Electromagnetic Pollution & its Management –An Overview

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Abstract:

P*roblems associated with all types of Electromagnetic Pollution in general and Electromagnetic Compatibility in particular are discussed in detail in this paper. Not only the problems have been identified, yet solutions are also thrashing out at length just to make the overview more interesting and meaningful.*

Keywords: EMI, EMC, Emission, Immunity, Shielding Effectiveness, Health Hazard

Introduction

What is joy for you may cause sorrow for others. Imagine a situation in which you are enjoying music from an FM receiver possibly at a high volume and not caring for others who are nearby attentively engaged with their works. Now, try to figure out the awkward situation of those people present over there. Certainly, what you are enjoying is creating interferences pertaining to the sense of hearing to others in their personal works. In other words, under such circumstances, you are a culprit troubling the normal functioning of others and others are victims as they are getting disturbed.

Now, imagine similar scenario in electromagnetic domain in which a number of electronic devices are operating together in a closed compound. It may be observed that an AM / FM transmitter radiating modulated signals may affect the normal operation of an aircraft passing very close to the transmitter. Similarly, a radar station may slip into the malfunctioning mode, in case a mobile set coming momentarily very close to it and gets interfered in its normal operation. Of late, with the increased proliferation of electronic and electrical equipments in various sectors – household, industrial, telecom, hospital, IT segment, automobile, defence etc., use of high frequency digital circuits has been spiralled up like anything. This has created inadvertently a lot many undue electromagnetic radiations – a new kind of invisible giant nuisance-makers in the environment. In this electronic era, this is a new phenomenon generating electromagnetic smog affecting normal operation of electronic gadgets and even upsetting human health thus making annoyance, delay, loss of revenue, significant property loss, and even death and serious injuries.

This highly uninvited, unsolicited and disturbing interfering signal producing toxic waste in the electromagnetic environment may be referred to as electromagnetic pollution or electromagnetic interference (EMI). In a while, paragraphs are going to present the general characteristic features of the unseen demon creating awful nuisance and its adverse effects in electronic technology. Methods to mitigate such challenging mischievous problems have also been discussed subsequently.

To start with, one should know about the meanings of various terminologies related with the abnormal, unique giant phenomenon possibly present in all Electronic and Electrical systems *ie*. EMC, EMI, EMC Conditions, EMI Sources, EMI Effects, and associated problems with non-compliance. Besides, various concepts and definitions associated with the event will be brought into light. In order to mitigate the related troubles, the outline of norms and standards formed by various regulatory bodies at national and international levels will be discussed. Some relevant design guidelines & methodology and process control will be presented as well. To start with, inner significances of some important terminology related to Electromagnetic Interferences, [EMI] and Electromagnetic Compatibility, [EMC] are presented below.

Connotation of relevant terms related to :

EMI-

Modern electronic equipments are designed using complex electronic components and dense assembly techniques. These devices emanate various spurious unwanted signals, which interfere with normal function of other sensitive receiving devices or even with themselves causing a havoc or complete failure of operation. This type of signals is normally branded as Electro-Magnetic Interferences [EMI]. It is also known as Radio Frequency Interference [RFI]. This may be referred to as *Electromagnetic Pollution* as well.

EMC-

The ability of an electronic device to function satisfactorily in an electromagnetically polluted environment without inflicting intolerable disturbances to any other electronic devices nearby is designated as its Electro-Magnetic Compatibility [EMC]. In order to satisfy the compatibility conditions in an EMC environment, devices are to observe certain norms. As for example, they are not to cause

- Interferences with the operation of other electronic devices in close proximity,
- Itself vulnerable to emissions from other electronic systems and should be able to tolerate a specified degree of interferences or, they must have Immunity to survive it,
- Interferences with itself or in other words, they should be self-compatible.

EMI SOURCES-

Basically, the prime causes of electromagnetic interferences are many; but for the sake of expedience, the EMI sources may be subdivided as follows: 1> man-made and 2> erratic.

1. **Man-made noise**

- Electrostatic charges generated within human body
- Noise caused due to ignition in automobiles
- Noise generated by electric machines like kitchen blender, hair dryers, refrigerator, AC, electric shavers, washing machines, etc.
- Switched mode power supply generating noise signals at the switching frequency and its harmonics that conduct through the power line
- High voltage transmission lines

- Household appliances like microwave ovens, laptops, printers, computer peripherals Fluorescent lamps
- Industrial control systems, medical devices, communication receivers
- Electromagnetic pulses (EMP) due to nuclear detonation producing gamma rays
- Fast switching digital devices, ICs and many more.

2 Erratic noise

- Atmospheric noise
- Space noise
- Lightning and discharge
- Etc.

Some of the practical examples of possible effects of electromagnetic interference (EMI) commonly observed in electromagnetic domain are listed below:

- False activation of weapons in warfront causing a failure in interception with target
- False alarming in security zones in vulnerable installations causing risk and hazard
- Interference in voice / data / video signals used by radio and television networks causing poor quality of reception
- Loss of stored data in digital systems
- Health hazards; destructive effects on biological cells on human, animal, vegetation
- The electronically operated automobiles start malfunctioning even when the radiated pulse signal from a piezo-electric cigarette lighter is lit nearby
- All the sensitive instrument in an aircraft stop working while a transmitting antenna starts radiating signals closed by
- Signals emitted from local security system (LAN) in a super speciality hospital may collapse the operation of all the sophisticated diagnostic instrument causing false and misleading diagnosis.

With the spiralling rise of popularity and production of electronic gadgets specially based on digital principle, it is realized, with heavy heart, that the electromagnetic pollution created in some critical situation has reached beyond the limit of tolerance especially in electromagnetic domain. In order to combat such an unendurable state of affairs, imposition of some effective electromagnetic compatibility (EMC) conditions must be enforced so as to have happy and satisfactory co-existence of electronic devices in a chaotic electromagnetic environment. Hence, the importance of EMC must be appreciated in these circumstances. That is, presence of proper EMC-rules means alleviation of EMI-effects in this issue.

