EMI – THE NEED FOR SHIELDING

Abstract

There are numerous electronic components, circuits, and building blocks used in electronic and RF systems across all industries. Due to an increase in the number of machines and gadgets emitting electromagnetic waves over the past few decades, protecting instruments and people from electromagnetic interference (EMI) has taken on greater importance. Effective EMC shielding aims to shield sensitive electronic circuits and equipment from electromagnetic interference (EMI) and radio frequency interference (RFI). Electromagnetic interference (EMI) shielding for electronic devices has recently become urgently necessary due to the rapid development of 5G communication technologies, where the creation of appropriate EMI shielding materials against harmful electromagnetic radiation plays a crucial role.In the meantime, new shielding applications have a strong need for EMI shielding materials with great flexibility and functional integrity. Additionally, a range of lightweight, multipurpose, flexible EMI shielding materials have been created.

Recently, a number of methodologies and procedures have been put out in the literature for resolving EMI-related issues. Also, efforts have been made to minimise EMI in specific systems and circuits using newer materials.

This chapter briefly examines the approaches and materials that can be used to resolve these interference issues.

Keywords: EMI, shielding, 5G technology,interference.

Authors

Rajini V Honnungar
Dept of ECE,
R N S Institute of Technology
Bangalore, VTU, India
rajinivhonnungar@rnsit.ac.in

Prabhavathi C N
Dept of ECE,
R N S Institution of Technology
Bangalore, VTU, India
prabhavathi.cn@rnsit.ac.in

I. INTRODUCTION

We encounter electromagnetic on a daily basis. The beneficial aspects of electromagnetic are not relevant in the context of power quality; rather, what matters is how electromagnetic phenomena negatively impact electrical and electronic equipment. The term "electromagnetic interference" (EMI) describes how electromagnetic forces affect proximity equipment.

EMI Techniques and materials known as shielding[1] are employed in electronic systems and equipment to prevent interference and interruption of an existing electromagnetic signal by external electromagnetic impulses, and vice versa. While stiff shields can be used in some applications, flexibility is increased by creating EMI shielding that is bendable, drapeable, and ideally even stretchable.

The following equipment and gadgets are examples of those that are more likely to create EMI than others: mobile phones, burners, motors, and LED displays. Since it is uncommon for electronics to function in a completely protected environment, products are frequently built to function in the presence of electromagnetic interference (EMI). This functionality would be extremely beneficial for instruments used in the military, aviation sector, or any other field where total reliability is required.

The complexity of electronic systems and gadgets is increasing together with their packing density for quick reaction, which leads to electromagnetic interference[2]. EMI, which consists of numerous broadcasted unwanted signals, may cause unacceptable harm to a system's or piece of equipment's performance. The safety features and communication systems of many electronic devices can be gravely harmed if these problems are not addressed. The most frequent reason for electrostatic discharge (EMI) is ESD. The click that may be heard on audio systems when a light is turned on, radio static, and distorted television reception that appears as screen flashes are all easy methods for a layperson to identify this unexpected event. Additionally, exposure to electromagnetic fields (EMI) might result in health risks like headaches, anxiety, and insomniac symptoms. Microprocessor-controlled devices use high frequency signals that can be sent from the device into the surrounding environment and cause adjacent equipment to malfunction. Electronic equipment need to be insulated so that incoming and outgoing interferences are filtered and do not harm neighboring devices in order to prevent malfunctions.

Eliminating EMI is imperative for several compelling reasons [3]. By conducting a statistical analysis of cancer incidence in individuals, both children and adults, who have been exposed to electromagnetic fields due to wiring configurations and anomalies detected in certain residential areas, the effects of these fields were assessed. The findings indicated that these fields were associated with a slightly elevated risk of cancer in both children and adults. Residences with marginally higher field strengths, including those near cell towers, as well as residences with expected field strengths, exhibited cancer cases. Homes with higher field strengths showed a somewhat higher number of cases. One study observed a minor uptick in nervous system tumors among individuals living within 500 meters (approximately 1600 feet) of overhead power lines, with evidence of childhood leukemia. Certain experiments conducted on rats and mice revealed physiological changes resulting from continuous exposure to high levels of EMF (400 mG), levels significantly exceeding typical human exposure at home or work. Another study exposed humans to elevated electrical and magnetic fields (more than 100 times the normal levels) for a brief period, resulting in a reduced heart rate and disruptions in other human physiological responses.

