

Can MIL-STD EMI requirements be met with conductively coated plastic enclosures?

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1) Introduction

1.1 Summary conclusion

The conclusion from this report is that it is possible to use small conductively coated enclosures to contain sensitive electronic equipment suitable for use in a military electromagnetic environment with a minimum of additional care in the design of the electronics to ensure immunity.

2.1 Advantages of a conductively coated plastic enclosure versus metal

Military electronic equipment mounted in vehicles, ships and planes are commonly housed in metal enclosures for ruggedness and thereby can, when correctly implemented, achieve very high levels of shielding effectiveness. The MIL-STD 461 EMI test requirements such as RE02/RE102 , RS01/RS101 and RS03/RS103 can be easily met using metal enclosures combined with either properly terminated shielded cables or filtered I/O and power lines.

For equipment carried on the person , such as communications, wireless telephone or other control and monitoring equipment the lighter weight of non metallic enclosures is a great advantage. One other application for non metallic shielded enclosures is in bomb suits which are typically made of kevlar, fiberglass and other fiber materials. The use of ballistic steel in these suits, to provide blast protection, is usually confined to certain areas to keep the weight as low as possible Some of these suits contain electronics for cooling systems, audio systems and communications and these electronics are prime candidates for shielding..

Meeting MIL-STD 461 type EMI requirements, without the use of any shielding in the enclosure, places extreme requirements on the design of electronics. Where highly sensitive analog or high frequency digital electronic or dc-dc converters are used it may be simply impossible to meet the requirements without shielding.

Traditionally conductively coated plastic or fiberglass enclosures have been used in commercial products, typically because a molded plastic enclosure is aesthetically more pleasing than a metal enclosure, but also to save weight and cost.

With correct PCB layout, common mode filtering on cables, spread spectrum clocks or low clock and data frequencies it is sometimes possible to meet commercial EMI requirements without shielding the enclosure. However with the increased complexity and speed of logic, using a conductive coating on non conductive enclosures is becoming a very common practice in order to meet radiated emission limits even in commercial equipment.

To ensure meeting the European EMC Directive, Medical Directive, or Automotive Directive, equipment must be immune to either 3V/m, 10V/m or 20V/m usually from 80MHz to 1GHz, but in the case of the Medical Directive to 2.5GHz. In order to meet these radiated immunity requirements with analog, RF or telephone equipment the use of a shielded enclosure may also be mandatory.

Experience has shown that the conductive coating by itself can be very effective. It is the joint between two halves of an enclosure or between enclosure and lid which is the weak link in shielding effectiveness and this is shown a number of times in this report. This is due to poor contact pressure at the interface, low contact surface area and gaps due to unevenness in the formed parts or the coating.

Only one set of measurements are described within this report and these are measurements on different types of small enclosures, either plastic conductively coated, cast metal or milled metal.

Another R&D enclosure shielding effectiveness project involves the use of a solid metal EMI and air tight enclosure with a rectangular aperture in one surface. Conductively coated plaques were obtained from a number of manufacturers and these were slightly larger than the aperture in the enclosure. Air pressure was used to hold these plaques in place. By using air pressure the use of fasteners is avoided and, as all the plaques had the same dimension, ensured the same pounds per square inch pressure on the periphery of the plaque, where it contacted the inside of the enclosure. The relative shielding effectiveness of these plaques for both H field and electromagnetic waves will be measured from 10kHz to 1GHz and the resultant report will also be published on the EMC Consulting web site in the future.

Although the emphasis is placed on sensitive circuits operating with MIL STD susceptibility test levels the shielding effectiveness described in this report is just as effective in reducing radiated emissions from circuits which are noise sources.

2) Coated plastic enclosure versus metal enclosures

A milled plastic enclosure was coated inside and out with a nickel vacuum deposited film. The enclosure contained a groove for a gasket and also a conductive contact between the two mating halves of the enclosure existed either side of this groove for the gasket. Two enclosures were made one with a film thickness of 0.001 inch (0.0254mm) and the second with a 0.002 inch (0.0508mm) coating.

The enclosures were tested for relative shielding effectiveness (SE) over the 10kHz to 250MHz frequency range. The test set up and test equipment used were in accordance with MIL-STD-462D , with the addition of a magnetic field shielding effectiveness test from 100kHz to 100MHz which is not described in MIL-STD 462D. From 10kHz to 100kHz the radiated susceptibility H field RS01/RS101 test set up was used. From 10MHz to 250MHz the RS03/RS103 test set up was used and an electromagnetic field was generated. Both the E field and H field inside the enclosure were monitored in this test.

2.1 Enclosure types

The dimensions of the different enclosures were either identical or in the case of bought out enclosures, as close as possible to the manufactured. In all enclosures either metal screws, non conductive nylon screws, or nylon washers under metal screws, were used to fasten the two halves of the enclosure together. The reason for using non conductive fasteners was to see the real performance of the joint which otherwise would be masked by the impedance of the fastener in parallel with the transfer impedance of the joint as well as to show the importance of the fasteners. For the cast aluminum and nickel plated plastic enclosures measurements were also made with and without EMI gaskets in the joints. The dimensions of the different enclosures and the locations of fasteners are as follows:

The milled aluminum enclosure:

6.9cm wide
10.8cm long
5.4cm high
3mm thick
with screws 3.3cm apart on the long seam and 7.8cm on the short seam

The nickel plated milled plastic enclosure:

7.1cm wide
11.5cm long
5.4cm high
coated on the inside and outside with either 0.001" (0.0254mm) or 0.002" (0.0508mm)
thick plating
with screws 3.5cm apart on the long seam and 6cm on the short seam

The aluminum foil covered plastic enclosure:

8.2cm wide
12cm long
5.7 cm high
foil thickness approximately 0.0005" (0.0127mm)
with one screw at each of the four corners

The cast aluminum enclosure:

12cm wide
12cm long
6 cm high
3mm thick
with one screw at each of the four corners

3) The tests performed

A summary of the enclosures tested and the type of field and frequency range is provided as follows:

RS101 10kHz to 100kHz

- 1) Nickel 0.001” thick vacuum deposited plastic enclosure. Non conductive screws

- 2) Nickel 0.002 ” thick vacuum deposited plastic enclosure. Conductive screws

- 3) Cast aluminum enclosure with four non conductive mounting screws, due to uneven contact surface gaps were present in the joint

- 4) Cast aluminum enclosure with four conductive mounting screws, due to uneven contact surface gaps were present in the joint

- 5) Cast aluminum enclosure with conductive mounting screws, Wire mesh gasket in the joint

- 6) Cast aluminum enclosure with conductive mounting screws, gaps. Gore gasket in the joint

- 7) Plastic enclosure covered in aluminum foil with silver loaded gasket

- 8) Milled metal enclosure with same dimensions as 1 and 2. Non conductive screws

- 9) Milled metal enclosure with conductive screws

H field 100kHz to 10MHz

- 1) Nickel 0.002 ” thick vacuum deposited plastic enclosure. Conductive screws. Current flow across the seam

- 2) Nickel 0.002 ” thick vacuum deposited plastic enclosure. Conductive screws. Current flow parallel to the seam

- 3) Cast aluminum enclosure with four conductive mounting screws, due to uneven contact surface gaps were present in the joint

- 4) Cast aluminum enclosure with four conductive mounting screws, gaps. Gore gasket
- 5) Cast aluminium enclosure with four conductive mounting screws, gaps. Wire mesh gasket
- 6) Plastic enclosure covered in aluminum foil with silver loaded elastomeric gasket
- 7) Milled metal enclosure with same dimensions as 1 and 2. Conductive screws

RS03 Electromagnetic wave using E field and H field probes

- 1) Nickel 0.002" thick vacuum deposited plastic enclosure. Conductive screws , no gasket
- 2) Nickel 0.002 " thick vacuum deposited plastic enclosure. Conductive screws, silver loaded elastomeric gasket
- 3) Cast aluminum enclosure with four conductive mounting screws, due to uneven contact surface gaps were present in the joint
- 4) Cast aluminum enclosure with four non conductive mounting screw, gaps. Gore gasket
- 5) Milled metal enclosure with same dimensions as 1 and 2. Conductive screws

4) Seams are the major weak links in a shielded enclosure

The shielding effectiveness of a material is dependent on the skin depth which is determined by its conductivity, permeability and thickness as shown in reference 1 page 285. Even a thin, highly conductive material , such as aluminum baking foil, should achieve a high level of shielding above approximately 10MHz. For a thicker pure conductor this frequency will be much lower. However the enclosures used to contain electronics must have seams and as demonstrated in the measurements described in this report the seams are the weak link in the enclosure.