Significance of EMC-rules

- Electromagnetic Compatibility [EMC] requires that systems / equipment must be able to tolerate a specified degree of interference and not generate more than a specified amount of interference.
- EMC is becoming more important because there are so many more opportunities today for EMC issues.
- Increased use of electronic gadgets such as

- Automotives applications
- Personal computing / entertainment / communication
- Increased potential for susceptibility / emission
- Lower supply voltages
- Increasing clock frequencies, faster slew rates
- Increasing packaging density to enhance compactness
- Demand for smaller, lighter, cheaper, lower-power-devices.

In case, EMC conditions not being properly abided by in practice, inconveniences that may be caused are classified mainly in three categories: minor, major and in-between as per their seriousness and nature of gravity. Minor effects, for example, may cause annoyance or delay, say, due to AM /FM / XM /TV interferences or cell-phone interruptions. This can be tolerated or ignored. Non-compliance of EMC regulations may, sometimes, create major problems as serious as death or severe injuries that may be due to, say, radar interruption in aircraft landing systems, or, erroneous ordnance firing, or improper deployment of airbags. Not a major neither a minor, but in-between hassles may cause loss of revenue, minor property loss and significant property loss. This may be due to critical communication interruptions or interference and automated monetary transactions.

However, it may be mentioned that now-a-days, non-compliance of EMC issues does not pose any major problem in industry, because, fortunately, industry is well regulated and standards are comprehensive. And, hence, major EMC issues are relatively rare. It is to be noted that for cost-effective compliance of EMC regulations are carefully considered and applied throughout product / system development from the very beginning of planning and design of the gadget, not in piece-meal basis before final testing of the device.

Modeling of interference process

The mechanism of interference , basically, concerns with the leakage of interference emission from a source of electromagnetic in origin, which gets coupled to a very sensitive receiver nearby through a suitable routing path creating serious functional problem to the receiver meant for some other purpose. In other words, EMC deals with the mechanism of interference in the following manner. Basically, it requires

- Source of emission of undesired interferences (culprit)
- Transmission path between the source (culprit) and the receptor (victim)
- Receptor (victim) – the most affected device that malfunctions on reception of interfering signal through a coupling path.

Pictorially, the model appears as depicted below:

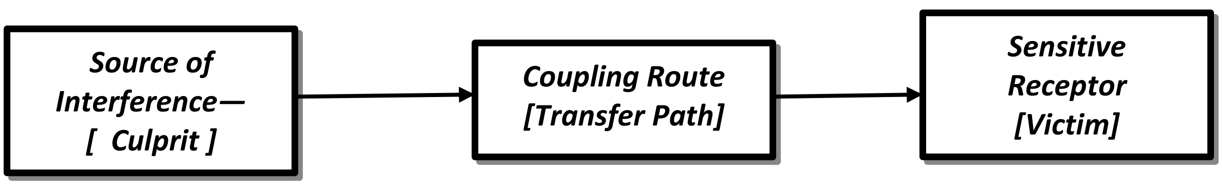

Figure 1. Schematic block diagram representing the mechanism of EMC problem

Decomposition of coupling path paradigm

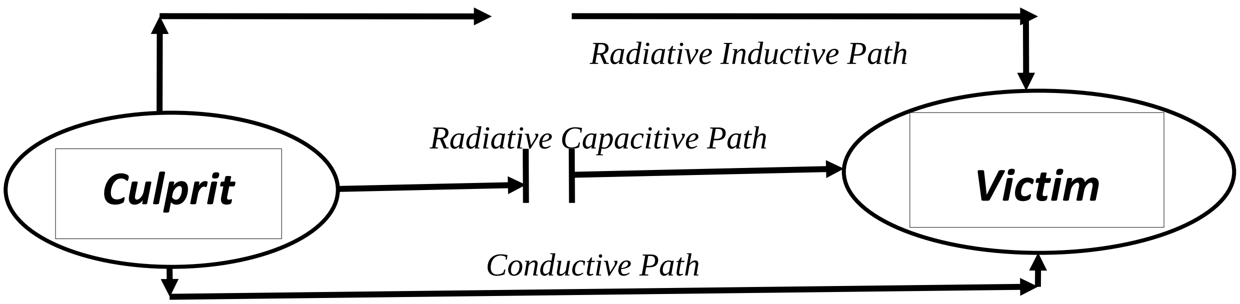

Figure 2. Detailed schematic view of EMC coupling Path between culprit and victim

In Figure 2, Susceptibility and immunity are the quality of the victim but they are antonyms to each other. However, susceptibility represents the sensibility of victim's response to interference and immunity stands for the ability to withstand any interfering signal without being perturbed. Here, coupling path transferring interfering signal can be of two categories, in general: Conductive (wired) or Radiative (wireless) in nature. The Radiative path is again subdivided in two varieties: magnetic or electric. It all depends on how close the victim is with respect to the culprit. If the victim is in the near field of the culprit's emission radiation zone where electric field is dominant, the coupling path is electric in character, while if it is Radiative near field region where magnetic field is dominant, it is magnetic in nature. On the other hand, when the culprit as well as victim is connected together through a conductive wire as it happens in having common power grid supply or having common signal data-base link, the coupling path is always conducted in character. In short, EMI is due to conduction having common impedance, is due to capacitive or inductive coupling when they are in the near-field region and finally, EMI is electromagnetic emission in nature when they are in the far-field region.

Depending on the coupling conditions, EMI entry into a victim Instrument, originated elsewhere in an external culprit device may be interpreted in the following manner.

i. Presence of impedance mismatch and discontinuity.
ii. Common-mode mismatch in a circuit leading to differential noise signals.
iii. Capacitively coupled unbalanced network is susceptible to voltage variation (dv/dt) in one causing noisy displacement current on the other, through the mutual capacitance in between them *e.g.*,1mA/pF due to voltage fluctuation of 1V/ns..
iv. Mutual inductance sometimes, creates difficult source of interference, if high value of di/dt induces a noise voltage on other circuit through mutual inductance *e.g.*,1V of noise voltage is contributed through a mutual inductance of 1nH for a change of 1A/ns of I.