II. THEORY OF EMI TESTING

Every electronic device produces electromagnetic radiation, which is a type of radio frequency. Over the years, a number of solutions have been created to block these unwanted messages. A low-effective shield would attenuate between 10 and 30 decibels, whereas a high-effective shield would attenuate between 90 and 120 decibels. In other words, the more efficient the shielding, the more the signal strength drops off after the barrier[4].
The device must go through radiation and EMI immunity testing to make sure it will work as intended in its environment. The two types of emissions testing also help to ensure that the device's conducted and radiated emissions won't interfere with other electronic equipment. Fig1 shows the overview of different EMI Measurement Techniques.

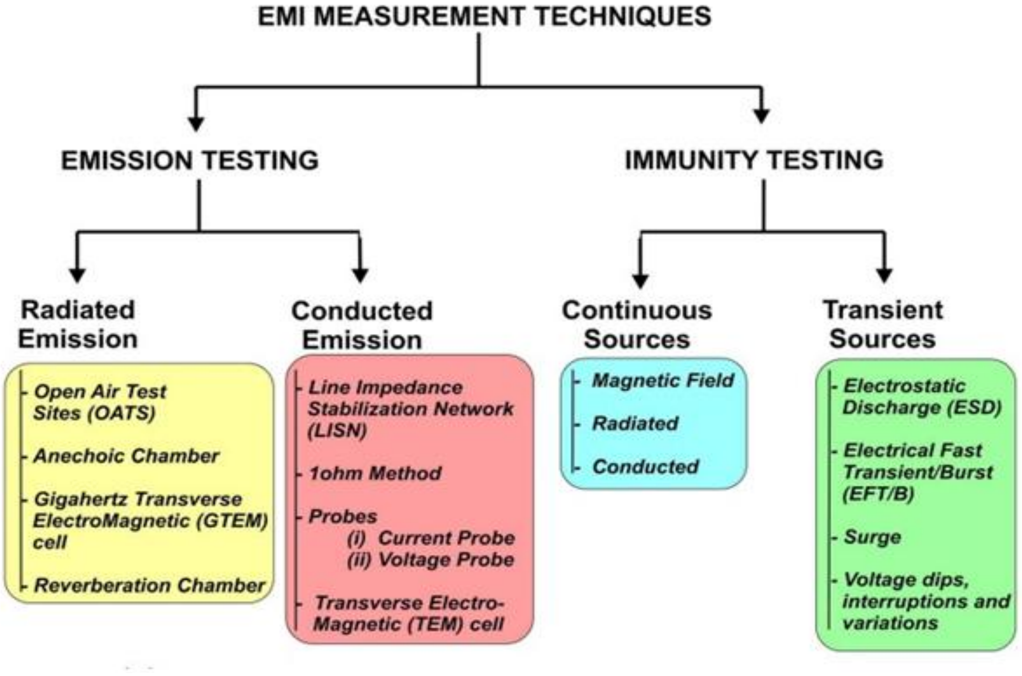


Figure 1: EMI Measurement Techniques

Depending on the test product, EMI emissions and immunity can be measured using radiation and conduction.

1. **ImmunityTesting:** Immunity tests, which look at how a product reacts to intermittent and steady electromagnetic energy sources, are used to assess a product's susceptibility to electromagnetic interference (EMI). We submit the apparatus to electromagnetic noise with different frequencies that simulates a power spike in order to evaluate the dependability of the power supply[5].

2. **Radiated Immunity:** In these tests, the amount of electromagnetic radiation that the device will typically be exposed to during use is simulated.

3. **Conducted Immunity:** In this process, the behaviour of the product is assessed when it is exposed to electromagnetic radiation that was unintentionally transmitted to it via a wire from somewhere else.

4. **Emissions Testing:** The purpose of emissions testing is to determine whether a product's internal electrical systems release no more electromagnetic interference (EMI) than is permitted. The amount of electromagnetic noise a piece of equipment generates can be measured by engineers using antennas, amplifiers, and spectrum analyzers.

5. **Radiated Emissions:** In order to determine whether a device's emissions fall within the permitted range for its size and power output, a process is used to quantify the EMI radiation it emits.

6. **Conducted Emissions:** The amount of electromagnetic radiation created internally that could potentially be transmitted over a wire and interfere with other systems is what defines this condition.

The amount of EMI that a source radiates into the atmosphere is measured by its radiative emission. A carrier medium, like air or other gases, is necessary for radiative emission, which is commonly measured in volts/meter (V/m) or microvolts per meter (μV/m).

