SHIELDED ROOMS & ENCLOSURES

Introduction

The shielded room and enclosure offers many advantages. It is and has been in use for a number of years for many types of electronic measurements where a low radiation ambient is required, or where signals must be contained. Its use has spread to nonmeasurement applications, such as the protection of personnel near high-power radar sites, the containing of certain industrial RF sources, and the protection of sensitive equipment such as computers.

The main advantage of the shielded enclosure for interference measurements is the RF isolation it provides from the outside world. Its use allows meaningful interference and susceptibility measurements to be made, both conducted and radiated, in locations where such testing would not ordinarily be possible. Much has been said about the effect of the shielded enclosure on the measurements without carefully pointing out that the only tests which may be adversely affected are the radiation tests. While radiation tests are quite important, there are sizeable numbers of other tests involved, all of which are more readily made in the low-level ambient afforded by the shielded enclosure. In one respect, the radiated measurement situation is improved, and that is in regard to outside signals causing invalid readings or preventing readings altogether.

The drawback is that inside the metal shielded enclosure, there can be multiple reflections of signals that result in standing waves in the room and potential measurement errors. This problem can be reduced by lining the walls with anechoic material. It may also be alleviated to an extent in some measurements by moving the test antenna over a small volume to determine the "worst cause" susceptibility or radiated interference.

The actual performance of tests in a shielded enclosure will proceed very much like any electronic test. There are several steps that may be taken to expedite and improve measurements. One is to keep the number of people in the enclosure during radiated measurements to a minimum to reduct the variation in the standing-wave patterns. At some frequencies, the movement of personnel can cause significant variation in this pattern and, consequently, variations in the indicated signals. Another is to limit the amount of equipment in the enclosure to the minimum for proper operation of the test sample and performance of the test. This will avoid any unnecessary effects on antenna impedances from nearby metal objects.

Questions may arise concerning the ambient inside a shielded room. There, of course, is an ambient since the room only attenuates rather than eliminates outside signals. In a conventional situation where the outside environment is not abnormal, a modern shielded room will provide attenuation sufficient to reduce all environmental signals to levels below the sensitivity of standard receivers. Signals below what might be considered "normal" RF frequencies would not necessarily be reduced so much. For example, 60-Hertz fields exist both inside and outside standard rooms to the same extent. The walls offer little or no attenuation at these frequencies and power lines allow easy entry. To reduce 60 or 400 Hz magnetic fields and their lower harmonics, it is necessary to use "extended frequency range" shielded rooms or enclosures.

Some electronic systems are too large to be considered for shielded enclosure testing, although the size of the enclosure or room has no theoretical limit, and enclosures have been built to sizes that enclose aircraft hangers. For example, the Titan ICBM is checked out in a five-story shielded enclosure, which also has a five-story door. Another example is the entire computer facility for an early model Atlas ICBM, located in a large shielded enclosure.

Shielded enclosures exist also in mobile configurations. A number of Government agencies and industrial firms have "mobile electronic laboratories" which are shielded enclosures constructed in a trailer or van. They may be simply mobile or portable screen rooms for general-purpose use, or they may be used to perform measurements in high field areas where protection is necessary for personnel and equipment.

Any metal, and even a few non-metals have shielding capability under some circumstances. But one of two materials, either steel or copper, is usually employed as the basic material in the shielded enclosure. The steel is usually in the form of galvanized sheet, while the copper is either in sheet form or in the form of the fine mesh screening. Which material is used will depend on weight restrictions, cost, shielding desired, and other variables. For equal cost, steel will probably furnish equal performance to copper at frequencies down to 150 kHz at which point the permeability of the steel begins to provide improved magnetic field shielding.

Low-frequency shielding effectiveness measurements should include magnetic field (H) as well as electric field (E) measurements. For shielding effectiveness determination at frequencies below about 500 kHz, only the H field measurement need be performed since the E field attenuation is invariably superior.

The first of the modern shielded enclosure construction methods was developed, to a great extent, at the Johnsville, Pennsylvania, U.S. Naval Air Development Center. This room was made with two layers of copper screen, separated by an inch or so.