5) Cables are normally the weakest link in the implementation of effectively shielded equipment

In twenty eight years experience in EMI testing of military, commercial, scientific, industrial, space, medical, and automotive equipment, the sources of radiated emissions and susceptibility, in a radiated susceptibility test, are invariably the cables. This is true when the electronics are placed in a conductive enclosure and the size of aperture is relatively small and the ratio of aperture to enclosure size is kept relatively low. To see just how large an aperture is possible without unduly affecting shielding effectiveness see reference 1 page 325.

Only twice in my experience has a really poorly manufactured enclosure leaked electromagnetic radiation at a higher level than the cables.

One good example of the shielded cable as the limitation on enclosure shielding effectiveness measurements is the test set up for RS03 described in this report.

Here the enclosure under test was mounted under a strip line antenna with the only the end of the cable connected to the enclosure illuminated by the incident E field. To measure the level of cable pick up and therefore the highest shielding effectiveness that could be measured on the enclosures, the milled shielded enclosure, with the highest predicted level of attenuation, was used and instead of an E -field probe or H field probe inside the enclosure, a 50Ω SMA termination was installed. The coaxial cable was a semi-flex type with no apertures, the gold plated SMA connectors are specified with greater than 90dB of shielding effectiveness, and the cable outside of the stripline antenna was covered with both high and low frequency ferrite baluns. Despite these precautions, the measured shielding effectiveness was as low as 23dB to a maximum 58dB. Once a solid copper pipe was used to cover the coaxial cable and beryllium finger stock was used to connect the end of the copper pipe to the enclosure under test, the shielding effectiveness, limited by the test set up coupling and not the enclosure, rose to 50dB to 76dB.

The reason to mention this is that however effective a conductively coated plastic enclosure is, it is still necessary to terminate the shield of shielded cables to the conductive surface of the plastic with a low impedance connection. If unshielded cables are used then it is necessary to terminate common mode filter capacitors to the conductive surface of the plastic with a low impedance connection and it is these connections which often pose the greatest engineering challenge to the mechanical/packaging engineer and not the design of the plastic enclosure. It is also typically these connections which limit the shielding against incident fields and not the enclosure.

6) RS01/RS101 test set up for shielding effectiveness.

6.1 Test set up

In this test set up a 22 turn coil of #18AWG magnetic wire with a diameter of 2.37cm was contained within each of the enclosures as a receiving antenna. An SMA barrel was soldered into a brass plate and each of the enclosures has an aperture over which the brass plate was placed and held in place by four 2-32 fasteners. A semi-flexible cable assembly with SMA connectors on both ends was used to connect from the SMA barrel on the enclosure to a bulkhead mounted SMA connector on the anechoic chamber wall.

The cable assembly has a greater than 90dB shielding effectiveness up to 18GHz according to the manufacturer. In addition low permeability high frequency as well as high permeability, low frequency toroidal ferrite baluns were placed on the receiving antenna cable to reduce the current flow induced onto the cable by the test field. For this test set up the cable achieved a sufficiently high attenuation so as not to limit the measurement on the enclosure. This is due to the low shielding effectiveness of the enclosure at these low frequencies so that the coupling between the transmitting loop and the receiving cable becomes insignificant.

Also the low frequency magnetic field coupling to a coaxial cable is a function of the eccentricity of the center conductor relative to the shield. When the center conductor is exactly in the center of the coaxial shield then the magnetic field coupling to the cable will be close to zero, and minimum cable coupling exists. As with all tests a measurement was made of the coupling between the transmitting loop and the receiving antenna cable and its termination to the enclosure alone. With the transmitting loop 5cm from the enclosure the receiving loop inside the enclosure was replaced with a SMA 50Ω load. The coupling between the transmitting loop and the receiving cable was below the noise floor of the measuring system, which included a 20dB pre-amplifier. The transmitting antenna used was the 20 turn 12cm diameter transmitting loop specified in MIL-STD-462 and MIL-STD-462D.

The transmitting loop has been calibrated using the 51 turn 4cm diameter receiving loop, specified in MIL-STD-461D, at a distance of 5cm from the transmitting loop. During measurements on the enclosure the transmitting loop was placed at a distance of 5cm from the enclosure under test and moved around the enclosure. As expected maximum coupling was seen when the transmitting loop was coaxial to the receiving loop in the enclosure. Figure 6.1 illustrates the test set up. A measurement was made with the transmitting loop and the receiving loop at the appropriate distance apart but without an enclosure. This is the reference unshielded level to which the measurements with all enclosures are compared. The receiving loop is then placed in each of the different enclosures under test and the measurement is repeated. The difference between the reference level and the level with the loop inside the enclosure is the shielding effectiveness of the enclosure.

The shielding effectiveness in dB is thus $20 \log (\text{reference level}/\text{level inside enclosure})$.

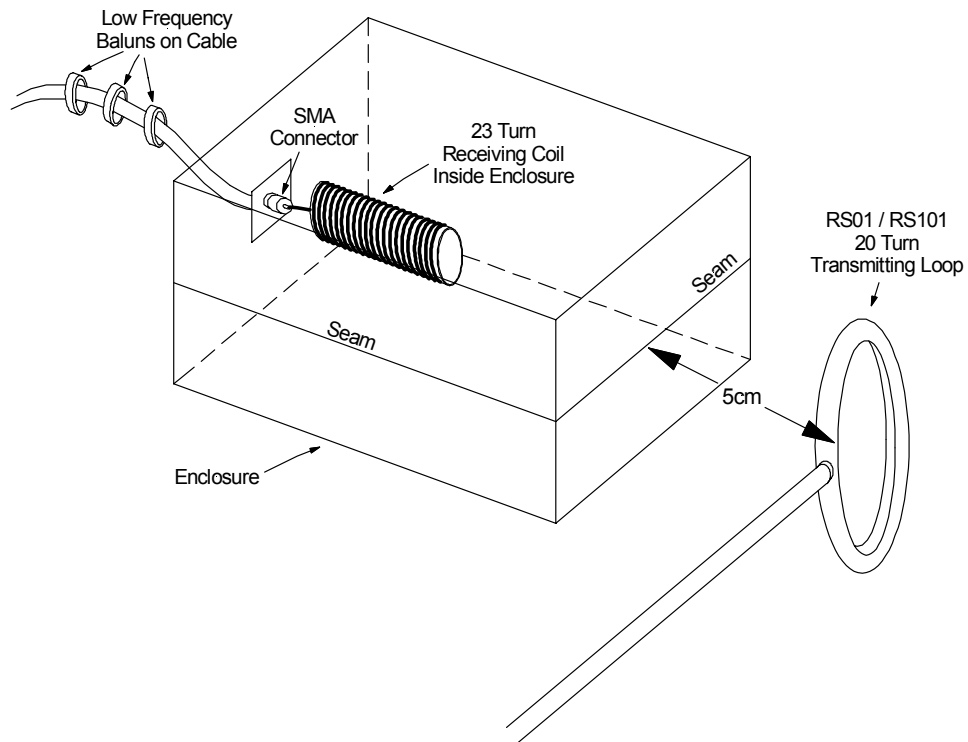


Figure 6.1 Test set up for RS01/RS101 shielding effectiveness

A summary of the shielding effectiveness of the different enclosures in the RS101 test is shown in figure 6.2.

6.2 H field shielding effectiveness test results with and without gaskets

Due to the thin plating on the conductively coated plastic and the thin aluminum foil on the plastic enclosure the low frequency shielding effectiveness is expected to be limited and ranges from 2 to 12dB over the 10kHz to 100kHz frequency range, as shown in figure 6.2. The measured shielding effectiveness of the 0.001” and 0.002” thick nickel plating was virtually identical and only the results for the 0.002” thick plating are provided in figure 6.2.

The cast metal enclosure has a thickness of 3mm and should be very effective, however due to the poor seam the shielding effectiveness is limited to 15dB to 24dB over the same frequency range. Adding a wire mesh gasket to the cast enclosure actually reduces the shielding effectiveness to from 12dB to 15dB. This effect may seem surprising, however

adding the wrong gasket normally results in a degradation compared to no gasket at all. The exception to this rule is when large gaps exist in a seam and this is filled by a conductive gasket. This is further explored in reference 1.

The cast metal enclosure with a Gore gasket results in a great improvement in shielding effectiveness from 21dB to 35dB.

The milled enclosure without gasket has the best seam and the result is a shielding effectiveness from 31dB to 49dB over the 10kHz to 100kHz frequency range.

The different enclosures with the RS01 transmitting loop are shown in photos 6.1, 6.2, 6.3, and 6.4.