Conducted emission quantifies the amount of electromagnetic interference (EMI) that travels through a conducting medium, including ground, power, or signal lines. The measurement of conducted emission is either in microvolts (μV) or millivolts (mV). Figure 2 depicts a basic instance of EMI occurring.

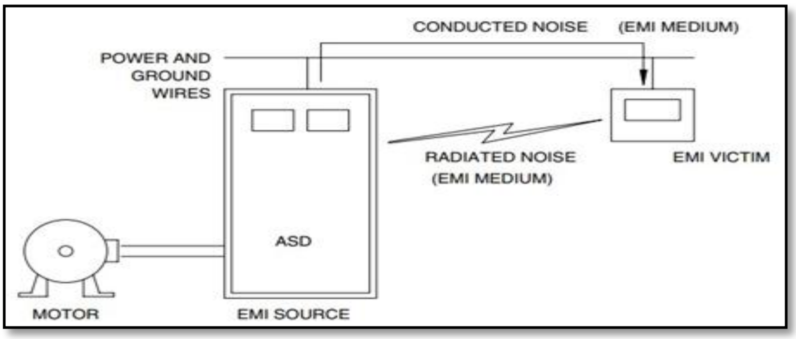
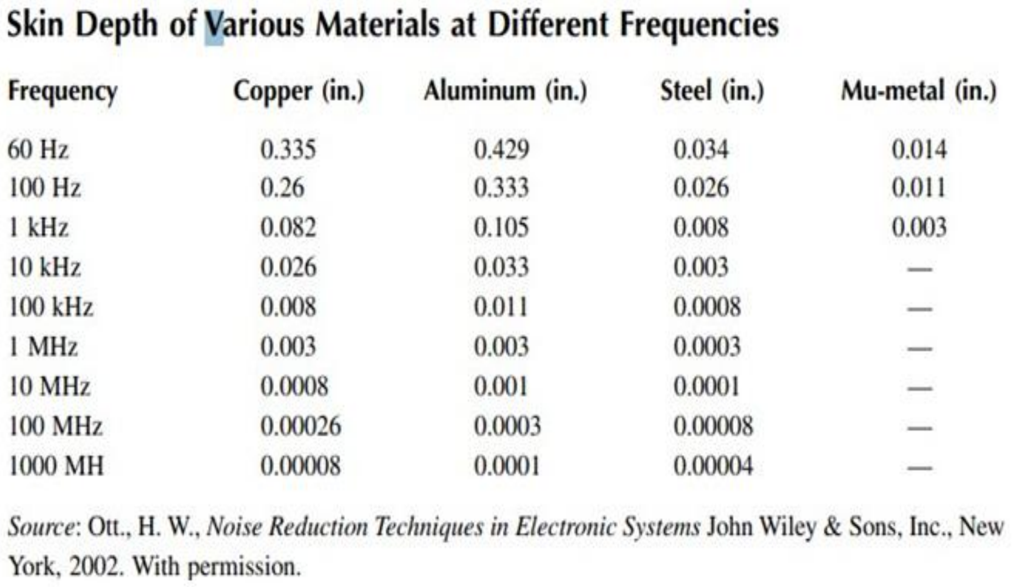


Figure 2: Example how EMI occurs

To generate electromagnetic interference (EMI), three essential components must be present. Firstly, there must be a source of interference. Secondly, there needs to be a "victim" that is susceptible to EMI. Thirdly, there must be a medium through which EMI can couple between the source and the "victim." The coupling medium can take various forms, such as inductive or capacitive, radiated through space, transmitted over wires, or a combination of these. Identifying these three elements of EMI, as illustrated in Figure 1, allows for the management of EMI in one of three possible ways [6]:

- Treatment of the EMI source through filtering, shielding, or isolation.
- By using suitable wiring techniques, conductor routing, and shielding, the coupling medium is eliminated.
- For effective EMI mitigation, more than one option might need to be used, such as shielding, applying filters, or moving the "victim" in some cases.

Table 1: provides the list the skin depth of various materials at different frequencies.



Skin Depth of Various Materials at Different Frequencies

Frequency	Copper (in.)	Aluminum (in.)	Steel (in.)	Mu-metal (in.)
60 Hz	0.335	0.429	0.034	0.014
100 Hz	0.26	0.333	0.026	0.011
1 kHz	0.082	0.105	0.008	0.003
10 kHz	0.026	0.033	0.003	—
100 kHz	0.008	0.011	0.0008	—
1 MHz	0.003	0.003	0.0003	—
10 MHz	0.0008	0.001	0.0001	—
100 MHz	0.00026	0.0003	0.00008	—
1000 MH	0.00008	0.0001	0.00004	—

Source: Ott., H. W., *Noise Reduction Techniques in Electronic Systems* John Wiley & Sons, Inc., New York, 2002. With permission.

