Plastics Topics – EMI shielding of plastics

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1. Introduction

We are all familiar with the pilot's request, just before take-off, to turn off mobile phones and other electronic devices but how many people know the reason for this? The simple reason is that all electronic devices give off electromagnetic radiation when they are operating and this can affect other electronic devices in the area if they are not adequately shielded. The unwanted emission of electromagnetic waves from a device can interfere with other devices in the area (which is bad for your neighbours or the plane) but reception of unwanted electromagnetic radiation can also interfere with the operation of your device (which is bad for you).

The amount of electromagnetic interference (EMI) given off by a device can be minimized by the device designer through good circuit design, adequate grounding and the use of suitable filters. However, this may not be adequate for sensitive areas and does not protect the device itself from external EMI factors. In these cases, the device designer almost always turns to EMI shielding for added protection.

The range of EMI present in the modern world ranges from mobile phone radiation through to wireless network radiation and all modern electronic devices need to have a high degree of electromagnetic compatibility (EMC), i.e., they must possess the capability to work in the operational environment without service degradation due to interference. Whilst we cannot see or hear electromagnetic radiation but the issue of electromagnetic 'noise' or 'pollution' from computers, radios, power lines and other sources is growing in importance as our dependency on the wireless connected world increases. This is driving an increase not only in the practical need for EMI shielding but also in the legislative requirements for any new devices that are going to be released onto the market.

2. Methods of EMI shielding

The main objective of any type of shielding is to prevent the passage of electromagnetic waves into or out of the device and EMI shielding can work by reflection, absorption or by carrying the electromagnetic radiation to ground. The fundamental aim is to establish a Faraday cage to provide an EMI shield (named after Michael Faraday who formulated the laws of electromagnetism).

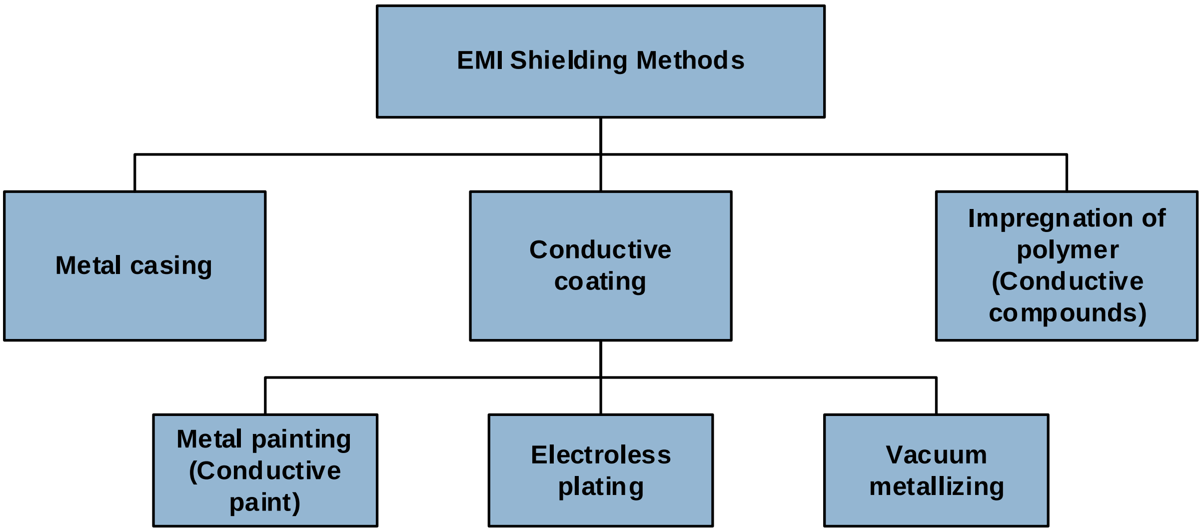
Metals were the original EMI shielding method and metal casings were, for many years, the only method of shielding electronic devices. Metal cans placed on the circuit board are still used in many cases to reduce EMI but their use must be considered early in the design stage and on some circuits the number of metal cans used can add significantly to the weight of the device and can increase the difficulty of recycling the product during disposal.

Plastics have made great inroads into the electronics enclosure market for a range of reasons such as:

- Cost reduction.
- Weight reduction.
- Ease of production
- Improved design freedom (integral and multiple colours, soft touch and product complexity).