The room was constructed of several panels, called cells, each one 8 feet by 4 feet in dimension. The individual panel edges butted together and were bolted through the wood framing that provided the shape and strength for each panel. One of the features of this room was that it could be disassembled, moved, and reassembled at a second location without major modification.

The door for this room was also framed with wood, but well-braced and covered with either copper or copper screen. The periphery of the door was furnished with two sets of spring fingers, one to provide contact with the inner edge of the doorjamb and sill, with the outer set to push against the outside of the door frame. This second set of spring fingers actually overlapped the door frame opening.

A similar enclosure construction is the cell type with only a single layer of screening or sheet. This method is not widely used since it is almost as expensive as the double-layer cell-type, and has poorer performance.

For double-layer enclosures, or the so-called double-shielded room, a fairly simple method has been developed recently. This is the sandwich panel, with two steel sheets bonded to a 3/4-inch plywood core. The panels are not butted together all the way, but are clamped on each edge by special continuous channels and strapping. The method of joining panels along the sides of a room and at the corners is shown in Figure 1. Machine screws pull the channel and strap together every few inches.

Another type of construction makes use of a single sheet of steel on a metal framework. The sheet is under some tension from the way it is welded to the frame, and the frame or panels are welded together.

See the LectroMagnetics shielded room ad on the back cover.

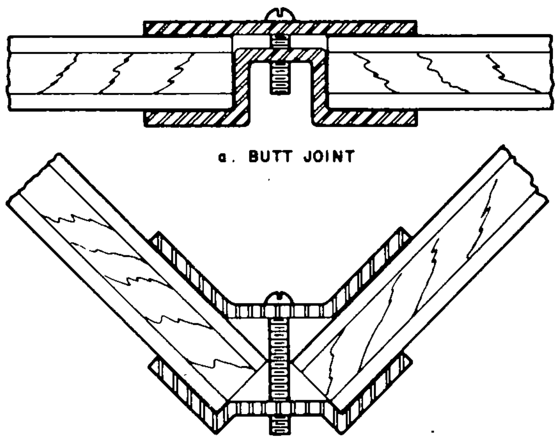

Fig. 1 Methods of Joining Sandwich-Type Panels

Variations are used by several manufacturers of shielded enclosures. Some newer developments in clamp design by Lectro-Magnetics (LMI) include a preassembled (welded) and interlocking three way corner which eliminiates common three way corner leakage problems. Also incorporated in the design is the use of a closed threaded insert to eliminate RF leakage and pentration at each of the clamping bolts. Typical features of this design are shown in Figure 2.

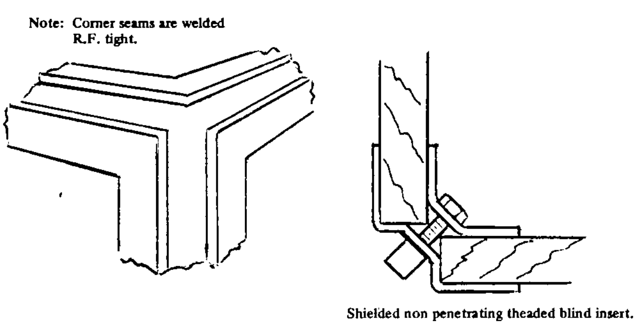

Fig. 2 Alternate Methods of Joining Panels

Doors for the newer shielded enclosures are considerably different in concept from the one first described. They are stronger, with stronger door frames as well, to provide better attenuation around the door. They still use two rows of metallic fingers or hidden rows to effect a good seal between the door and door frame. There are also improvements in the latching arrangements, so that the door may be opened and closed easier. Doors for high performance, all welded, shielded enclosures require uniform clamping or sealing pressures well beyond the standard approach. A very effective and reliable high performance shielded door is the pneumatic sealed door developed and patented by LMI. This door uses neither finger stock nor RF gaskets and is used on high performance all welded shielded enclosures.