7. **Materials and Methods used for Shielding :** There are various materials and methods available for EMI shielding. This section deals with the different methods and materials employed for EMI shielding[7].

III. LEVELS OF EMI SHIELDING

EMI Shielding Material, From the standpoint of design engineering, EMI shielding needs to be taken into account at every stage, from the PCB to the module to the enclosure. An essential part of EMI shielding at these several levels is a Faraday cage, or a protective structure that keeps electromagnetic radiation from entering or leaving an area

- **Enclosure Level:** The Faraday cage is used in EMI shielding of enclosures to reduce signals coming from within. This can stop outside interference from entering the enclosure and reduce the amount of signals that escape and interfere with other equipment in the vicinity. Therefore, the issue might be resolved in both ways.

- **Module Level:** The shielding of active components, including drives, screens, etc., inside the electronics container to prevent internal interference is known as module-level shielding.

- **PCB Level:** The shielding of individual components, including integrated circuits, at the PCB level involves using shielding cans to create a miniature Faraday cage for those components. The various EMI shielding levels are displayed in Fig. 3.

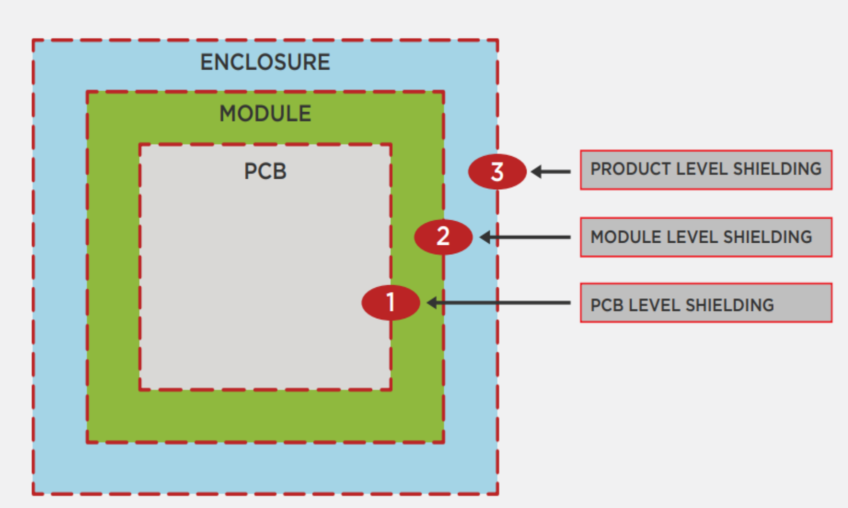


Figure 3: Levels of EMI shielding

- **Courtesy:** Recent Advances in Design Strategies and Multifunctionality of Flexible Electromagnetic Interference Shielding Materials , Junye Cheng etAl.

There are currently two types of EMI shielding available: transparent conductive coating and EMI mesh. Transparent conductive coating can be found on either film or glass, while EMI mesh comprises wire mesh, micromesh, and lasermesh. Each option offers different levels of light transmission, attenuation, and sheet resistance. Traditionally, coated glass provided higher light transmission compared to EMI mesh. However, recent advancements in the field have led to current EMI shielding products offering higher light transmission than traditional ones. EMI mesh provides a broader effective attenuation range than coated glass and exhibits significantly lower sheet resistance than coated conductive coatings. Key considerations for mesh size and color include the number of openings per inch and the blackening of the mesh. When evaluating EMI shielding options, it's important to also take into account factors like grounding options (such as bus-bars and conductive tape), mesh angle, and enhancement options.

Fig 4 shows the different EMI shielding techniques[8].

Other types of shielding are also available as follows:

1. **Metal Shielding:** Metals may absorb, reflect, and transmit electromagnetic radiation in addition to being good electrical conductors.