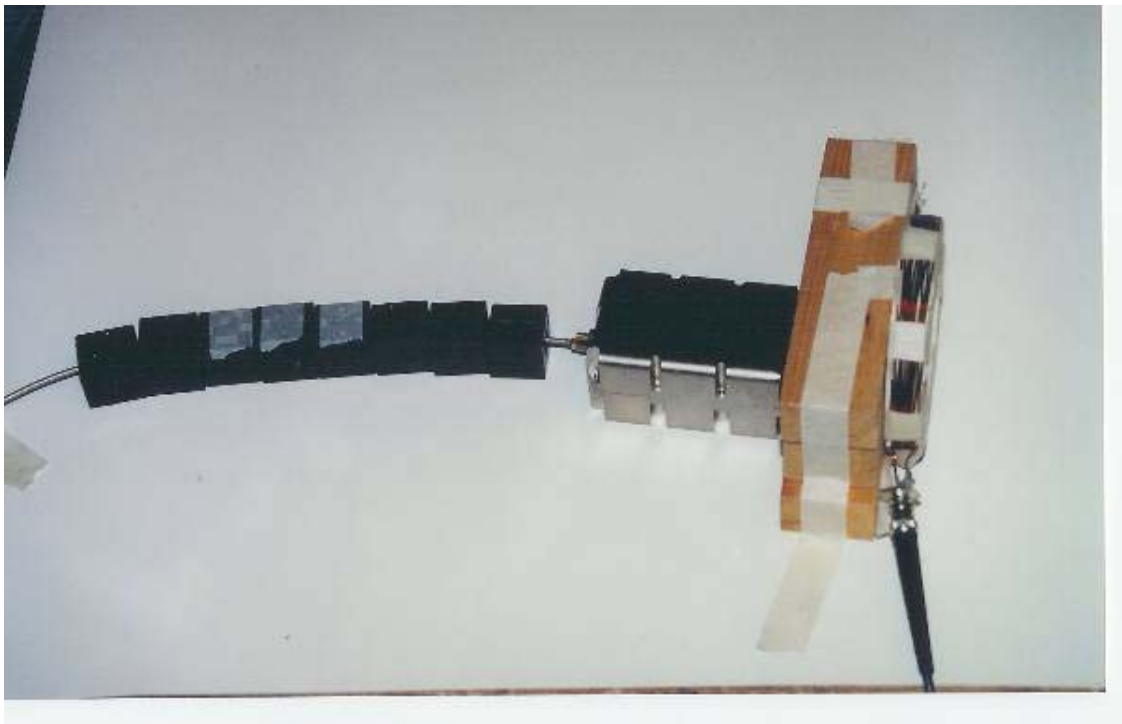


Photo 6.1 Nickel plated plastic enclosure in the RS01 test set up

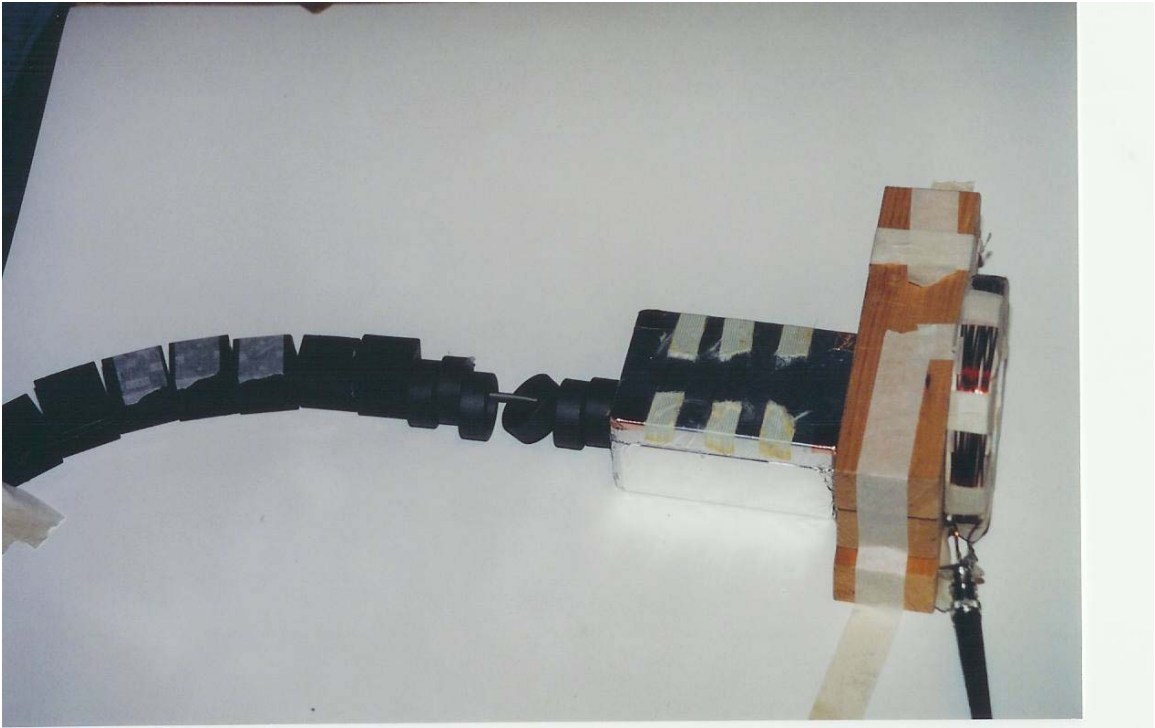


Photo 6.2 Foil covered plastic enclosure in the RS01 test set up

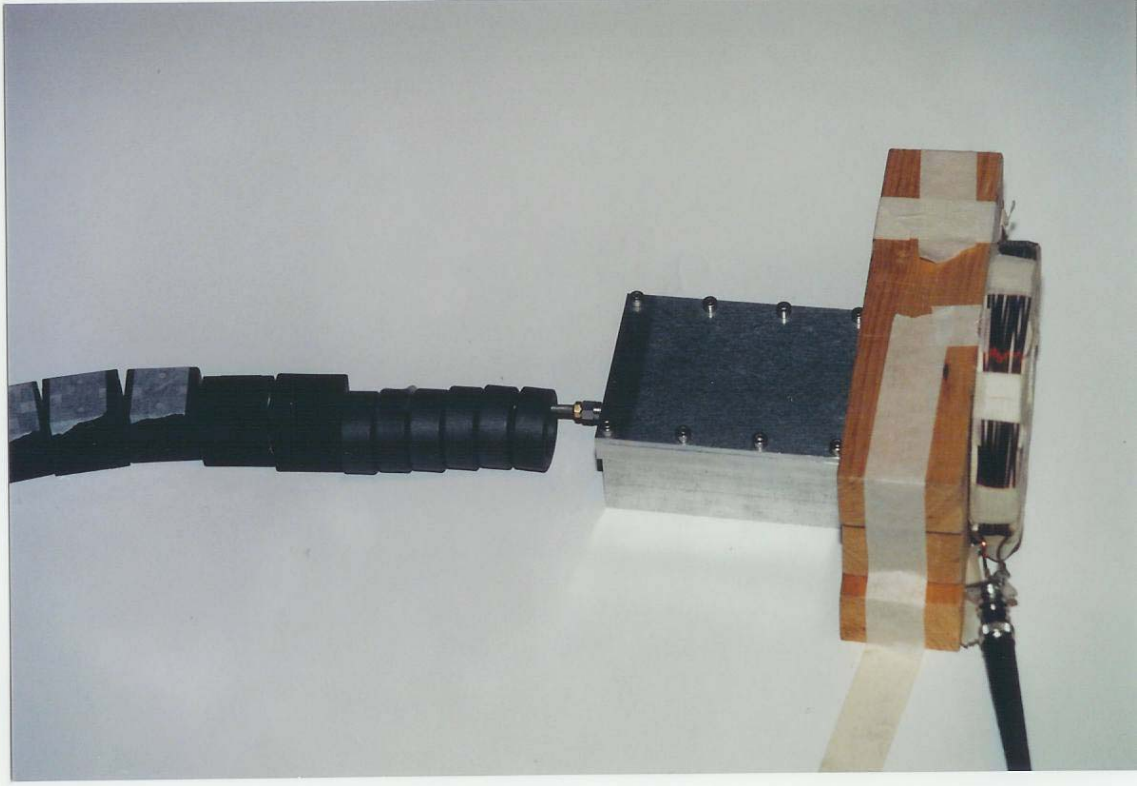


Photo 6.3 Milled aluminum enclosure in the RS01 test set up

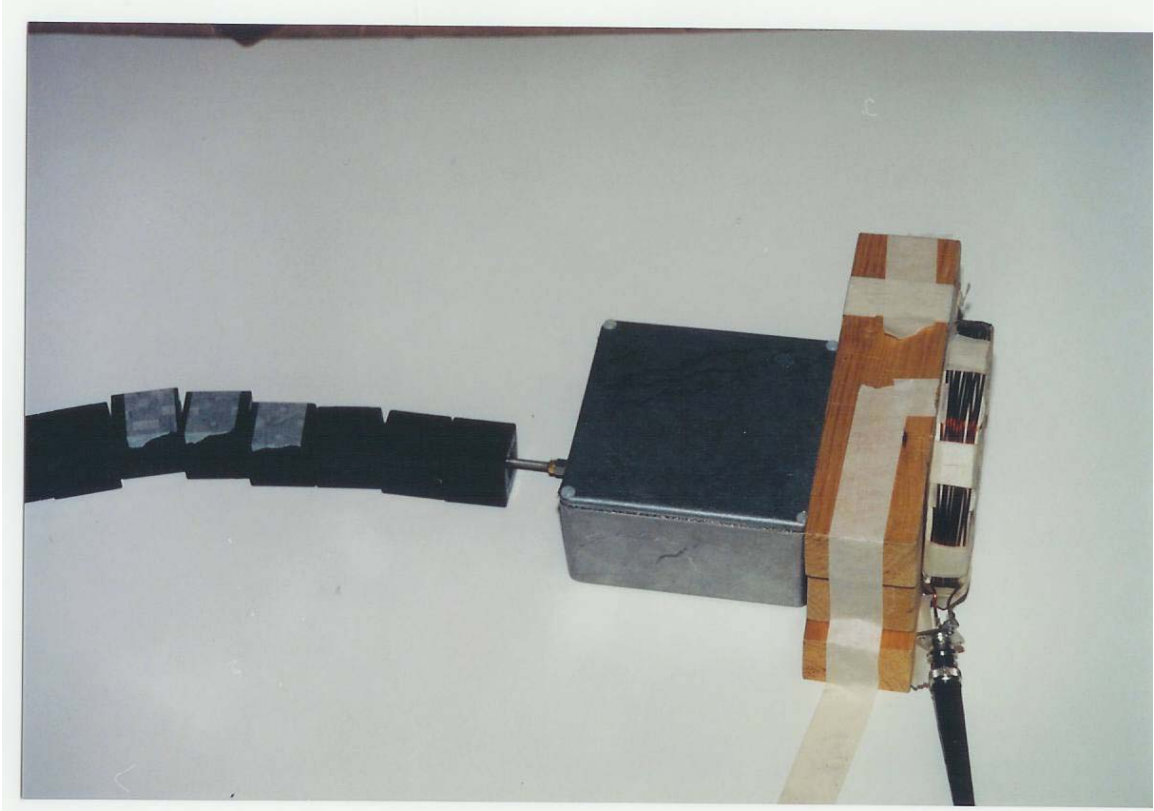


Photo 6.4 Cast aluminum enclosure in the RS01 test set up

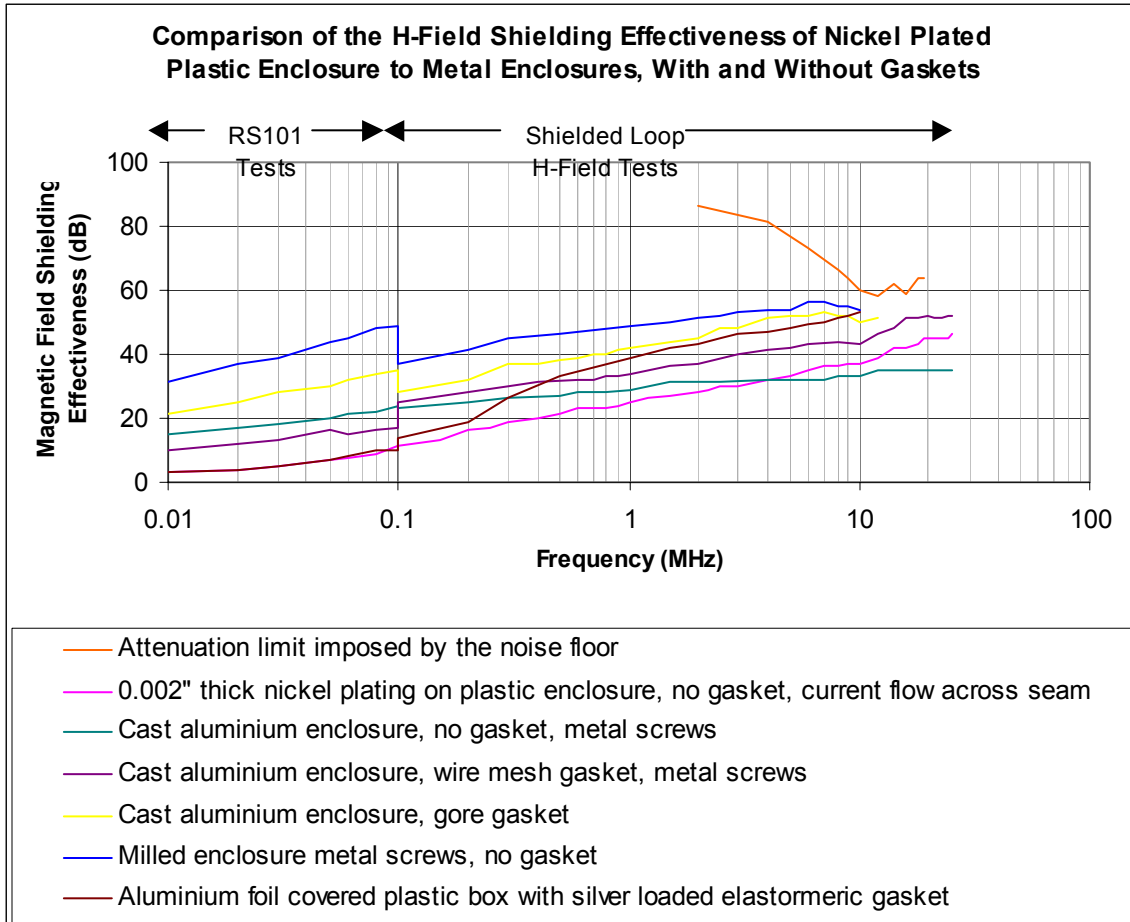


Figure 6.2 H field shielding effectiveness of the different enclosures from 10kHz to 100kHz in the RS101 test and from 100kHz to 10MHz or greater in the H field loop test.

6.3 The role of fasteners

The type of fastener used to seal the enclosure plays a role in the shielding effectiveness. A conductive fastener will provide an alternative current path to the seam and also result in a higher pressure between the mating halves of the seam than is usually obtainable with non conductive fasteners.

Figure 6.3 shows the difference in H field shielding effectiveness for the cast aluminum enclosure with metal screws and the same metal screws insulated from the lid of the enclosure by nylon washers. This test result shows the increased shielding effectiveness when screws bridge the gap. The screws with nylon washers result in the same pressure on the seam as without and so this effect is eliminated.