Unfortunately, unlike metals, plastics are transparent to electromagnetic radiation and provide no inherent EMI shielding. The rapid rise in the use of plastics in portable consumer electronics has therefore driven the development of a variety of methods for EMI shielding of plastics.

The main methods of establishing a Faraday cage and EMI shielding are shown below:



The main methods of EMI shielding

3. Conductive coatings

Whichever type of conductive coating is used there are several common issues involved in coating plastics for EMI shielding:

- The coating must adhere to the plastics substrate. This is difficult for some plastics and not all plastics will take a coating, e.g., the polyolefins and the fluoropolymers. The majority of coating methods rely upon a mechanical bond between the coating and the plastic and solving this concern may require a pre-treatment (etching) to give the adequate bonding. Even for plastics that do take a coating well, the supplier may produce 'plating' or 'painting' grades with enhanced coating adherence. For some plastics the additives can have an effect on adhesion (particularly plasticizers) and these should also be reduced to a minimum for good adhesion.
- The plastic product should be clean and oil free. Moulding residues such as silicone mould release agents and oil can dramatically affect adhesion between the coating and the plastic substrate. Products should generally be cleaned before coating to ensure a good bond. It is preferable that the mouldings are clean to start with so that contaminants are reduced to a minimum.
- The plastic product should contain a minimum of moulded-in stresses to give good coating adhesion.
- The plastic product should be designed for electrical continuity when assembled and should avoid the creation of 'designed-in' slot antennae.
- The plastic product should be designed for end-of-life recycling, reuse or effective disposal.
- Masking is often necessary to ensure that the correct areas are covered with the desired coating.
- The integrity of the coating must be maintained over time even when exposed to adverse environmental and operating conditions:
    - Scratching of the coating surface can inadvertently create a slot antenna.
    - Parts rubbing together during assembly or use can abrasively remove the coating and break the continuity of the EMI shielding, e.g., snap-fits and location lugs.
    - Thermal cycling can create cracks and loss of continuity due to differences in the coefficient of thermal expansion of the coating and the plastic substrate.

Conductive paint

Conductive paint was one of the first methods used for EMI shielding of plastics and is still one of the most popular methods of providing EMI shielding. There are many types of conductive paints available (silver, silvered copper, copper and nickel) and the metal conductive fillers are included in a variety of paint systems to provide the continuous metal network. The choice of conductive filler is critical to achieving good results, i.e., copper and silver-based paints provide good EMI shielding against electrical fields but are not as effective against magnetic fields and nickel-based paints whilst resistant to scratching have a lower level of conductivity than other paints.

Conductive painting is a multi-stage process:

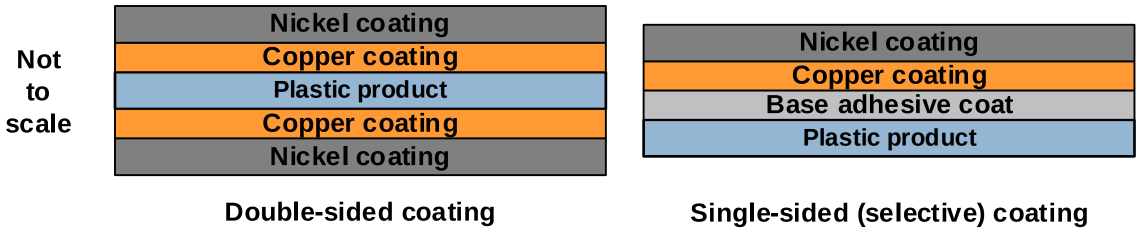
- The part is cleaned to provide good adhesion between the plastic substrate and coating.
- If selective coating is required the product is masked to cover any areas that do not require coating.
- The paint is sprayed onto the product (up to 80-micron thick layer).

The process of conductive painting

As with any spraying process, ‘over-spray’ is inevitable and this is generally in the region of 30-40%. This is paint that is lost to the process and this can increase the cost of the process for complex products where multiple spray passes are needed for the required conductive paint thickness. New spraying techniques such as high-volume, low-pressure (HVLP) spraying can reduce ‘over-spray’ considerably.