   The primary reason that metals are used in so many various applications is their capacity to carry heat and electricity. In order to prevent damage, electrical equipment that generates heat or has a considerable buildup of static charges is usually grounded using metal conductors. As a result, heat and static charges may disperse. In a manner similar to this, metal shields and covers are used to either stop high frequency electromagnetic radiation from the equipment from issuing or to shield the device from radiation from the outside. A common material for creating shielding enclosures is mumetal. a highly permeable alloy consisting of 14% iron, 79.5% iron, 5% copper, and 1.5% chromium. Other metals and materials that can be used as shields include brass, aluminium, silver, nickel, stainless steel, metalized polymers, and composites of conductive carbon and graphite. The brittleness of carbon/graphite, the low impact resistance of aluminium, and the high density of stainless steel are some of the disadvantages of these conductive composites. Due to the metal shield's susceptibility to corrosion, intermodulation issues, particularly in maritime environments, might arise from the nonlinearity of the Rusty BoltEffect.

2. **Plastic Material Shielding:** Plastic housings don't reflect or absorb EMI because polymers are naturally insulating materials. The thermoplastics do not prevent the majority of the energy waves from entering or leaving the housing, which results in interference problems. Technical approaches to improve polymers' electrical conductivity have been thoroughlyinvestigated.

- Conductive Coating on Plastics in order to reduce EMI.
- Using conductive fillers when compounding.
- ICP, or intrinsically conductive polymers.

Conventional plastics have the capacity to incorporate a conducting substance while maintaining their excellent electrical insulation properties, with resistivities falling within the range of 10^15 to 10^18 cm [9]. Carbon black was one of the early materials employed for this purpose. Thanks to its graphitic structure, carbon black behaves as a semiconductor, boasting a typical dry resistivity ranging from 20 to 0.5 cm. When utilized as an additive in rubbers and plastics, it imparts conductive and antistatic characteristics to the material. Additionally, aligned glass and carbon filaments are continually introduced into a thermosetting plastic matrix, such as epoxy or polyester, to create composite materials with remarkably high specific strengths and stiffness. These composites filled with short carbon fibers (SCF) exhibit higher electrical conductivity at lower filler loadings in comparison to those filled with carbon black [10].

When comparing these composites to the microwave frequency range of 100-2000 MHz, it becomes evident thattheir shielding effectiveness (SE) is notably higher in the X-band frequency range of 8-12 GHz. Specifically, composites containing short carbon fibers (SCF) prove to be technically valuable materials in the X-band region, boasting an SE of 20 dB. Resins that incorporate 30% graphite fibers exhibit a high modulus of 15 to 20 MPa andsufficient electrical conductivity, making them suitable for various electromagnetic interference (EMI) shielding applications. The effectiveness of carbon and Kevlar composite panels in providing adequate EMI SE has also been demonstrated. In addition, when examining conductive rubber composites based on Ethylene - Propylene - Diene Rubber (EPDM), Acrylonitrile butadiene rubber (NBR), and 50/50 (w/w ratio) blends of EPDM/NBR, which contain varying levels of short carbon fiber (SCF), it is observed that the volume resistivity of these fiber- rubber composites increases as temperature rises. The rate of this resistivity increase in response to temperature depends on the loading of carbon fiber and the nature of the base polymer [11].

When compared to an epoxy matrix, continuous carbon-fiber composite with a carbon matrix is more conductive, reflective, more effective at shielding, with an EMI SE of 124 dB between 0.3 MHz and 1.5 GHz.

Various fillers are incorporated into these materials, including PAN-based carbon fiber, aluminum flakes, stainless steel fibers, and aluminum-coated glass fibers. The primary polymers used in these composites include ABS, polyphenylene oxide polystyrene mix, nylon 6,6, and polyphenylene sulfide (PPS). In a series of SE experiments conducted in the 1 GHz range under different exposure conditions, it was observed that chemical exposures had no impact on compounds that derived their electrical conductivity from conductive carbon black or carbon fibers. One notable composite is the PMMA-encased exfoliated graphite composite, which can be directly molded using hot pressing. This molded product exhibited superior electrical conductivity and electromagnetic interference (EMI) shielding effectiveness compared to the mechanically mixed exfoliated graphite-PMMA composite. Furthermore, flexible graphite demonstrates exceptional EMI shielding effectiveness, with an SE as high as 130 dB at 1–2 GHz, surpassing that of solid copper. In addition to its use in conventional shielding applications, flexible graphite can also serve as a resilient shielding gasket material [12].

3. **Stainless Steel Fibers:** ABS, nylon 6.6 (PA 6.6), polycarbonate, and polyphenylene oxide are among the thermoplastics that contain stainless steel fibres packed with 7% (w/w) steel fibres. These compounds typically have shielding efficiency between 36 and 42 dB.