Concepts and Definitions:

Effective EMC design has become a critical component in the design of most of modern electronic devices / systems. The EMI environment is becoming more and more cluttered / clumsy with the increasing application of small sized high speed wireless components in the marketplace. In order to combat the entire EMC problem, one has to carefully identify types of coupling mechanism of fields between emitter (culprit) and receptor (victim). Logically, it is either wireless or wired. However, based on this categorization of coupling path, specific EMC components now boil down to four major types as follows:

- Radiative Emission (wireless)
- Conductive Emission (wired)
- Radiative Immunity / Susceptibility (wireless)
- Conductive Immunity / Susceptibility (wired)

In order to explain the nature of EMC problems classified above, help of a schematic view (Fig.3) depicted below has been employed. Here, DUT refers the Device Under Test.

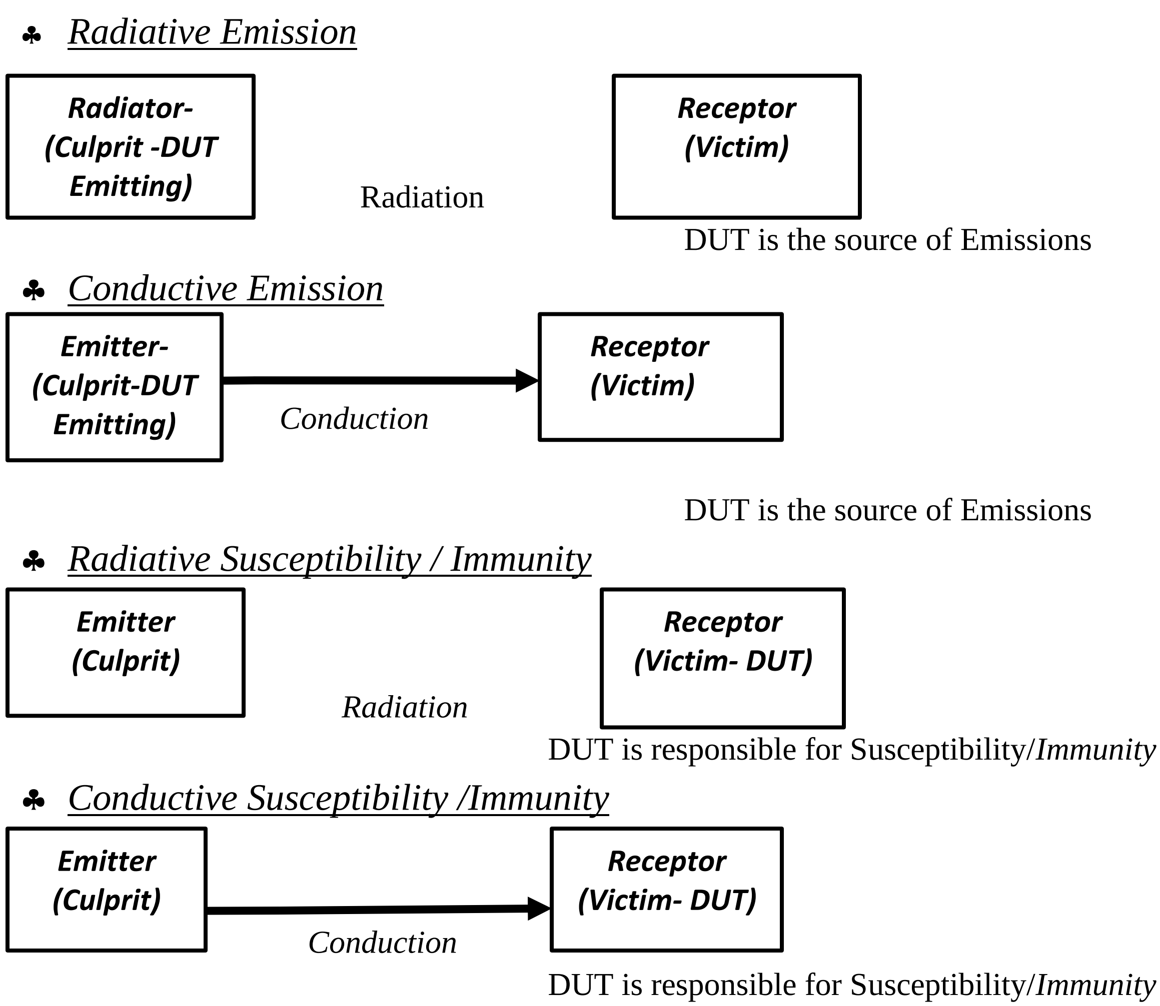

Figure 3 Pictorial interpretations of the four types of EMC problems.

Prevention of EMC issues

In order to frustrate completely or else, at least to alleviate EMC enigmas, it is realistic to consider following four steps.

- ♥ Suppression of the unwarranted emission at its source point (culprit, Fig. 2)
- ♥ Making the unintended coupling path as inefficient and ineffective as possible
- ♥ Making the inappropriate receptor (victim, Fig.2) less susceptible or more immune to the unwanted emission, if any. Or else, it should be able withstand a specific degree of interference from nearby emission (culprit).
- ♥ Combination of the above

In other words, the possible steps that one has to comply with in order to mitigate EMC problems are the following (Table no. 1).

Table no. 1.