Electroless plating

Electroless plating is a method of attaching a thin coating of metal to the plastic to provide the shielding. Unlike electrolytic plating, electroless plating does not need an externally applied current for the process and operates autocatalytically from solution. Electroless plating can be used as either a double-sided coating where the plating is over the complete product or as a single-sided coating (selective coating) where the coating is applied only to selected areas of the plastic. When selective coating is used the product is pre-treated with a base coat and then masked to ensure that coating only takes place where desired. The relative build-up of materials in these two cases is shown below:

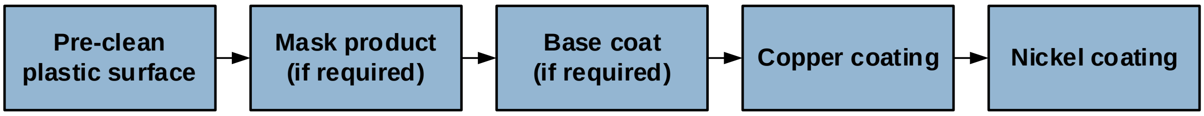


The electroless plating layers

Electroless plating is a multiple stage process:

- The part is cleaned to provide good adhesion between the plastic substrate and coating.
- If selective coating is being used the product is masked to cover any areas that do not require coating and the base coat is applied to the areas to be coated.
- A layer of copper (up to 3 micron) is applied to the plastic surface to provide the conductivity and main EMI shielding. Copper is both soft and susceptible to corrosion and must be protected from abrasion and wear.
- A top layer (up to 1 micron) of electroless nickel alloy is applied over the copper coating to provide corrosion resistance and protection for the copper layer.

The steps in electroless plating are shown below:



The process of electroless plating

Electroless plating provides good EMI shielding against electrical fields and this can be increased by increasing the thickness of the copper layer (either by continued electroless plating or by conventional electroplating. However, the process is not very effective against magnetic fields.

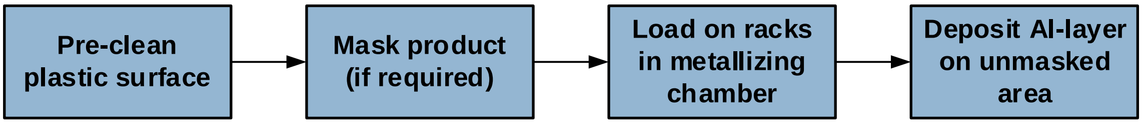
Vacuum metallizing

Vacuum metallization applies a thin coating of aluminium to the surface of the plastic to provide a highly conductive layer and very effective EMI shielding. Aluminium is used because it is inexpensive, has a very high conductivity and is highly corrosion resistant in most environments.

Vacuum metallizing is a multiple stage process:

- The part is cleaned to give good adhesion between the substrate and the vacuum deposited aluminium.
- If selective coating is being used the product is masked to cover any areas that do not require coating.
- A layer of aluminium (up to 10 micron) is applied to the plastic surface to provide the conductivity and main EMI shielding.

The steps in vacuum metallizing are shown below:



The process of vacuum metallizing

Vacuum metallizing can be used for complex shapes but often requires a mask to ensure that the metal is deposited in the correct locations. This can be either by custom mask tooling or by hand masking although custom mask tooling is preferred for larger volumes.

Vacuum metallizing can also be carried out on thermoformed parts to form the equivalent of a metal can for board level EMI shielding.

4. Conductive plastics

Conductive plastics work in a fundamentally different way to conductive coatings. Rather than establish a Faraday cage on the surface of the plastic product they shield by absorption of the radiation in the bulk of the material. The conductivity is in the walls of the plastic enclosure rather than simply on the surface. In this case there is no relationship between the surface resistivity and the shielding; the shielding effectiveness depends on the volume resistivity of the plastic. Due to this volume effect, the actual shielding effectiveness with conductive plastics is also dependent on the thickness of the part, the dispersion of the modifier in the part and the overall conductivity level of the modifier.

Conductive plastics work by including either conductive metals or conductive metallised fibres into the bulk of the material. The fibres have a high aspect ratio (length to thickness) and form a continuous conducting network inside the bulk plastic to provide the EMI shielding. The fibres can be either metal or metal coated and typical fibres used are stainless steel fibres, copper fibres and carbon fibres (alone or nickel coated). These fibres are added in conjunction with a thermoplastic matrix and the overall compound can also include flame retardants or other additives.