Due to the distribution of the conducting threads within it, the composite material would function more like a conducting mesh for electromagnetic shielding purposes. The SE attained in the X-band area was around 11 dB. Additionally, they claimed that a rise in specimen thickness would roughly double SE. The incident electric field, aperture size, fibre orientation inside the composite material, and properties of the material all have an impact on the SE. This composite material is used for shielding purposes as well as to build electromagnetically absorbent walls.

4. **Aluminumfibers:** Copper fibres have the highest intrinsic electrical conductivity of any metal, while aluminium fibres have the benefit of having a low specific gravity. However, in a typical environment, surface oxidation can happen to either of these materials. The SE of EMI was studied by Osawa and Kobayashi 30 using polyethylene, a variety of chatter-machined metal fibres (aluminium, copper, steel, and brass), and carbon fibre. They looked at the effects of filler content and thermal treatment of the composites at 80oC in air.

Brass was generated first, followed by steel, copper, aluminium, and carbon. While brass and steel and carbon fibre systems showed very little and very small thermal deterioration of SE, respectively, copper and aluminium systems showed a notable amount of degradation.

Only aluminum flakes, which have a high aspect ratio and are useful economically in EMI shielding composites, are available as fillers among the various flakes and powders. There are also uses for precious metal powders such as silver, gold, and platinum, although their exorbitant cost significantly restricts their use. These specialty materials are mostly utilized in conductive elastomers and conductive epoxy adhesives, which are used to attach electronic components and shield gaskets from electromagnetic interference. Matrix materials such as ABS, Nylon, PC, PET, PPO, and PS are commonly utilized. At a 40 weight percent loading, a 30 to 40 dB shielding performance can be achieved.

5. **Nickel Coated Graphite Fibers:** The favourable reinforcing qualities of carbon/graphite fibres are combined with the conductivity of the metal coating in nickel coated graphite fibres, which are employed as conductive additives for polymers.

   For EMI shielding, intrinsically conductive polymers (ICP) offer an alternative to conventional materials. For EMI shielding, the two conducting polymers that are most frequently employed are polyaniline (PAn) and polypyrrole (PPY). Conjugated polymers, or conducting polymers, are good candidates for systems that can be given metallic conductivity since they exhibit electronic conductivity when doped. One of their primary difficulties is the difficulty to produce useful products from intrinsically conductive polymers (ICP). This is especially true for PAn, a chemical known for its reputation as being environmentally stable, having a moderate level of electronic conductivity, and being economically viable.

6. **Conducting polyaniline:** Numerous articles have addressed the broad industrial uses of using textile materials as substrates and reinforcing materials for various polymers. Polyaniline composites , Polypyrrole composites are also used for many applications.

7. **Transparent Conductive Coating:** A transparent conductive coating is used to trap a number of EMI emissions.