Source (culprit)	Modify Signal Routing	Add Local Filtering	Reduce Signal Level	Spread Spectrum
Coupling Path	Increase Separation	Shielding	Reduce Interconnections	Filter Interconnections
Receptor (victim)	Modify Signal Routing	Add Local Filtering	Operating Frequency Selection	———

Some other aspects of EMC problems

There are some other aspects of EMC problems that are of equally interesting and noteworthy. Just to name a few, a short list of them is given below:

(i) Electrostatic Discharge (ESD); (ii) Electromagnetic Pulse (EMP); (iii) Lightning; (iv) TEMPEST (Secure Communication and data Processing)

EMC Standards

In order to deal with the emerging and ever increasing problems of EMI, in 1933, the International Electrotechnical Commission (IEC) arranged a meeting in Paris and recommended the formation of the International Special Committee on Radio Interference (CISPR). The CISPR reconvened another meeting after World War II in London in 1946. Subsequent meetings provided various technical publications, which concerned with measurement techniques as well as recommended emission limits. Some European countries adopted versions of CISPR's recommended limits. The Federal Communications Commission (FCC) of United States of America (USA) suggested a rule that was the first regulation for digital systems in the USA, and the limits follow the CISPR recommendations with variations peculiar to the USA environment. Most manufacturers of electronic products within the USA already had internal limits and standards imposed on their products in order to prevent "field pollutions" associated with EMI. However, the FCC rule made what had been voluntary a matter of legal compliance. With the increasing application of digital devices in electrical systems ranging from satellite communication to radar to television to electronic typewriters, the EMI (both conducted and radiated) becomes significantly predominant creating nuisance in electromagnetic domain. The

FCC in USA promulgated a regulation in 1979 fixing the permissible limit of emission of a digital device on sale. This has alerted the manufacturers of the digital device-systems. The FCC defines a digital device as: *Any unintentional radiating device or system that generates and uses timing pulses at a rate in excess of 9000 pulses (cycles) per second and uses digital techniques………* This rule includes any electronic system employing digital circuitry using clock signal in excess of 9 KHz like electronic typewriters, calculators, personal computers, printers, modems etc.

In order to combat this problem of EMI, some standard-making bodies are formed by various government agencies in their respective national level. They try to achieve a goal of creating an atmosphere so as to have certain degree of compatibility among the electronic gadgets while working together in a region. As for example, a list of such regulatory bodies in different countries is provided below. However, numerous EMC standards exist. But the common fundamental theme is to fix up the limits of emissions (conducted and radiated) and immunity or susceptibility (conducted and radiated).

REGULATORY INSTITUTIONS FOR EMC STANDARDS

- Federal Communication Commission (F C C) in United States America
- U S Military (DoD)
- European Union (E U)
- Radio Technical Commission for Aeronautics (R T C A)
- Comite Internationale Special des Perturbations Radioelectrotechnique (C I S P R)
- National Association of Radio & Telecommunication Engineers (N A R T E)
- British Standard Institution (UK)
- Verband Deutacher Elektrotechniker (VDE) in Germany
- Voluntary Control Council for Interference (VCCI) in Japan
- China Compulsory Certification (CCC) in China

It may be carefully noted that all countries are not having exactly same requirements. It is the responsibility of the government of a country to enforce the EMC regulations as much as required for that country, matching with its EMC environment. So, the EMC settings of different countries are more or less similar but not identical. However, some of the countries prefer to adopt the CISPR-22 standards instead of having their own. As for illustration, the standards promulgated by FCC for Radiative Emissions and Conductive Emissions for digital devices applicable in United State of America are as shown in Table nos 2 & 3 respectively.

Table no. 2.

FCC STANDARDS FOR CONDUCTED EMISSIONS [FCC PART 15]

**********	Frequency [MHz]	Quasi-Peak Limits [dBμV]	Average Limits [dBμV]
Class-A	0.15 – 0.50 0.50 – 30.00	79 73	66 60
Class-B	0.15 – 0.50 0.50 – 5.00 5.00 – 30.00	66 to 56 * 56 60	56 to 46 * 46 50

*Decreases as logarithm of frequency

<u>Table no.</u> 3.

<u>FCC STANDARDS FOR RADIATED EMISSIONS [FCC PART 15]</u>

*******************	Frequency [MHz]	Field Strength Limits [μV / m]
Class A [10 meters]	30 – 88 88 – 216 216 – 960 Above 960	90 150 210 300
Class B [3 meters]	30 – 88 88 – 216 216 – 960 Above 960	100 150 200 500

It may be carefully noted that due to obvious reasons stated before, the limits of conducted and radiated emissions are much more stringent for class B than those of class A digital devices. However, in an identical fashion, other regulatory bodies like CISPR have recast the limits of emissions as a function of frequency, are also useful and valuable.

Identically, Tables for radiated and conducted Susceptibility / Immunity are also prepared for setting the corresponding limits required and available in the respective standards.

<u>Design Guidelines and Methodology</u>

➢ ***<u>Near-Field and Far-Field concept</u>***

While propagating in free space, much away from the source of radiation, the propagation supports only the TEM mode. In this case, the electric field vector, E (Volt/meter) and magnetic field vector, H (Ampere/meter) are orthogonal to each other as also to the direction of propagation. The wave impedance, η (Ω) of free space is given by the ratio of E/H (~377Ω). However, it will be worthwhile, now, to bring in the concept of near-field and far field of an RF emitter in order to characterise the EMC problems due to EMI. Considering the field expressions of elementary RF emitters, the range between emitter and receptor [Pozar, Harrington] may be divided mainly in two fields, *e.g.*, Near-Field & Far-Field (Fraunhofer zone). Near-Field, once again, is sub-divided in two regions as Reactive Near-Field and Radiative Near-Field (Fresnel zone). Figure 4, shows the detail below.