Filters

Part of the job of providing attenuation for a shielded enclosure is accomplished by the structure itself, i.e., the wall sections, seams, and door. But these are of no value, no matter how well designed, if the room is penetrated by any unfiltered lines or wires. For this reason, the power-line filters are an integral part of the enclosure.

The basic requirement for the filters is that they provide a certain minimum attenuation over the frequency range of the room, usually from approximately 14 kHz to 10 GHz.

The difficult problem is to determine how much attenuation the filters must offer to complement a particular room design or application. The degree of attenuation that must be furnished by the filters is only roughly related to the attenuation of the room.

The usual solution to the problem is to provide filters with attenuation capability somewhat less than that of the room. For example, if the room offers attenuation of 120 db over most of the frequency range, filters offering 100 db should prove adequate. If the required enclosure performance exceeds the RF Power Line filter capability, the filters may be enclosured in a shielded electrical panel cabinet to increase the low frequency magnetic isolation. Normal installation practice places the filters outside the enclosure, with the line coming through pipe nipples into the room.

The mechanical design of high-attenuation filters is quite an important factor in their performance. To reduce coupling between the input and output of the separate sections, well designed compartments are required. The buyer of power-line filters must be cautious in his selection, since a variety of sizes and qualities of shielded enclosure filters are available.

Performance-Shielding Effectiveness

The end shielding effectiveness per MIL-STD-285, or similar specifications such a USAF Class I Shielding, or NSA 65-6 must be well defined before the selection of the type of shielded room or enclosures. Size is also an important factor as shown in the cost section.

The well designed and installed shielded rooms of the modular clamp together shielded rooms as shown in Figure 1 & 2 conform to well know shielding requirements of MIL-STD-285 and others as previously mentioned. The shielding effectiveness of the modular rooms, using two sheets of 24 gauge steel on ¾ inch plywood is typically shown in Figure 3.

The performance of all welded rooms is shown in Figure 3 for the different classes of shielded rooms based on the thickness of the shielding steel used. The performance of the all welded rooms follows the theory of design in the magnetic field attenuation, while the slope of the magnetic shielding for the modular room follows a curve that is the result of the properties of the materials used plus a proven derateing necessary for the magnetic seam impedance of the clamping arrangement.

Cost

Cost considerations are very important and should be resolved at the earliest possible point when a new shielded enclosure is being considered. Cost and performance are interlocking features.

As a rule of thumb, if performance is secondary, for smaller enclosures and up to a size of approximately 24 ft x 30 ft, the modular room is less expensive in its initial cost. The environments of useage and maintenance must be considered to determine the end cost. If performance, and/or environments are most important, the all welded room is less expensive both initially and in the end cost.

An exception to this rule of thumb is in the case of large structures that are appreciable in size than stated above, and in particular when such structures must pass building codes and other environmental factors, wherein the all welded enclosure is generally less expensive regardless of the degree of shielding effectiveness required. In such applications, the modular rooms are not self supporting and require considerable framing. The all welded rooms are in accordance with the Uniform Building Code and are self supporting. An important cost and weight advantage is also in favor of the all welded room due to the elimination of plywood in the total structure.

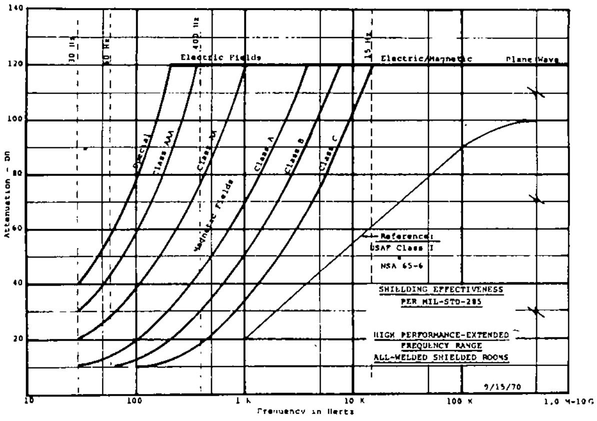

Fig. 3 Shielding Effectiveness Curves

Maintenance

Shielded enclosures require a certain amount of maintenance if they are to retain their designed attenuation. The vulnerable areas of a shielded enclosure are the joints and seams of bolted structures, and the door. The fastenings between panels must be kept tight; the enclosure manufacturer usually gives a torque rating on the fasteners. No maintenance is required on all welded enclosures.