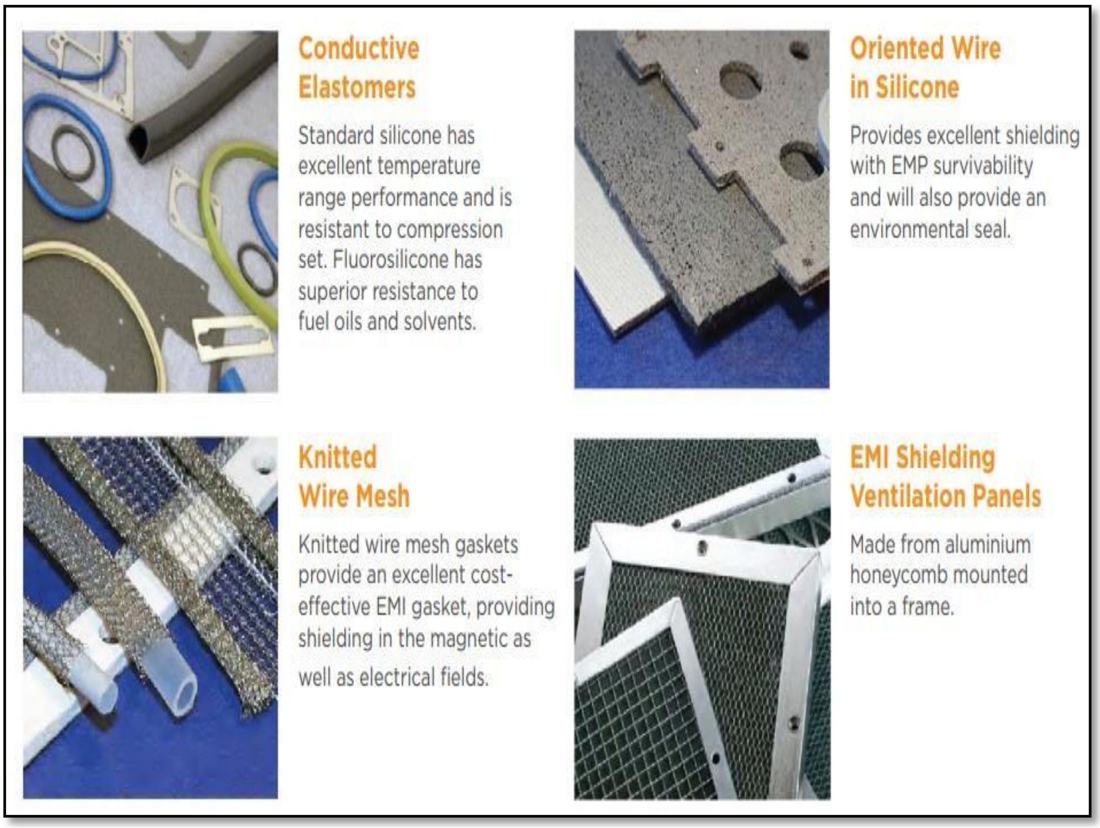
   - Coated glass exhibits excellent optical properties while providing low to moderate electromagnetic interference (EMI) shielding. An example of a transparent conductive coating is a transparent conductive oxide, such as indium tin oxide (ITO). This is the preferred choice for electronic displays that require high-quality optical properties. By incorporating an ITO coating, any device can be brought into compliance with the regulations of the Federal Communications Commission, including Class A (for electrical equipment used in offices) and Class B (for household use). ITO is classified as a resistor due to its imperfect conductivity. It possesses low resistance, with the unit of measurement for sheet resistance or conductive coating resistance being ohms per square (/sq) [12].

   - Coated film gives modest to moderate EMI shielding together with good optical properties, depending on the spectrum of the EMI emissions. As PET is often employed as the substrate layer, coated films are more vulnerable to ITO cracks and surface abrasions than coated glass. Typically, the sheet resistance is 15 [/sq]. Reducing resistance won't make the shield more effective, but it will reduce optical quality.

8. **Electromagnetic shielding using Aluminium foil:** The type of incident field, the foil's thickness, and the frequency all affect how well aluminium foil shields. The two main

components of shielding efficacy are reflection and absorption loss. Even a thin sheet of aluminium, which is not magnetic but is an excellent conductor, nearly completely reflects an incident electric wave. The electric field weakens below 100 MHz in frequency. Low frequency magnetic fields are not very well attenuated by thin sheets of aluminum[11].

9. **Electromagnetic shielding using Carbon nanotubes (non-metal) and polystyrene(Thermocol, dielectric) : Electromagnetic Shielding Using Graphene :** In recent years, there has been a lot of research into polymer composites using carbon nanotubes with the goal of enhancing the mechanical properties of the composites for shielding purposes. Carbon nanotubes have extraordinary electrical qualities in addition to their exceptional mechanical properties. In addition to their exceptional mechanical and electrical qualities, carbon nanostructures also have a fascinating property that makes them lightweight structures for electromagnetic interference (EMI) shielding.
   When compared to gold film of the same thickness, CVD-produced graphene exhibits EMI shielding efficiency that is more than seven times greater. Shielding can be enhanced by fabricating an ultrathin, transparent, weightless, and flexible EMI barrier from one or more atomic layers of graphene.



Conductive Elastomers

Standard silicone has excellent temperature range performance and is resistant to compression set. Fluorosilicone has superior resistance to fuel oils and solvents.

Oriented Wire in Silicone

Provides excellent shielding with EMP survivability and will also provide an environmental seal.

Knitted Wire Mesh

Knitted wire mesh gaskets provide an excellent cost-effective EMI gasket, providing shielding in the magnetic as well as electrical fields.