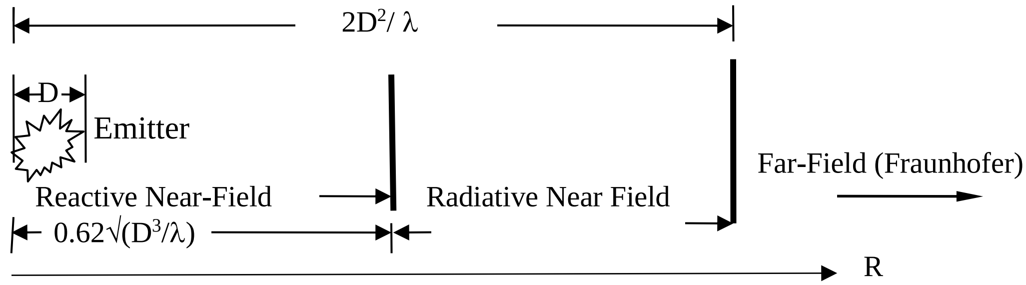

Figure 4. Depicts the field regions when emitter has a maximum dimension of D and R represents the range from the emitter.

Now, it is evident that the Far-Field (Fraunhofer) region starts from a distance $2D^2/\lambda$ from the emitter and goes beyond this limit to infinity, when the maximum linear dimension of the emitter is D. Or in other words, for Far-Field, $R > 2D^2/\lambda$, at the same time, $R >> D$ and $R >> \lambda$. In this region, E-field and H-field die off at the rate proportional to 1/R and the power density as $1/R^2$. Far-Field radiation pattern of the emitter is independent of R.

The Reactive Near-Field extends up to a distant of $0.62\sqrt{(D^3/\lambda)}$ from the emitter and stay alive in immediate vicinity of the emitter. This region is highly reactive in nature and the E- and H-fields are out of phase by 90^0 with each other and falls off as $1/R^3$.

The Radiative Near-Field (Fresnel) region ranges between $0.62\sqrt{(D^3/\lambda)} < R < 2D^2/\lambda$ and Reactive fields do not dominate yet Radiative fields begin to emerge. The shape of the radiation pattern in this region may change appreciably with distance R. The values of R and the wavelength λ will determine if, at all, this region will stay alive or not (especially when $D << \lambda$). E- and H-fields are dependent on R as $1/R^2$.

- ***Common-mode and Differential-mode Currents***

In case, EMC standards are not properly and meticulously taken care of at the time of circuit design stage, there is every possibility of the presence of noise (EMI) currents, $\bar{I}_C$ flowing through two parallel conducting wires or PCB lands, that cannot be interpreted and understood by the circuit theory or transmission line theory alone. Along with the noise currents, $\bar{I}_C$, the normal functional currents, $\bar{I}_D$ will coexist making the net overall currents, $\bar{I}_1$ and $\bar{I}_2$ over the two parallel wires, a linear superposition of these two types of currents. Or in other words, the currents $\bar{I}_1$ and $\bar{I}_2$ on the two parallel wires may be resolved into two types of currents *e.g., Differential-mode currents,* $\bar{I}_D$, which on the lines are oppositely directed and *Common-mode current,* $\bar{I}_C$ flowing in the same direction (Fig.5). It may be noted that $\bar{I}_D$ currents are functional and desired. Hence, these are predictable by the circuit theory. On the other hand, $\bar{I}_C$ *i.e., Common-mode currents* represent, mainly, the noise currents in the system and are non-functional and undesired entity. And these currents are inexplicable by the circuit theory. Therefore, mathematically, the current relations are as flow:

$\bar{I}_1 = \bar{I}_C + \bar{I}_D$ and $\bar{I}_2 = \bar{I}_C - \bar{I}_D$.. Hence, the expressions of the decomposed current components can be obtained as $\bar{I}_D = ½ (\bar{I}_1 - \bar{I}_2)$ and $\bar{I}_C = ½ (\bar{I}_1 + \bar{I}_2)$. Both these current components *e.g., Differential-mode currents,* $\bar{I}_D$ and *Common-mode currents,* $\bar{I}_C$, by their nature, produce radiated emissions as $\bar{E}_D$ and $\bar{E}_C$. Normally, the magnitudes of $\bar{I}_D$ are much larger than that of the noise currents $\bar{I}_C$, but due to their nature, the radiated emissions $\bar{E}_C$ is much more effective and damaging than $\bar{E}_D$. This is explained in Fig. 5. Now, it is worthwhile to mention that at the time of designing any electronic product, care should be taken to alleviate or at least mitigate the possibilities of any *common-mode currents* through conduction paths in the system.

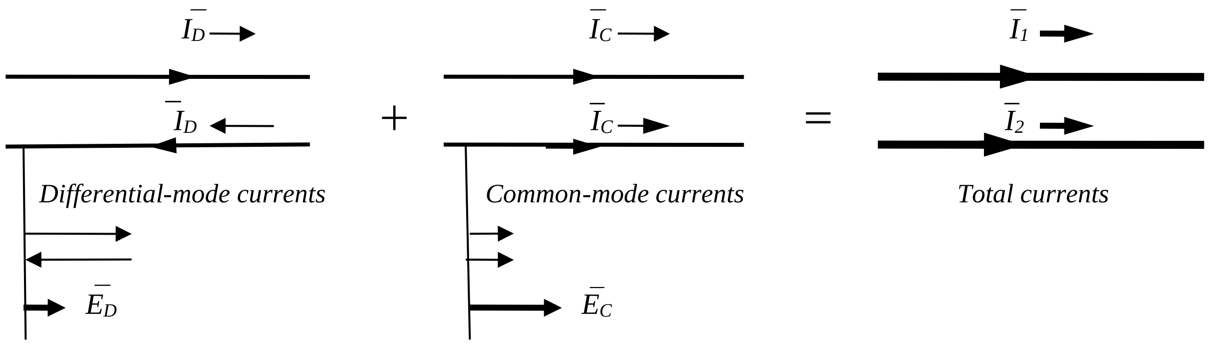

Figure 5. Illustrates the *Differential-mode current,* $\bar{I}_D$ and *Common-mode current,* $\bar{I}_C$ form the total net currents as $\bar{I}_1$ and $\bar{I}_2$ on the parallel conducing wires. Correspondingly, they produce radiated emissions all around as $\bar{E}_D$ and $\bar{E}_C$.