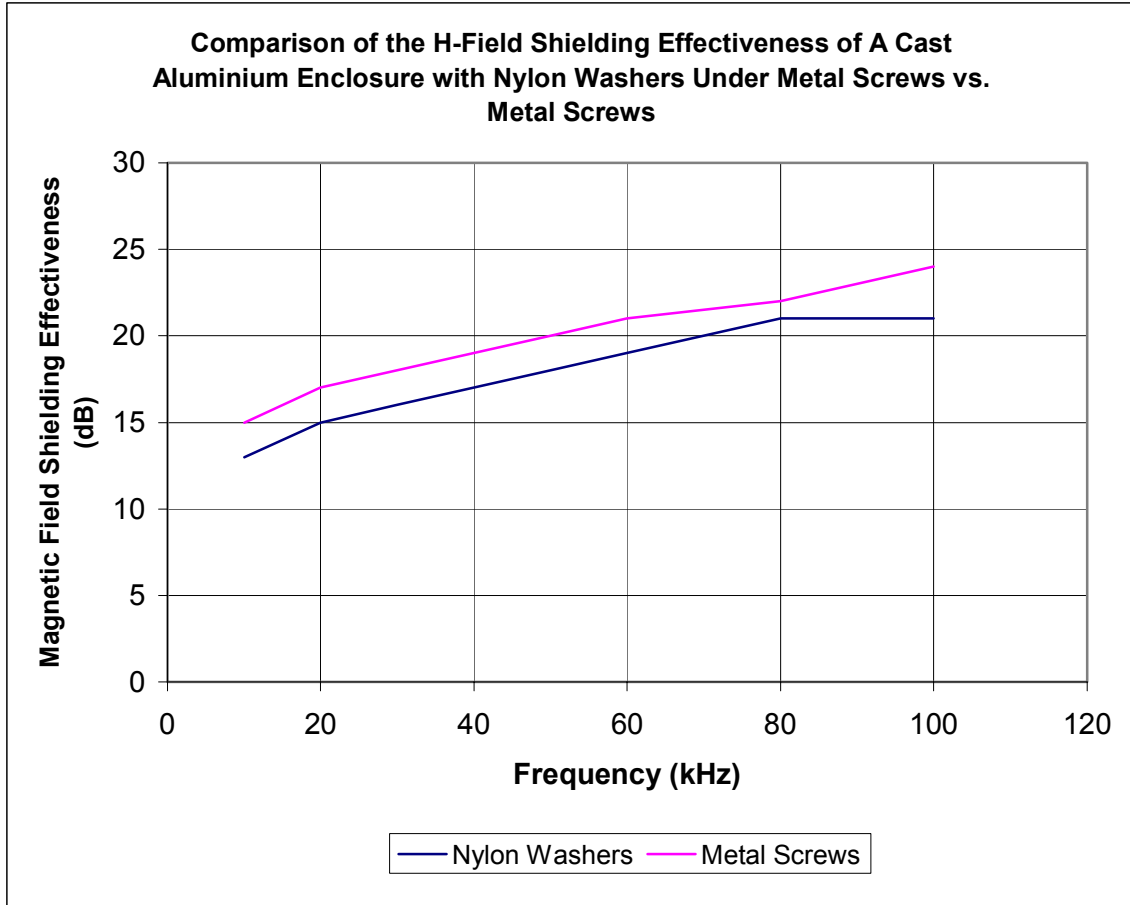


Figure 6.3 Cast aluminum enclosure with metal screws and with nylon washers under the metal screws.

Figure 6.4 shows the difference in shielding effectiveness of the milled enclosure with metal screws and with nylon screws. Both the pressure on the seam will be different as well as the effective bridging of the gap by the screws and the difference is anywhere from 15dB to 20dB.

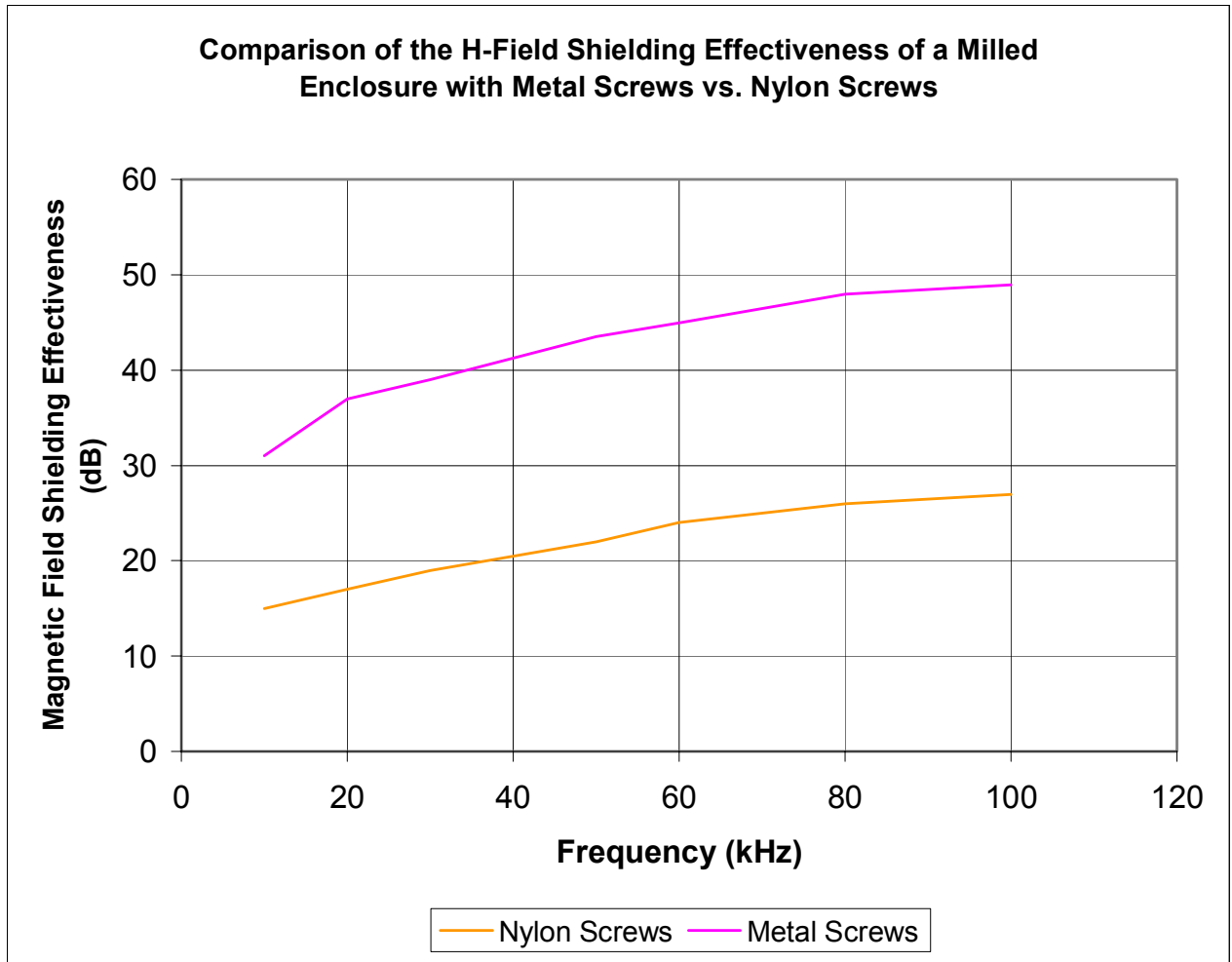


Figure 6.4 Milled enclosure with metal screws vs nylon screws.

The rule of thumb for a thin 1/16" (1.59mm) thick aluminum enclosure is to have metal fasteners no further than 1" (2.54cm) apart to make an effective EMI seal. For milled enclosures the distance between fasteners may be as much as 2.5" (6.35cm).

6.4 Prediction tool for magnetic field shielding effectiveness

The low frequency magnetic field shielding effectiveness of an enclosure without apertures is dependent on the dimensions, thickness of the conductive material, resistivity and permeability of the material and the presence of gaps in the seams and the dc resistance across the seams.

Reference 1 pages 317 to 320 describe the relationship.

The cast metal enclosure contains small gaps in the seams due to the use of only four fasteners one at each corner of the enclosure and imperfections in the casting. The above measurements of SE were made with; ungasketed seams, with a wire mesh gasket and a thin elastomeric gasket manufactured by Gore. At the same time a dc resistance

measurement was made across a single 0.12m long seam. The measurements were made with nylon fasteners and so the only electrical contact was at the seam. The results of these dc resistance measurement are shown in table 6.1.

Table 6.1 dc resistance of seams in the cast aluminum enclosure

Cast aluminum enclosure No gasket	Cast aluminum enclosure Wire mesh gasket	Cast aluminum enclosure Gore gasket
dc resistance mΩ		
1.0	2.16	0.06

In reference 1 equations are provided for the magnetic field shielding effectiveness of metal enclosures (page 318 equations 6.24 - 6.29).

The data inputs are:

- Dimensions of enclosure
- Length of seams and number of seams
- Contact impedance of the seam
- Inductance of the seam
- DC resistance of the seam
- Relative conductivity of the material
- Relative permeability of the material
- Thickness of the material
- Number of apertures (if any)
- Diameter of apertures

Table 6.2 compares the predicted shielding effectiveness with the measured and a very good correlation exists

The measurements were made using metal screws and so the dc resistance of the enclosures would be lower than shown in table 6.1 The contact resistance (which is multiplied by \sqrt{f}), the inductance in Henries and the dc resistance data were all set to match the measured test results. The values are as follows:

Cast metal enclosure , no gasket

$$R_c = 1e-6$$

$$R = 1m\Omega$$

$$L = 1e-9H$$

Cast metal enclosure wire mesh gasket

$$R_c = 5e-9$$

$$R = 1m\Omega$$

$$L = 3e-9H$$

Cast metal enclosure Gore gasket

$$R_c = 1e-9$$

$$R = 0.2m\Omega$$

$$L = 4e-10H$$

As seen in other measurements, described in reference 1, adding a wire mesh gasket increases the inductance of the seam, even when apertures exist, and adding a gasket with conductive particles decreases the inductance when small apertures exist in the seam which are filled by the gasket material.