EMI Shielding Ventilation Panels

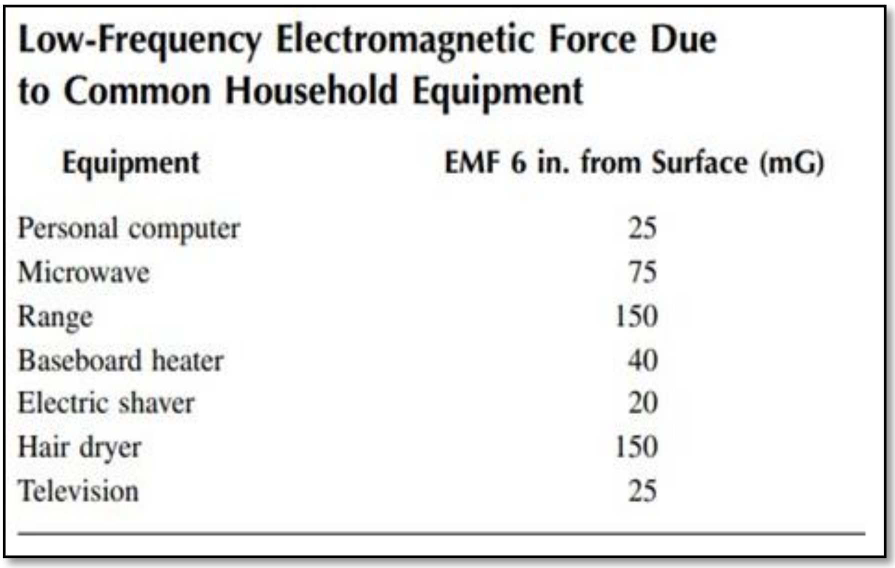
Made from aluminium honeycomb mounted into a frame.

Figure 4: Various EMI shielding Techniques

Courtesy: Electromagnetic Interference Shielding A Key Component of Engineering Design Trends, Insights, and Design Considerations, Kemtron Limited.

Table 2 provides the list of EMFs produced by common household equipments [12].

Table 2: EMF in common household equipments.



Low-Frequency Electromagnetic Force Due to Common Household Equipment

Equipment	EMF 6 in. from Surface (mG)
Personal computer	25
Microwave	75
Range	150
Baseboard heater	40
Electric shaver	20
Hair dryer	150
Television	25

Courtesy : CRC press

Although the electromagnetic field (EMF) levels may be considered high in some instances, it's important to note that exposure duration is typically short. The complete implications of exposure to low-frequency fields are not yet comprehensively understood, so it is prudent to exercise caution and avoid prolonged exposure to electrical and magnetic fields. Maintaining a sufficient distance between the EMF source and individuals in the vicinity can be an effective strategy for minimizing exposure. As observed earlier, the strength of electrical and magnetic fields diminishes as one moves farther away from the source [13].

IV. CONCLUSION

Electromagnetic fields are an integral part of our surroundings, and they serve essential functions. Technologies like radios, televisions, and cell phones rely on these fields for their operation. Additionally, conveniences such as automatic door openers and in-car garage door remotes are made possible through electromagnetic energy. While these fields are indispensable for daily life, it's worth noting that some electronic devices can be vulnerable to their effects. The good news is that the exposure of these devices to electromagnetic fields can be reduced. As previously mentioned, shields, filters, and isolation techniques are valuable tools that help us navigate the electromagnetic interference (EMI) environment. It's crucial to identify the source of interference, understand the tolerance level of the affected device, and recognize the medium facilitating interaction between the two. To effectively address any EMI-related issues, a comprehensive understanding of all three aspects is necessary [6].

This review chapter starts with a detailed explanation of the meaning and history of EMI, which is followed by a look at its background. Methods of measuring electromagnetic interference (EMI) are also discussed in length under the two primary categories of immunity testing and emission testing. The two types of emissions that are considered for EMI measurements are conducted and radiated emissions. Radiated emission testing chambers include reverberation chambers, GTEMs, and anechoic chambers. By carrying out emission testing, you may measure the electromagnetic interference (EMI) caused by abrupt fluctuations in the voltages and currents within the EUT's circuitry. To do this, methods such as the LISN, 1X, probe, and TEM cell techniques are used.This review focuses not only on the previously stated EMI measurement techniques, but also on general measures used to reduce EMI induced by electrical equipment. These methods include the use of spread spectrum technology, EMI filters, electromagnetic shielding, and changes to circuit topology. Particular attention is paid to electromagnetic shielding, since it is perhaps the most widely used technique for EMI reduction. Numerous methods for evaluating a material's shielding capacity are described in theory. The review chapter covers both the measuring techniques and the reduction procedures, covering the entire subject of EMI. Consequently, it might be advantageous for both experienced researchers and new researchers to gain a thorough understanding of electromagnetic interference.

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