- ***Shielding***

In order to mitigate the Radiative EMC problems, mention has been made to make the coupling path between the culprit and victim as inefficient as practicable. Of various methods suggested like grounding, bonding, filtering and the like, effective shielding is used as the first line of defence at least for mitigating the radiated emission / radiated susceptibility. In case of any applications, if it cannot afford to offer the overall shielding effectively, some other means of controlling EMC may be relied upon. Normally, electric shielding is provided by solid metal enclosure / chassis. Sometimes, in place of metal housing, the electronic circuit is placed within a cover made up with rubber / polymer impregnated with carbon fibre or carbon powder. Occasionally, housing may be a plastic cover painted with highly conductive coating or vacuum deposition.

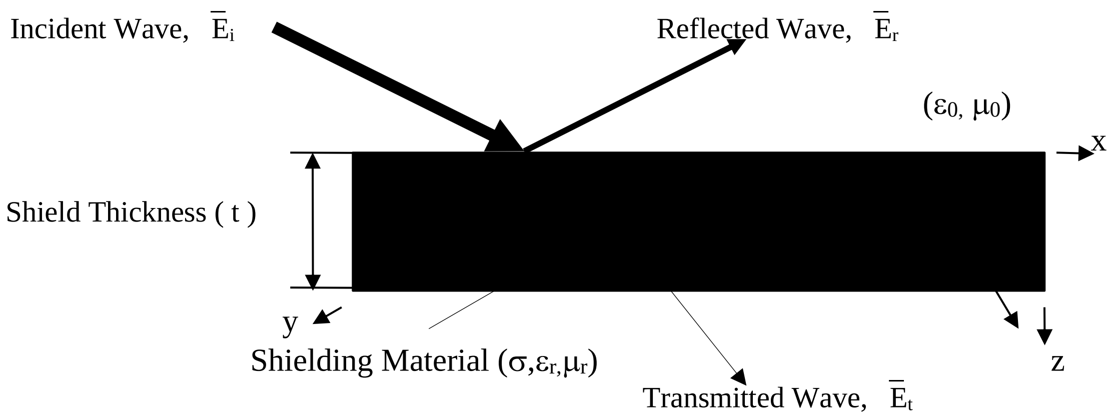

Figure 6 Mechanism of wave propagation through a shielding material showing how Reflected and Transmitted waves are generated from an Incident wave.

The working principle of wave propagation through a shielding material or barrier is explained and exemplified in the Figure 6. In fact, how well an enclosure can prevent an electric field to enter inside is quantified by the parameter defined for electric field, E as Shielding Effectiveness in decibel, SE (dB) = $20 \log_{10} | E_{inside} / E_{outside} | = 20 \log_{10} | E_t / E_i |$. Theoretically, SE of any homogeneous material consists of the following loss-terms, *e.g.*,

- ♦ Reflective losses, R (dB) due to reflection in the plane of incidence.
- ♦ Absorption losses, A (dB) due to power absorptions taking place while passing through the material.
- ♦ Secondary reflective losses, B (dB) due to secondary reflections within the material along the dotted paths as shown in Fig. 6. Normally, B is neglected when A > 8 dB.

Under such situation, SE (dB) = R + A + B ≈ R + A.

Some of the useful parameters of the material in controlling the values of shielding effectiveness, SE are the following: Frequency-*f*, shield material thickness-*t*, Emitter to shield distance-r, Permeability of the shield material relative to air-μ_r and Conductivity of the shield material relative to copper-σ_r. The shielding materials as used in practice are Aluminium, Copper, Cold Rolled Steel and the like, essentially because of their relatively high conductivity and high reflectivity. The Shielding Effectiveness, SE of those materials theoretically is adequately high and found to be more than 200 dB at 10 KHz and above for Aluminium and Cold Rolled Steel, and for Copper it is so at 1 GHz and above.

But all said and done, in reality, the values of SE are very much limited typically because of the fact that there are inevitable necessity for apertures and holes on the shield cover. As for example,

- ∗ Removable shield-cover, which may be unavoidable for regular repair and check.
- ∗ Holes for ventilation and passage for connectors inside.
- ∗ Holes for control of components from outside.

Under such circumstances, some measures of enhancement may be recommended as

- ✓ Minimum possible number and sizes of holes / apertures / seams, if inevitable.
- ✓ In case of metal-to-metal interface, recommend for gasket/spring-finger for good well-ensured contacts.
- ✓ Adequate contact surface areas free from paints & debris in the interfaces of seams.
- ✓ Enclosure with seams must have adequate conductive contact areas with as many as possible contact points over adequate overlap areas. Gasketing helps ensure good electrical contact between fasteners.

EMI Mitigation Techniques

As long as the conductive interference is concerned, the main power supply line or signal or data links (victim) can be completely isolated from the defective equipment (culprit) causing contamination of the interferences in the victim system with the help of the Line Impedance Stabilization Network (LISN) having sharp cut-off low-pass filters. This is a good method of alleviating conductive interference causing conduction noise current in a conductive path. In this context, it is to be remembered that LISN is also used to measure the magnitude of conductive interferences flowing through the phase as well as neutral lines of the defective product. Furthermore, it may be recalled that in the design of a circuit, keeping common mode current produced within the product, to its minimal value is another effective way to mitigate conductive interference to a certain extent. In order to combat EMI, it is always advisable to make use of passive components like resistors, inductors and capacitors for design of LISN and filters.

Coupling path in between the culprit and victim, as discussed before, should be made to design as ineffective as possible so as to produce minimal amount of radiative interference to be coupled to the victim. One of the suggested methods is the application of good and effective shielding material (with adequate SE value) around the victim as well as culprit or in between them in a suitable manner so as to avoid easy passage of the radiative interference through victim to culprit. In case, for the purpose of unavoidable ventilation, there is a need for holes or slots required to be drilled on the surface of the shielding material, these are to be properly designed so as to have effectively continuous conductive electrical surface inside the shielding material (based on the fact every waveguide has a cut-off frequency) without affecting ventilation. Such a type of shielding structure design is standardised and is available in literature.