Table 6.2 Measured versus predicted H field shielding effectiveness

f (kHz)	cast metal ,no gasket		cast metal, wire gasket		cast metal, Gore gasket	
	predicted	measured	predicted	measured	predicted	measured
10	6	13	6	-	20	21
20	11	15	11	-	25	25
30	14	17	13	13	27	28
50	18	19	15	16	31	30
60	19	20	16	15	32	32
70	19	21	16	15	32	33
80	20	22	17	16	33	34
90	20	22	17	16	33	34

100	22	22	18	17	34	35
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The measured versus predicted values for a plastic enclosure coated both inside and outside with nickel and with metal screws is provided in table 6.4. Here the value of R for the joint resistance was set to $1.0\text{m}\Omega$, Rc to $1\text{e-}6$ and $L = 1\text{e-}9\text{H}$ for the closest match to the measured values as shown in table 6.3

Table 6.3 Measured and predicted shielding effectiveness of a plastic enclosure with a .001” thick nickel coating

$f(\text{kHz})$	Predicted shielding effectiveness (dB)	Measured shielding effectiveness (dB)
30	2	4
50	6	6
60	8	7
100	12	11

The usefulness of these equations is in collecting measured data on different types of enclosure, gasket and spacing of fasteners which can then be used to predict the magnetic field shielding effectiveness of enclosures with different dimensions.

7) Magnetic field shielding effectiveness tests from 100kHz to 10MHz or greater.

When an incident H field or the H field component of an electromagnetic wave impinges on a small enclosure it sets up a current flow on the outside surface of the enclosure. In the real world we can not typically control the direction of the current flow across the seam of the enclosure and electromagnetic waves are often both vertically and horizontally polarized and may have different angles of incidence due to reflections. In all of the H field tests described in this report the antennas are oriented to ensure maximum current flow across the seam of the enclosure with one exception where the transmitting antenna was oriented to cause the current flow down the length of the seam. When a current is induced by an incident field onto the outside surface of a small enclosure some of the current diffuses through the seams and a current flow occurs on the inside of the enclosure. This internal current flow results in an internal magnetic field in a small enclosure. Regardless of the incident wave impedance it is the magnetic field shielding effectiveness which is the most important at these frequencies and typically the electric field shielding effectiveness is much higher.

In this test set up a small shielded loop antenna is placed inside the enclosure under test and a 6cm diameter shielded loop antenna is placed outside the enclosure at a distance of 5cm from the enclosure. Photo 7.1 shows this test set up for the cast aluminum enclosure.

The transmitting antenna and receiving antenna are both oriented coaxially for maximum coupling and a reference measurement is made between the two antennas without any enclosure. The test is then repeated with the antennas the same distance apart and with the same input levels.

These measurements were made between 100kHz and 10 - 18MHz.

The relative shielding effectiveness of the different enclosures changes with increasing frequency. For example the nickel plated plastic enclosure has a higher level of shielding effectiveness than the cast enclosure without gasket above 4MHz. This is because the cast enclosure has small gaps in the seam and the nickel coated plastic does not. Also the cast metal enclosure with wire mesh gasket has a higher level of shielding effectiveness than the cast metal with no gasket in this test set up and this increases with increasing frequency. The cast metal with Gore gasket is close to the same level as the milled enclosure above 4MHz. The most surprising result is how good the aluminum foil covered plastic enclosure, with silver loaded elastomeric gasket, is with increasing frequency. Figure 6.2 contains the H field shielding effectiveness data in the shielded loop test. As the test results with the 0.001" and 0.002" thick nickel plating were virtually identical the results for the 0.002" are presented in Figure 6.2.

The conductivity of the enclosure material is normally high enough and it is the seam which is the weak link even in the relatively thin nickel plated plastic enclosure. This is shown dramatically in figure 7.1 which shows the magnetic field shielding effectiveness of this enclosure with the induced current flow across the seam versus the current flow down the length of the seam. The shielding effectiveness at 4MHz is 40dB higher when the current does not flow across the seam, proving conclusively that in this enclosure the seam is the weak link.

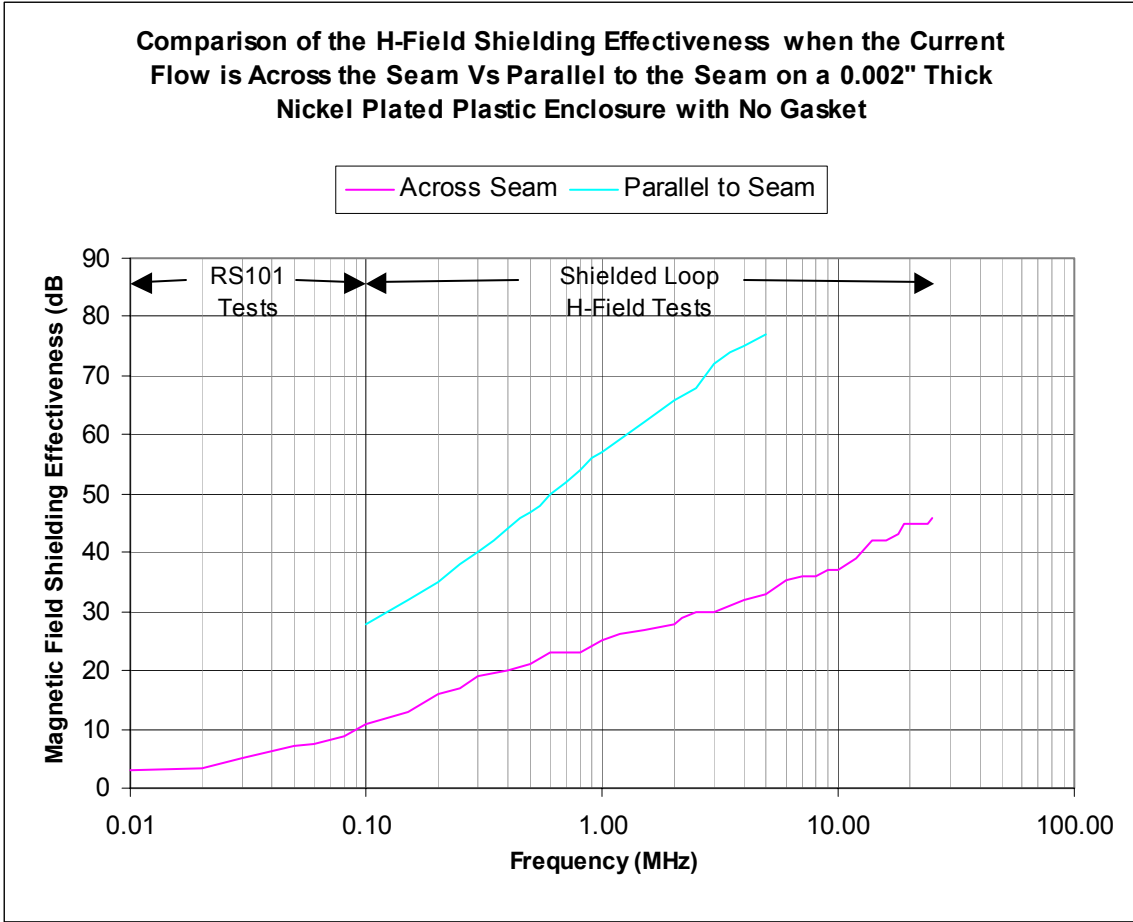


Figure 7.1 Comparison of the magnetic field shielding effectiveness with the induced current flow across the seam versus down the length of the seam.