Conductive plastics can be processed in injection moulding or extrusion applications although the method of adding the conductive fibres is very slightly different.

Conductive plastics have significant advantages over the conductive coating methods such as:

- The EMI shielding is an integral part of the product and cannot be scratched or delaminated during use.
- Products are complete when moulding is complete and do not require additional spraying or other treatments that can introduce further scrap rates.
- Conductive plastics compounds can be developed for inclusion in almost any plastic material.
- Conductive plastics compounds have no requirement for spraying/coating masks and therefore have very low set-up costs and lead times. This makes them cheaper and sometimes faster for small to medium product volumes.
- Conductive plastics compounds can be used for complex product designs where the cost of masking would be either very expensive or prohibitive.

The arguments are not entirely positive for conductive compounds and for very high volumes (> greater than 1,000,000 parts), the cost of setting up one of the coating processes can be amortized sufficiently to make them very competitive with conductive compounds.

5. Testing

The effectiveness of an EMI shielding method can be indicated either by the surface resistivity (for metals and conductive coatings) or by the volume resistivity (for conductive plastics). This is because of the fundamentally different ways in which these processes act to reduce EMI.

In either case, the measure is an indicator only and the shielding achieved on the final product is the real measure of the effectiveness of the process. The real indicator for a real product is the shielding effectiveness (SE) of the complete item in the actual environment, i.e., the attenuation of the electromagnetic field after the shield has been introduced. This is expressed in decibels (dB) by the formulae:

$dB = 20 \log (EM_{incident}/EM_{transmitted})$ – for any electromagnetic field.

Note 1: If the field is an electrical field, then the EM refers only to the electrical field (E) and if the field is a magnetic field, then the EM refers only to the magnetic field (H).

Note 2: The dB scale is a log scale and that an attenuation of 70dB is therefore 10 times more shielding than an attenuation of 60dB.

The actual attenuation for any EMI shielding method is strongly dependent on the frequency of the incident radiation and shielding methods are rarely equally effective across the wide range of electromagnetic radiation frequencies experienced in real life.

Testing of shielding effectiveness has been carried out by ASTM ES7-83 'Test Method for Electromagnetic Shielding Effectiveness of Planar Materials (withdrawn in 1988) and by ASTM D4935-99 'Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials' (withdrawn in 2005) and there remains some disagreement about the testing method for shielding effectiveness.

For conductive coatings, testing is usually carried out on:

- The ability of the coating to adhere to the plastic substrate. This is very important and can be checked by ASTM D3359 'Standard Test Methods for Measuring Adhesion by Tape Test'.
- The thermal cycling performance. The expansion rate of most coatings is significantly different to the thermal expansion rate of most plastics and long-term thermal cycling can lead to delamination of the coating. This can be checked by thermal cycling tests such as UL 746C.
- The conductivity of the coating. This is an important property for EMI shielding and can be checked using point-to-point measurements (Ω) or ohms-per-square testing (Ω/sq) but the details of these tests are beyond the scope of this document.

For conductive plastics, testing is usually carried out on the conductivity of the overall part.

6. Applications

EMI shielding is used for a wide variety of products such as:

- Personal computer and mobile communication housings.
- Medical equipment housings.
- GPS devices.
- Aerospace components.
- Automotive components
- Analytical instruments.
- Defence and military component housings.

7. Costs

The costs of EMI shielding naturally vary with the method of shielding used and it is important to consider the complete cost for the project and not simply the set-up costs or the individual part treatment costs. It is almost impossible to rank the available processes unless a specific product is considered and the intended production volumes known. The coating methods suffer from set-up costs (mask and racking production) and part costs (cleaning, masking, loading and unloading) whereas conductive plastics have none of the set-up costs but slightly higher part costs.

Designers and manufacturers of parts needing EMI shielding should always consider the options available. What they have traditionally done to provide EMI shielding may not always be the correct solution.

8. Summary

EMI shielding is a topic that is rising in importance in the wireless world where we (and our devices) are subjected to increasing amounts of background electromagnetic radiation. We need to ensure that our devices are not only unaffected by electromagnetic radiation but also that they do not contribute to increased electromagnetic radiation. EMI shielding is destined to become more important as an enabling technology in the future.