It is to be kept in mind that an earthing and equi-potential bonding implementation is another important area in which one has pay careful attention not only for human safety alone but for EMC mitigation reason as well. As a rule, for the sake of human safety, all metal enclosures in offices, commercial as well residential buildings where IT installations exist, are connected together as a part of an equi-potential bonding network to all other parts likes metal conduits (both water and gas conduits) metal beams, steel girders etc.. It will be surprisingly observed that such equ-ipotential bonding networks improve concurrently the EMC performance. Hence, it may be inferred that EMI and EMC are heavily dependent on earthing and equi-potential bonding principle, which will ultimately fetch both human safety and EMI mitigation.

Besides technological considerations in the product-design as mentioned above, strict implementation and imposition of regulations set-up by regulatory bodies (like FCC, CISPR, MIL-STD etc.) of different countries are to be properly executed and tested before permitting the manufacturers of digital-based electronic devices to put their products into legal markets for sale. It is the responsibility of the respective governments to look after the proper implementation of this regulatory process with adequate infrastructural facility. Side-by-side, the violation, if any, of the regulations done by a manufacturer deliberately or otherwise should be subjected to a penalty which may include fines or jail time. Under such circumstances, companies concerned may be afraid of negative publicity of their merchandise.

For the purpose of avoiding the last minute test-failure and to achieve the cost-effectiveness in respect of mechanized goods, it is always advisable to take suitable steps for necessary EMC considerations before the design, layout and fabrication of the products with EMC experts. EMC certified materials and modules are to be used for manufacturing of the products. Further, for the system installation and project supervision, EMC trained staffs and skilled experts are to be employed.

EMC Metrology

The measurements methods of the EMC parameters are as important as the design techniques employed for controlling the EMI in a noisy environment. Yet, it should be as reliable as possible - meaning must be accurate, repeatable irrespective of time, space and person. However, this worth mentionable significant area can be broadly categorized as (1) Diagnostics, (2) Pre-compliance, (3) Full-compliance and (4) Production. The testing methods should be properly standardized and characterized as per the requirements of a country. However, a brief review of the theories involved in the major EMC measurements is presented below.

Measurable EMC parameters are as follows: *1. Conductive Emission, 2. Conductive susceptibility / Immunity, 3. Radiative Emission and 4. .Radiative susceptibility / Immunity*

Measurement of Radiative Emissions
The most important requirement for the testing site is to have a noise-free environment, which will ensure a direct link between the Equipment Under Test (EUT) and the test-probe without allowing any other signals whether reflecting or otherwise to pollute the receiving signal at test-probe. In order to simulate the free space condition, some novel arrangements have been suggested to test and evaluate the Radiative Emission of EMC measurements. These are as follows: Open Area Test Site (OATS), TEM Cell, GTEM Cell and Anechoic Chamber.

OATS
A good account of OATS as regards its concept and construction has been provided in ANSI C 63.4 and CISPR 16.1.1 (Radiative Emissions /Immunity) rules. This is referred to as "CISPR Ellipse" and is as shown bellow in Figure 7.

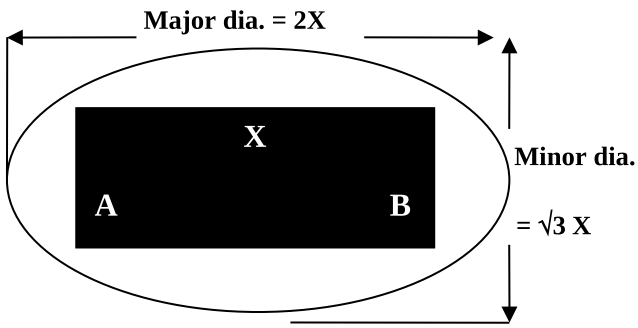

Figure 7. CISPR Ellipse for OATS design.

X represents the distance between the foci, A & B of the ellipse; A is for the position of EUT and B is for Antenna test-Probe. Preferred value of X is chosen based on the recommendation of the regulation applied as 3m or 10m or 30m. Of the ellipse, Major diameter = 2X and Minor diameter = √3 X. The ellipse area must be free of reflecting objects. Ground plane, a metal mat, extends from A to B as shown by shaded test area (Fig.7). Antenna test probe positioning height is adjustable at 1m to 4m from ground.

Generally, being an open space, ambient environment prevails over the test area of OATS, which may swamp the EUT signals with strong broadcast and legitimate radio transmissions of TV, AM, FM and Cellular carriers. However, fortunately, there are efficient methods to differentiate these signals. It would have been better if OATS was installed in a remote place surrounded with mountains all around providing natural nevertheless effective shielding. 27.8.15

Anechoic Chamber

This is altogether a different approach to rectify the inherent demerit linked with the OATS. As for example, due to ambient environmental setback, other radio waves may prevail in the testing ground affecting the authenticity and accuracy of the measured data. Here, an anechoic chamber, which is well treated, adequately large and perfectly shielded all around even the roof space as well. The inner sides of metallic screening walls of the chamber are covered with RF compatible adhesive, upon which RF absorbing materials either in the form of pyramidal carbon-loaded foams or ferrite-loaded flat absorbing tiles available commercially in the market, are pasted. As such, there will be no risk of infiltration of external Radiative Emissions at all, if any, within the chamber, neither, internally, there will be any RF reflections. However, a costly ingeniously contrived chamber creates a pure free-space ambience that is ideal for accurate field strength measurement. The measuring set-up is same as that of OATS.
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Antenna Factor
CISPR specified frequency span for Radiative emission limits ranges from 30 MHz to 1 GHz. Under such circumstances, the bandwidth requirement for the antenna-probes has to have an

adequately large value. As for example, in the experiment the preferred antenna-probes recommended for are as follow.

