrically insulated enclosures, there may be a decrease in attenuation because of the single layer plus associated multiple connections between inner and outer shields. To alleviate this situation a special r-f feed-through connector has been designed to maintain isolation between both inner and outer shields, and still present a nominal impedance of 50 ohms. Use of a ferrite sleeve over the coaxial conductor also prevents intense external high-frequency radiation from entering the shielded enclosure. UHF connectors of BNC connectors are not recommended if a minimum VSWR is desired of the r-f feed-through connector.

VENTILATION

Ventilation openings, if improperly designed, could cause a serious reduction in shielding effectiveness. The amount of air entering or leaving the enclosure is based upon the amount of heat that must be extracted from the room due to electronic equipment in operation, plus the number of operators present during testing.

Another ventilation consideration is the amount of r-f attenuation presented by a particular opening. Screened openings usually have to be extremely large in area to permit sufficient air to flow through the fine mesh required to prevent r-f leakage. When frequencies about 1000 MHz need not be attenuated to a high degree, a multi-layer opening of 1/4 in. copper mesh is satisfactory. At frequencies above 1000 MHz, the multi-layer 1/4 in. mesh rapidly decreases in effectiveness. A ventilating opening must then be designed as a waveguide attenuator operating below cutoff at its lowest propagating frequency. In this manner, shielding efficiencies of up to 100 dB can be obtained at frequencies of 10,000 MHz. A 1/4-in. diameter tube, 1 inch in length would have approximately 102-dB shielding effectiveness at 10,000 MHz. A 1/2 in. diam tube, 2-1/4 inches long would give approximately 100-dB effectiveness at 10,000 MHz. Openings 1 inch or more in diameter would have little or no attenuation at 7000 MHz. (2) To obtain an opening of sufficient size to admit the required volume of ventilating air, these tubes are placed side by side until sufficient air flow is achieved.

ILLUMINATION

Lighting requirements can be most easily met by using incandescent sources. This type of lighting normally does not produce any interference. However, in a large enclosure, the heating effect of a sufficient number of lights to produce the required illumination could cause a heat dissipation problem. Flourescent lamp fixtures are available that are both filtered and shielded. Unfortunately, these fixtures must be considered carefully because the remaining amount of interference present may affect test results obtained in the shielded enclosure.

References

1. *Total Shielding effectiveness of a given material at a given frequency is penetration loss plus reflection loss in dB. For penetration loss (shield effectiveness), see "Electronic and Radio Engineering," F. E. Terman, McGraw-Hill Book Co., New York, pp 22, 36; for reflection loss, see "Report NADC-EL-54129," U.S. Naval Air Development Center, Johnsville, Pa., p. 15.*
2. *"Designing Noise-Free Enclosure Openings," Arnold I. Albin, Electronics Buyers' Guide," June 1959.*

SHIELDING EFFECTIVENESS TESTING

Once a shielded enclosure of any type has been developed and constructed, methods must now be provided in which to determine the actual shielding effectiveness of this enclosure. The most practical way to specify shielding effectiveness is in dB which will enable one to know how well a given enclosure will reduce his particular signal level that he is trying to eliminate. MIL-STD-285 is the current military specification regarding shielding effectiveness testing. However, a much later specification, the IEEE 299 spells out in much more detail how shielding effectiveness tests can be performed at various frequencies in the magnetic field, electric field, plane wave and microwave field techniques are discussed. These four basic types of tests normally cover given frequency ranges with some possible overlapping. They are as follows: for the magnetic or H field frequencies from 30 Hz on up to 1 MHz; for the electric or E field, from 30 Hz to 25 MHz; for the plane wave field, from 25MHz to 1000MHz; and for the microwave, from 2GHz to 10GHz. Shielding effectiveness tests are also performed at higher frequencies but at the present time no specific standard for testing has been developed.

The magnetic field and electric field shielding effectiveness testing distance between antennas, position of antennas, and maximizing of signal responses is very important in determining the accurate level of shielding effectiveness for a given enclosure. For a given homogeneous material of infinite length and width, position of the loop antenna with one another will not cause any variation in the value of shielding effectiveness determined. That is to say whether the loops are coaxial with respect to one another or coplaner in either the vertical or horizontal plane. Variations in shielding effectiveness readings with the different loop positions occur in the practical sense in that there are seams or discontinuities at the edges of panels, at filter panel locations, at access door openings, air vent openings, and other wave guide type openings provided to permit different types of services to enter the enclosure. Coplanar loop measurements tend to produce the lowest readings when testing seems at both the door and between adjacent panels.