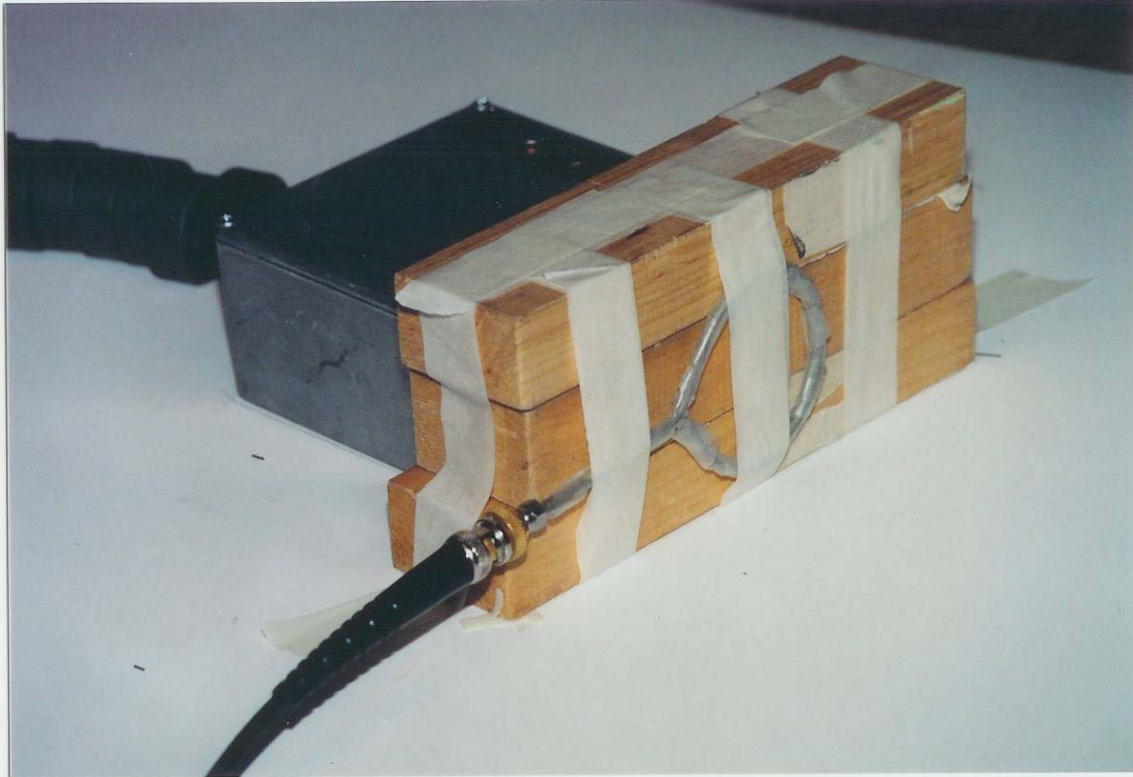


Photo 7.1 Test set up for the magnetic field shielding effectiveness test 100kHz - 10MHz or greater

8) RS03/RS103 tests on the enclosures from 10MHz to 250MHz.

For this test the enclosures were placed inside the plates of a stripline antenna. The advantage of the stripline for radiated susceptibility tests is that a very high field may be generated for a given input power, the field uniformity is very good and the field is mostly confined between the plates, meaning that coupling to the cable connected to the enclosure under test is reduced. Despite the use of ferrite baluns, a well shielded cable and connector, the maximum shielding effectiveness measurable with this set up was limited. As with all tests the limit is tested by terminating inside the enclosure, with the highest predicted shielding effectiveness, using a 50Ω termination and measuring the coupling to the cable.

Only when the test cable was placed in a solid copper pipe and the pipe terminated to the enclosure under test was the maximum shielding effectiveness sufficiently high.

Photo 8.1 shows the termination of the pipe to the enclosure.

The wave impedance inside any transmission line terminated in its characteristic impedance, as long as the medium inside the transmission line has a relative permittivity of 1, is 377Ω . This is the wave impedance of a plane wave and the strip line antenna also generates a TM wave up to 250MHz with this impedance.

A small shielded loop antenna and a small e field probe were used inside the enclosures to measure both the E field and H field shielding effectiveness. As seen many times before the E field shielding effectiveness is much higher in all enclosures than the H field shielding effectiveness. When the electronic circuits inside the small enclosure are high impedance then it is the E field shielding which is important. However when wire or PCB loops exist and the termination is a low or even medium impedance than the H field shielding is the most important.

Figure 8.1 shows the magnetic field shielding effectiveness from 10MHz to 250MHz. The highest attenuation is achieved by the cast aluminum enclosure with Gore gasket. However without a gasket the cast enclosure has the lowest attenuation. The second highest attenuation is achieved by the milled enclosure without gasket, proving that in some cases EMI gaskets are not required. Adding a gasket to the nickel plated plastic enclosure only increases the shielding effectiveness very slightly, but even without a gasket the enclosure is as at least as good as and even better above 170MHz than the cast enclosure with no gaskets. A groove was provided in the rim of the nickel plated plastic enclosure but the gasket was too thick and although compresses enough to ensure a contact the coating did not make contact to the material either side of the groove. With a conductive gasket and electrical contact either side of the gasket the shielding effectiveness may improve slightly.

Figure 8.2 shows the electromagnetic field shielding effectiveness where the source is an electromagnetic wave and the measuring antenna is the small E field probe. Here the nickel coated plastic enclosure has one of the highest levels of attenuation and the milled enclosure with Gore gasket is very slightly lower. The lowest level of attenuation is achieved with the cast aluminum enclosure without gasket and the milled enclosure, cast enclosure with gasket and nickel coated plastic enclosure are all very similar above 150MHz.