- Bi-conical Antennas [30 MHz --- 300 MHz]
- Log-Periodic Antennas [200 MHz --- 1 GHz]
- Broadband Antennas [30 MHz ---- 1 GHz]

Further, it is to be noted that in the measurement, the antenna-probe on receiving interfering signals from EUT provides only the magnitude of voltage (volts) at the input terminals of the antenna probe, corresponding to the electric field incident at plane of the antenna-probe. In order to derive the most wanted quantity *i.e.,* electric field, E in V/m (say, A) at the antenna plane from the measured quantity *i.e.,* voltage, V in volts, (say, B) at the antenna input terminals, Antenna Factor (AF)—a transfer function like parameter will be useful to define as the ratio of A/B. Logarithmic unit is extensively used in engineering measurement, because of its unique property of data compression and computational advantages of complicated mathematical expressions into summation of data. Hence, AF (dB /m) = E (dB μV /m) – V (dB μV). Or, in other words, E (dB μV /m) = AF (dB /m) + V (dB μV). Therefore, the electric field strength at antenna plane in dB μV /m may now, be obtained by adding the measured voltage in dB μV at the antenna terminals with the Antenna Factor (AF) in dB /m. The AF of an antenna probe being the unique property of an antenna itself is to be supplied by the manufacturer only. Along with AF, they should supply its calibration chart of its frequency dependence as well for correction factor if there is a change in frequency.AF, in general, is a complex quantity. AF for magnetic field may be identically defined and used.

Measurement of Conductive Emissions

The Line Impedance Stabilization Network (LISN) is a passive low-pass filter that is extensively and successfully used to measure the Conductive Emissions, if present in the power cord lines supplying 230 volts, 50 Hz connected with the DUT or defective DUT generating interferences to the power cord lines. In fact, LISN isolates the power cord lines from the DUT and vice versa, at the same time, it provides constant impedance to the DUT over the frequency range of the interferences to be blocked. It is to be noted that the Conductive Emissions limits are regulated by the FCC standards over the frequency range 450 KHz to 30 MHz and by the CISPR 22 from 150 KHz to 30 MHz.

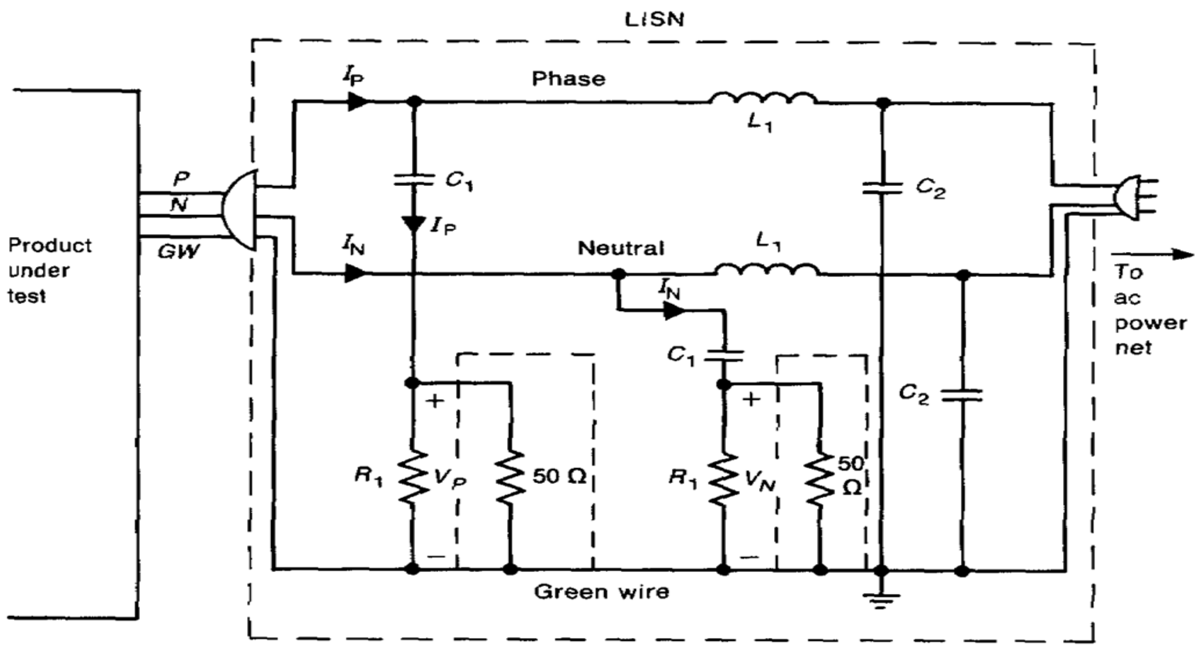

FIGURE . 15 The line impedance stabilization network (LISN) for the measurement of conducted emissions.

Conclusion

With the proliferation of digital electronics, a Frankenstein-like monster has been slowly but steadily grown-up in the electromagnetic domain behind the knowledge of engineers and scientists. Normally, such an ogre is known as Electromagnetic Interferences. It produces colossal amount of disturbances, annoyances, nuisances and havocs leading to the extent even to serious injuries, deaths and destructions. It affects, even, the health of human beings and other biological breeds. Intentionally or otherwise, such an electromagnetic interference is mostly man-made in nature. It has been defined and characterized in this paper. Further, it is classified suitably in groups and their nature and properties are discussed in detail. In order to mitigate and alleviate effects of interference such as this, necessary counter measures are also discussed by suitable imposition of rules and applications of technologically supported means. It is also an intension to raise the awareness of Engineers and other consumers using electronic goods based on digital principle, about the nature of the danger they are handling every day and how to make them domesticated and compatible with the existing environment. In order to characterise and standardise problems, salient features of EMC metrology are discussed and over-viewed in short.

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