The finger stock along the edge of the door must be kept in good condition. If any fingers are damaged or broken off, a new section of fingers may be soldered on as a replacement. These fingers provide a good connection between the enclosure and the door by sliding, for a short distance, along the door frame. To maintain this good connection, the door frame must be kept smooth and clean. One exception is the pneumatic door, which does not use fingers.

Lighting

Lighting must be provided for the enclosure. This should in all cases be incandescent lighting, since other types of lighting usually involve ionization processes and subsequently produce RF noise. There exist some fluorescent fixtures which have RF suppression built into the unit. While this type of lighting may be of benefit to lower the RF ambient in a laboratory, they generally are not suitable for shielded enclosures. Any other services to be provided in addition to lighting, such as electric heating should be installed in such a way that it cannot produce any RF signals.

Additional Penetration

Additional penetrations of the enclosure walls may be necessary to provide other services. Gas, water, and compressed air may be furnished through steel or copper piping. If the pipe is joined to the enclosure wall in a clean, tight connection, the attenuation of the room will not be appreciably affected.

The same method must be used to bring coaxial lines through the wall of the enclosure. In this case, special coaxial fittings are available that are similar to a threaded pipe nipple, except they have the suitable coaxial construction and fittings at each end.

The use of coaxial cables can, in some cases, reduce the shielding effectiveness of an enclosure by providing a path of entry for high-level signals. These high-level signals can penetrate the cable shield and be conducted into the enclosure. For this reason, double-shielded coaxial cables should be used for these connections if high ambient signals are known to exist.

Checkout

A newly installed shielded enclosure usually receives a thorough check of its attenuation to determine if it performs to specification. Often these tests are performed in accordance with MIL-STD-285, which prescribes test frequencies and equipment, as well as antenna separation distances. The testing of an enclosure is basically a near-field measurement which means that the results may vary widely as a function of distances, antenna types, and frequency. For this reason, it is important that the methods indicated in MIL-STD-285 (if it is the test specification) be followed as closely as possible so that meaningful and repeatable results may be obtained.

Testing of an enclosure should be accomplished periodically to verify that its attenuation still meets the original specification. In this respect, the enclosure may be considered as an item of equipment in the laboratory inventory, and placed on the periodic calibration schedule. After the initial checkout, the enclosure should be checked at least every other year. Interim spot checks may be desirable in conjunction with special interference tests as a validation move, or in the event degradation of enclosure attenuation is suspected for any reason.

Ventilation

Shielded enclosures of all types require some means of force ventilation, especially the solid-wall enclosures. This service must provide moving air without affecting the shielding effectiveness of the walls. The standard method of achieving this requirement is to utilize the waveguide-beyond-cutoff principle and there are several physical satisfactory configurations.

The finished unit, sometimes termed "honeycomb," may have the appearance of an automobile radiator. The placement and size of these air vents will depend on the individual room requirements, as will the size and type of blower. If the room is to contain large amounts of equipment and/or personnel, air conditioning must be furnished.

ELECTRICALLY ISOLATED DOUBLE SHIELDED ROOM
(Another school of thought)

There has been a long-standing controversy over the advantage of completely separate layers, electrically isolated, in the double-shielded room as opposed to the cell-type room. Some think that the test reports which show no difference in attenuation factors between an Electrically Isolated Room and the Not Isolated Room made of exactly the same materials, are both misleading and a misrepresentation of test results. One point which is almost universally agreed upon is that regardless of the type of construction, no shielded room is better than the effectiveness of its filter, door and seams.