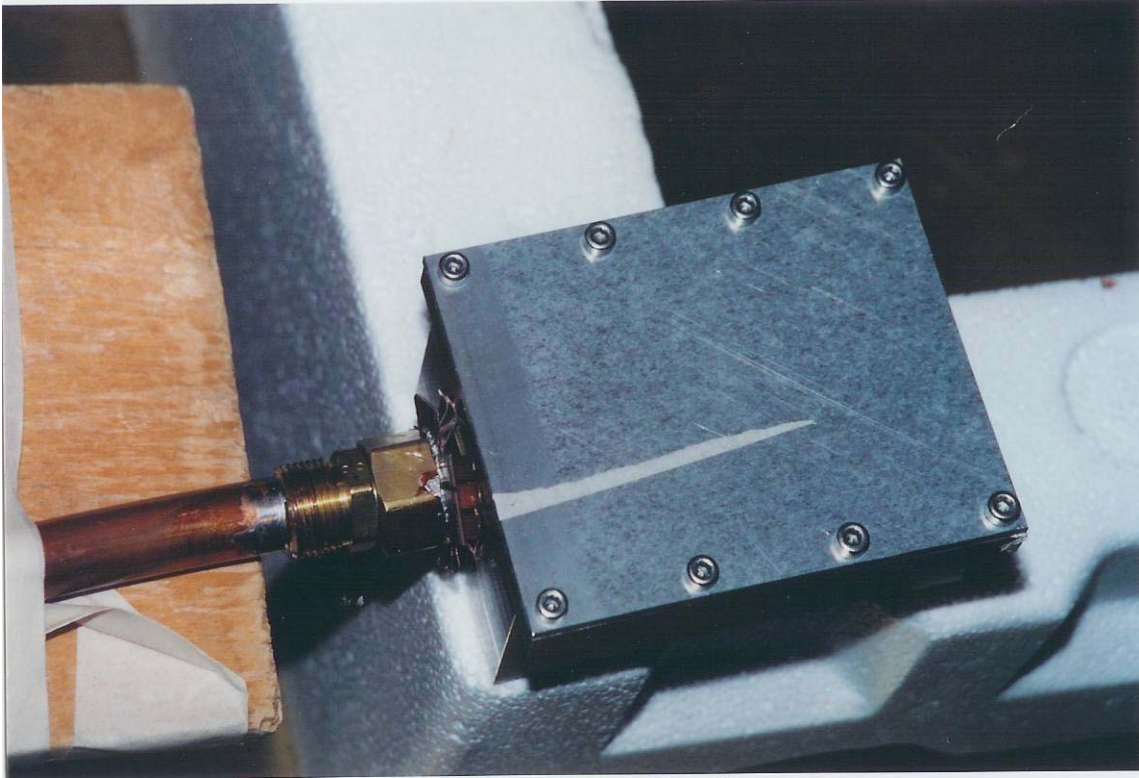


Photo 8.1 Termination of the copper pipe to the enclosure

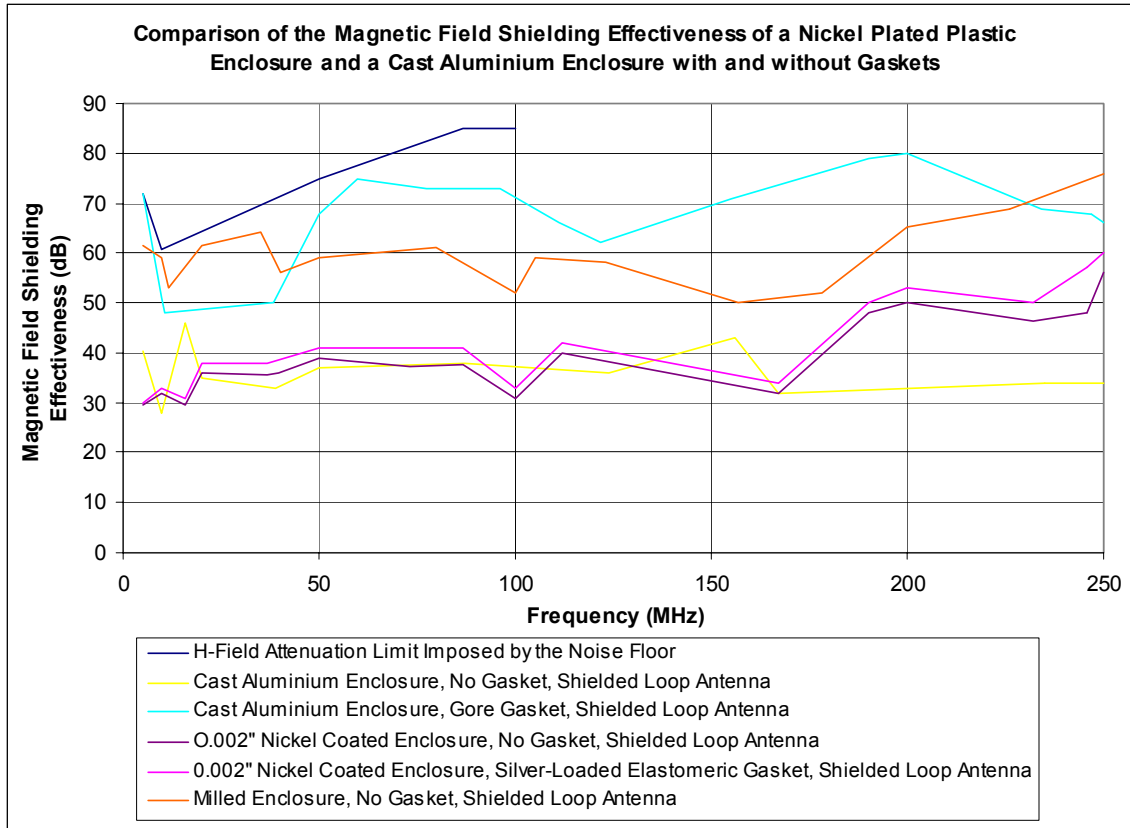


Figure 8.1 Magnetic field shielding effectiveness measured using a RS03 test setup and a small shielded loop antenna for monitoring

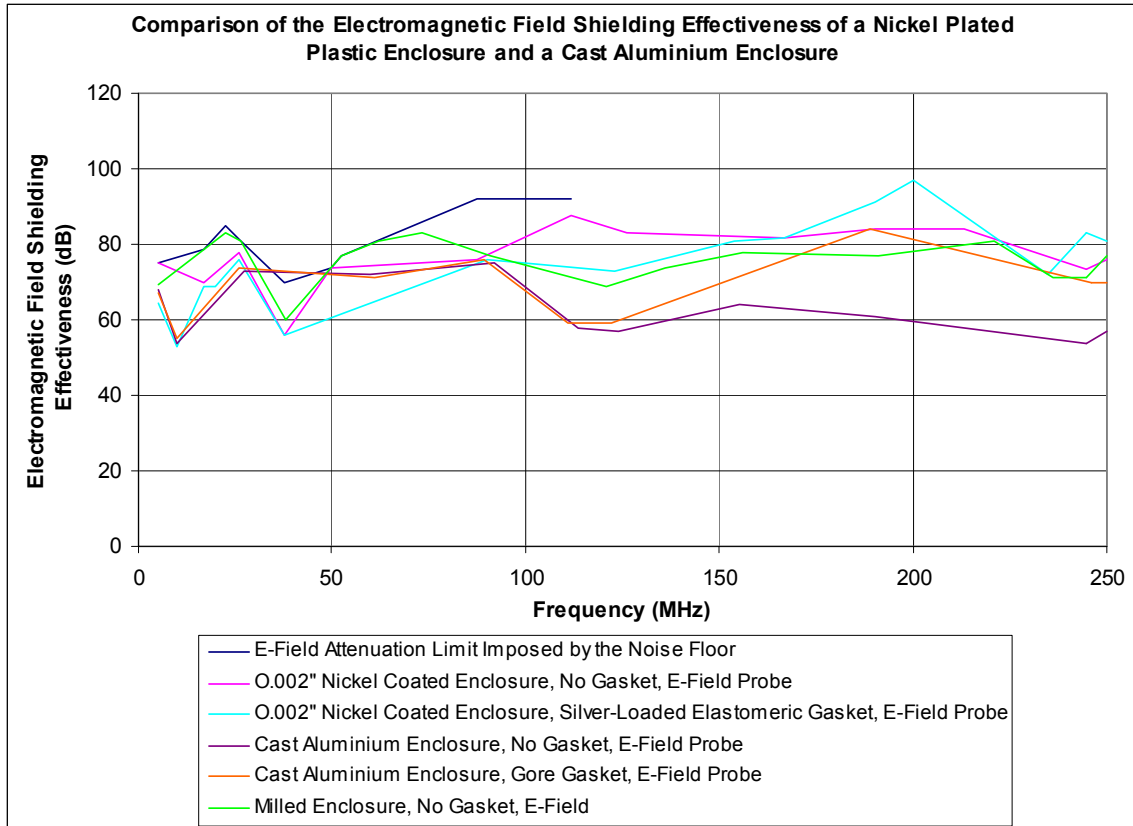


Figure 8.2 Electromagnetic wave shielding effectiveness measured using a RS03 test set up and a small electric field probe.

9) Conclusions

The vacuum deposition of nickel results in a surface conductivity which is very close to pure metal. It can also be expected that electro-plated and plasma flame sprayed plastic will have a very high conductivity. Another investigation will be made of different types of conductive coating such as paint, but it is predicted that the attenuation achieved with paint will be lower than with a pure metal plating. Thus we must consider the measured shielding effectiveness of the nickel plated plastic enclosure described in this report to be as high as achievable with a conductive coating.

The RS101 radiated susceptibility test starts at a frequency of 30Hz and even a milled enclosure will have negligible shielding effectiveness at this frequency.

Achieving immunity to the RS01/RS101 test from 10kHz to 100kHz is more difficult when using a thin conductive coating compared to solid metal due to the skin depth effect.

Figure 6.1 shows a lower shielding effectiveness over this frequency range. However even with the milled enclosure the shielding effectiveness is limited to 32dB at 10kHz. Thus to achieve immunity to the RS01/RS101 test level from 30Hz to 1kHz the same

circuit level precautions must be with the conductively coated plastic as for a solid metal enclosure.

From 10kHz to 100kHz , and even, above some additional care in the design may be required when using the conductively coated enclosure. This involves reducing loop areas in PCB traces and wiring, the use of balanced differential inputs and high impedance loads at low frequency.

From 10MHz to 250MHz, and we can presume beyond , the E field induced into the enclosure during the electromagnetic field test shows the shielding effectiveness of the coated enclosure and the milled enclosure are either at the same level or the nickel coated enclosure is even higher. Thus achieving immunity to the E fields induced during application of the RS103 test level, which is amplitude modulated with a square wave at 1kHz, will require the same circuit design for both types of enclosure. For magnetic field shielding (magnetic fields are also induced inside the enclosure during the RS03/RS103 tests) the conductively coated enclosure shows a shielding effectiveness up to 20dB lower than the milled aluminum enclosure. This means that some additional “design for immunity” may be required at the circuit level. Any semiconductor junction will rectify an amplitude modulated RF signal and the level may be heard in a audio signal or result in noise in an analog, RF or control signal. The most common and effective solution to am demodulation at the circuit level is the use of a low value capacitor at the input of potentially susceptible circuits and ICs. The capacitor must be as close to the input pin/s of the IC as possible and be connected to a solid ground plane, using no or very short and wide PCB traces.

The main problem with achieving sufficient overall shielding with the conductive plastic enclosure is in the technique used to terminate the shields of cables , or the housing of filtered connectors or filter plates to the conductive coating. One technique is to use a small pad of copper or brass mounted inside the enclosure and contacting the conductive coating. The cable shield or connector housing is then terminated to the pad. This pad , which can be thin, has the effect of spreading and increasing the contact area , but it must make good contact, under pressure, to the conductive coating to be effective.

The conclusion is that it is possible , with some minimal additional care in the design, to use a conductively coated plastic enclosure to contain sensitive circuits and be compatible with the military EM environment.

**Reference 1 “Electromagnetic Compatibility: Principles and Applications.
D. A. Weston Published by Marcel Dekker 2000.**