Determining the shielding effectiveness of a given panel or air vent opening, with coaxial oriented loop antennas will pinpoint the areas directly between the loops in a more conclusive manner. Measurements made at a vertical and horizontal corner such as between a floor and wall panel, and a ceiling and wall panel, will be normally less than for a parallel plane wall between the two antennas. In evaluating a shielded enclosure, therefore, consideration should be given to the various configurations when the shielded material meets at right angles or some other angle other than a plane sheet.

IEEE STD-299 attempts to standardize its techniques for problems of types such as this. For enclosures which are small, an adapation of loop sizes and distance between loops must be made. In performing electric field measurements it is important that the vertical rod antenna on both of the receiving unit and the transmitting unit be maintained at a constant distance before and after the insertion of the shield,and that the antennas be as perpindicular as possible and at the same height. Electric field test procedures have been designed for interpreting shielding effectiveness of plane surfaces rather than corners or intricately designed enclosures. If an electric field measurement is required to be performed at the corner of a enclosure, the readings in general tend to be slightly higher for a given material when compared to a plane sheet of the material.

Electric field tests are normally of more value on single wall constructed enclosures of screening type or perforated type of shield. Distance is important between the antennas because the ratio of field intensity to distance is inversely proportional to the distance squared whereas in the magnetic field, the distance factor is further compounded in that the shielding effectiveness or field intensity is inversely proportional to the distance cubed. By being extremely careful with the distances and heights of the receiving and transmitting antennas, with respect to measurements made with and without the shield inserted between them, repeatable shielding effectiveness values can be obtained which are very reliable.

The next series of tests normally performed on a shielded enclosure are the plane wave tests. Plane wave evaluation of enclosure frequencies are normally selected in the 400 to 1000MHz range. The higher the frequency the greater potential of leaks occurring from small openings such as may occur around doors, access panels, filters, both the power line type and the wave guide air vent filters. The transmitting antennas is set approximately 6 to 8 ft. away from the side area of the enclosure that you wish to test. The receiver is placed inside of the shielded enclosure and the receiving antenna is fed through a narrow closed opening of the door and probed approximately 1 or 2 ft. in front of the enclosure in the path of the transmitting antenna. The maximum field is measured and is the known field without enclosure. The receiving antenna is then brought into the enclosure, the door closed and the area 1 ft. away from the enclosure wall is probed in its entirety. The rest of the room area is probed for a maximum reading. The difference in the maximum reading without enclosure and with the enclosure is the shielding effectiveness of the enclosure. To localize leakage points, a small loop probe approximately 3 to 4 inches in diameter of several turns is very useful.

Plane wave tests results are usually repeatable on a basis of approximately + or −5dB. In an enclosure that is approximately 10 x 10 ft. square the antenna is placed on each of the four sides if at all possible. In practical instances other objects in the way such as walls, and partitions, will modify the number of sides that one is able to check. However, this does not say that the other walls will not be tested, in that the plane wave field will move in all directions around the area and will locate any leaks that may tend to form on the other sides not directly exposed to the transmitting antenna. Certain leaky enclosures, depending upon the size have a reasonant frequency that can be picked up due to the dimensions of the enclosure. This can be found in IEEE 299 which discusses the reasonant characteristics. If this frequency should fall in an area where you will be using the enclosure extensively or you know that there would be a high level of signal present at a given frequency, it may be wise to also check that frequency. The single shielded enclosure is more prone to exhibit the wave guide cavity affect. Variations and differences of a few feet will affect the readings very much. The approximate error due to a 2 ft change in distance from going from the outside to the inside of the enclosure would be in the area of approximately 1 to 2 dB. At plane wave frequencies the path loss is less than inverse to the distance ratio.

In performing microwave shielding effectiveness tests, the frequency range of 1GHz to 10GHz is normally investigated. The microwave antenna which is normally a wave guide antenna is set up at a distance of approximately 6 to 8 ft. from the area to be tested. The microwave receiving antenna is placed directly in line with the transmitting antenna and oriented for maximum pickup on the receiver output indicator. The receiving antenna is placed inside the enclosure, the door closed and the area directly opposite the transmitting antenna is probed first for indication of signals entering the enclosure.

In conclusion, one can have reliable and repeatative readings if care is taken in antenna placement and maintainence of constant power output to the particular antenna being used for the particular test being made. With a reliable shielding effectiveness test result good shielding design can be achieved.