Whenever specialists or "experts" on RF shielded enclosures congregate, you can expect endless discussion on the test methods. There is a standing argument that you might conceivably leave the subject of test methods, test procedures and instrumentation where it was 20 years ago because what was true in 1951 is still true today, that is; "The test is only as good as the skill and integrity of the engineers who conduct the test." One should not make the mistake of comparing a 0.015 inch thick copper screen Double Electrically Isolated room with a plywood room laminated with two layers of 18 guage or 24 guage steel, or comparing a plywood room with a single layer 0.125 inch thick solid steel room having welded seams and joints. Illustrations of the three types of rooms are shown in Figure 4.

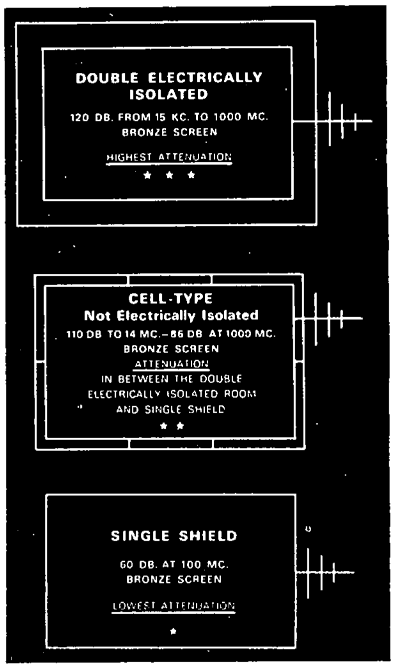

Fig. 4: Three of the most popular types of r-f shielded rooms currently in use are diagrammed here.

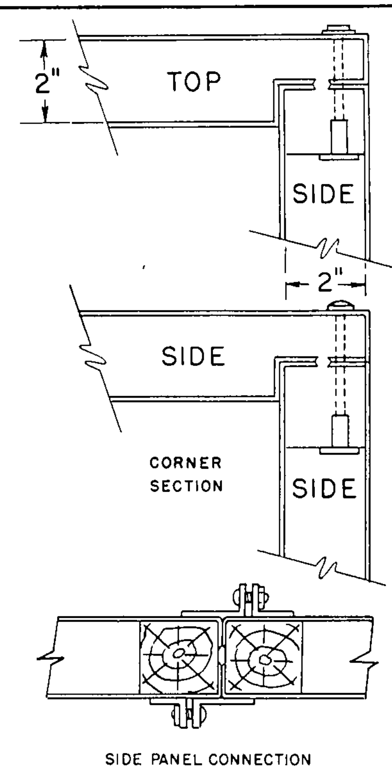

Fig. 7: Patented Construction of the Lingren Double Shielded Electrically Isolated Room. Panel construction permits easy remodeling or enlargement that may be needed.

The case for the Double isolated room is well presented in a book entitled "Contemporary R.F. Enclosures", written and published by Erik A. Lindgren in 1967. (Copies are available from Erik A. Lindgren & Associates, Inc.) The book points out that no meaningful comparative test has ever been made on Cell-type and Isolated rooms since 1951 except those published therein comparing the performance of the Isolated and the Not Isolated construction. Actually, Naval Air Development Center Report 3908, dated 14 November, 1951, shows the test results between two Not Isolated Rooms.

The test results shown in Figures 5 & 6 are considered to be significant because they show a comparison between different constructions using the same materials. The figures also show that the materials used also affect the performance of the room. If the use of a screen is considered as a separate factor, and the use of a solid metal another factor, five factors will then be available in order to evaluate the three types of constructions as shown in figure 4. These factors are:

1. Double Electrically Isolated
2. Double Not Isolated
3. Single Shield
4. Screen Shield
5. Solid Shield

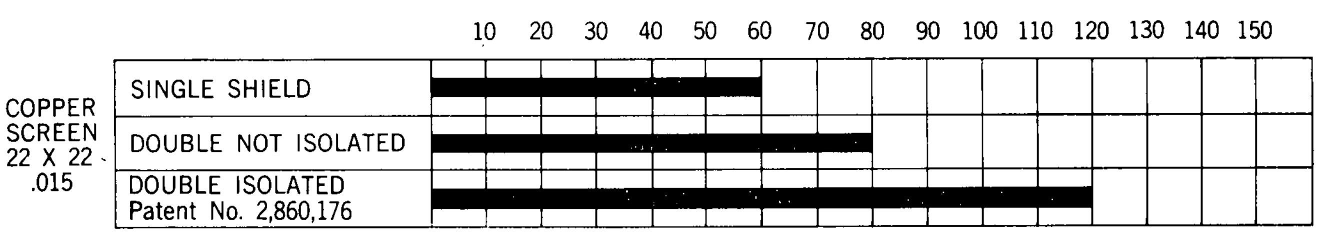

Figure 5

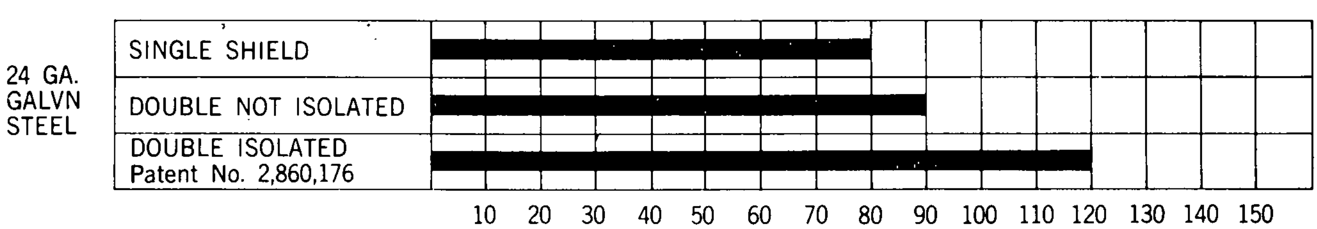

Figure 6

The chart in Fig. 9 shows test results of a double shielded electrically isolated bronze screen room. This room has attenuation of 120 dB from 15 KHz to 1000 mHz. (Attenuation of 120 dB shown in charts accompanying this article was probably greater since this figure was the maximum limit of the instrumentation used.) Actual tests reveal that all rooms have an inbuilt handicap if bolts penetrate from the inside to the outside surface of the shield. By comparison, in this same report, the cell-type room shows attenuation falling below 100 dB at 1000 MHz and as low as 87 dB at 400 MHz. Most rooms will have 120 dB attenuation for frequencies from 15 KHz to 150 MHz, if erection is correct. However, for frequencies of 450 MHz and higher a bolting system which does not permit direct mental contact by bolts bonding the inside and outside shields is definitely indicated. This is also true below 15 KHz.

Figure 10 is excerpted from Table 4, page 39 of the NRL Report 3908 referenced above. In this report comparative tests of a cell type room and a double isolated room are described. Results are indicated by (X) chart A, showing lower attenuation for the double shielded room. Openings for light and ventilation in the latter were covered by hardware cloth dipped in a copper plating solution. Shielding effectiveness of this material was challenged, as noted in the report. "It was suspected that if ordinary bronze fly screen had been used over the openings in the double shielded room, in place of hardware cloth, the overall shielding effectiveness of the room would have been better. The hardware cloth over the door opening, about 8 x 10 in. was replaced with bronze screening to test their contentions and the leakage as measured in the center of the room again was found at 3 frequencies. Table 4 summarizes the results and indicates that fly screen is superior"–(X) curves (O) and (X) on chart A.

Construction & Design

Because good performance in any r-f shielded room depends upon leak proof seams, construction and design are of great importance. Fig. 7 illustrates the patented joint constructions of a modern double electrically isolated room. It shows that no metallic paths or connections exist to provide a conductor for any r-f signal from the outside to the inside. Fig. 8 shows methods of construction in which the bolts extend from outside to inside.

If strength and rigidity were the only considerations the construction used in Fig. 8 would be equal to that used in Fig. 7. But conductivity is a more important factor and here the type shown in Fig. 8 falls short. Any bolt penetration from inside to outside is a direct conductor for any signal when the bolt loosens even slightly.

Improved attenuation obtained by the substitution of wire screen over the openings of the double shielded room when added to the curve (X) makes a new curve (Δ) that shows the superior attenuation of the double shielded room. Even the most cursory comparison of engineering appraisals will point out the superiority of the construction covered by patent #2,765,362 (issued in 1956) and shown in Fig. 7.

Improvement Continuing

Improvement is continuing and at present double electrical isolated rooms build with 24 oz. copper and 24 ga. steel attain an attenuation of 36 dB at 60 Cycle magnetic field, 100 dB at 15 KHz and 120 dB at 1000 MHz.

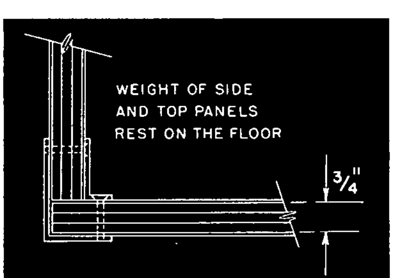

Figure 8: Construction of non-electrically-isolated double shielded room showing bolts passing through both shields.

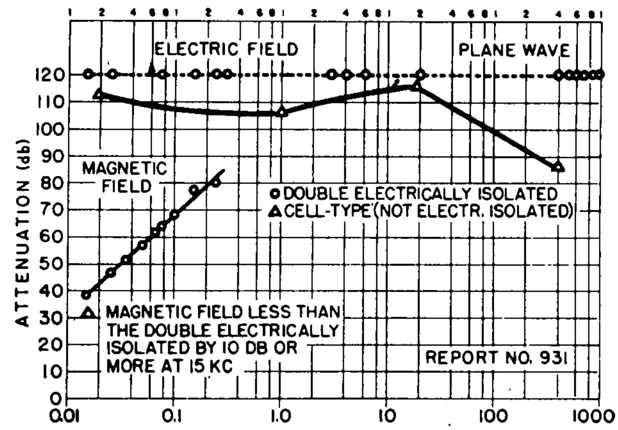

Figure 9: Chart shows attenuation at various frequencies of Double Shielded Electrically Isolated Room compared with Cell type.

Most rooms have the same attenuation of 120 dB (limit of Instrumentation) in the electric field from 100 KHz to 30 MHz but this does not mean that they all have the same attenuation at other frequencies. In the magnetic field at 15 KHz there is much difference and this difference is of extreme importance.

It is probably safe to state that out of thousands of r-f rooms existing in the U.S. there are less than 10 that claim 120 dB attenuation at 10,000 MHz. Engineering reports have indicated and field use has confirmed that it is impossible to get 120 dB at 10,000 MHz with any screen shielded room. It requires a particular type of construction and a solid copper r-f shield to achieve this attenuation at this frequency—a real accomplishment.

Comparison of Hardware Cloth with Bronze Fly Screen in Door Opening

Frequency	Improvement in Attenuation Realized by the Use of Bronze Screening (dB)
18 KHz	8
1.5 MHz	16
15 MHz	26

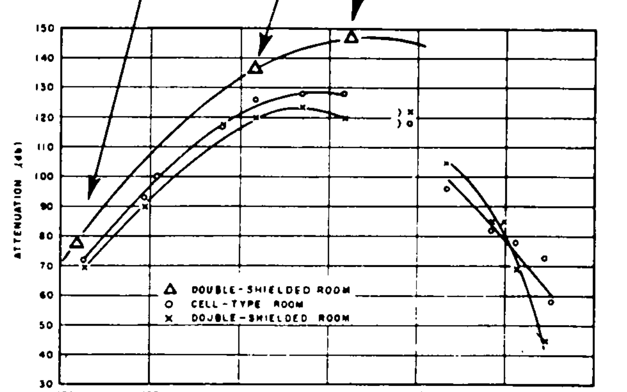

Figure 10: Chart is a comparison of the attenuation curves for the double-shielded and cell-types of room. Table is above.