EMI SHIELDING APPROACHES FOR WIRELESS DESIGNS

A THESIS REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
BACHELOR OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING
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CERTIFICATE

This is to certify that the work in this thesis entitled ***"EMI shielding approaches for wireless designs"*** by ***Tanveer Ahmmed*** **and** ***Ramanikanta Jena***, has been carrying out under my supervision in partial fulfilment of the requirements for the degree of Bachelor of Technology in **'Electrical Engineering'** during session 2005-2009 in the Department of Electrical Engineering, **National Institute of Technology, Rourkela** and this work has not been submitted elsewhere for a degree.

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ABSTRACT

Wireless transceivers and transmitters radiate intentional and unintentional electromagnetic (EM) signals. The unintended emissions result from electric (E) and magnetic (H) fields surrounding the current carrying traces, wire and other conductors. To address the concern for cellular phone electromagnetic interference (EMI) to aircraft radios, a radiated emission measurement process for wireless handsets has been proposed. Spurious radiated emissions can be efficiently characterized from devices tested in either a semi-anechoic or reverberation chamber, in terms of effective isotropic radiated power. This report provides a detailed description of a proposal of the measurement process.

Aircraft interference path loss (IPL) and navigation radio interference threshold data from numerous reference documents have been referred and proposed accordingly. Using this data, a preliminary risk assessment has been provided for wireless phone interference to aircraft localizer, Glideslope, VOR, and GPS radio receivers on typical transport airplanes. The report identifies where existing data for device emissions, IPL, and navigation radio interference thresholds needs to be extended for an accurate risk assessment for wireless transmitters in aircraft.

In order to suppress these types of effects several techniques have been proposed. We hereby propose a new technique for suppression of radiated EMI which is very essential in present day context in the field of wireless communication. In our article we have proposed for board-level shielding and EMI gasketing for wireless communication system designs.

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Chapter…..1

INTRODUCTION

Widespread use of electric and electronic systems for household, industrial, communication and other application makes it necessary for circuits to operate in close proximity of each other. Often these circuits affect performance of other near or far region electromagnetic fields. This interference is thus called ELECTROMAGNETIC INTERFERENCE (EMI), and is emerging to be a major problem for circuit designers. In addition the use of integrated circuits are being put in less space close to each other, thereby increasing the problem of interference.

Equipment designers need to make sure that their equipment will work in the real world with other equipments nearby. This implies that the performance of the equipment should neither be affected by external noise sources nor should itself be a source of noise. Avoidance of EMI is a major design objective, besides the principal objective of achieving intended circuit function.

ELECTROMAGNETIC COMPATIBILITY (EMC) is the ability of any electronic equipment to be able to operate properly despite if the interference from its intended electromagnetic environment and equally important not to be a source of undue interference to other equipment intended to work in the same environment.

1.1 Basic Definitions:

Electromagnetic interference **(EMI)** is an unwanted disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. The source may be any object, artificial or natural, that carries rapidly changing electrical currents, such as an electrical circuit, the Sun or the Northern lights.

EMI can be induced intentionally for radio jamming, as in some forms of electronic warfare, or unintentionally, as a result of spurious emissions and responses, intermodulation products, and the like. It frequently affects the reception of AM radio in urban areas. It can also affect cell phone, FM radio and television reception, although to a lesser extent.

Electromagnetic compatibility (EMC) is the branch of electrical sciences which studies the unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects (Electromagnetic Interference, or EMI) that such energy may induce. The goal of EMC is the correct operation, in the same electromagnetic environment, of different equipment which uses electromagnetic phenomena, and the avoidance of any interference effects.

In order to achieve this, EMC pursues two different kinds of issues. Emission issues are related to the unwanted generation of electromagnetic energy by some source, and to the countermeasures which should be taken in order to reduce such generation and to avoid the escape of any remaining energies into the external environment. Susceptibility or immunity issues, in contrast, refer to the correct operation of electrical equipment, referred to as the victim, in the presence of unplanned electromagnetic disturbances.

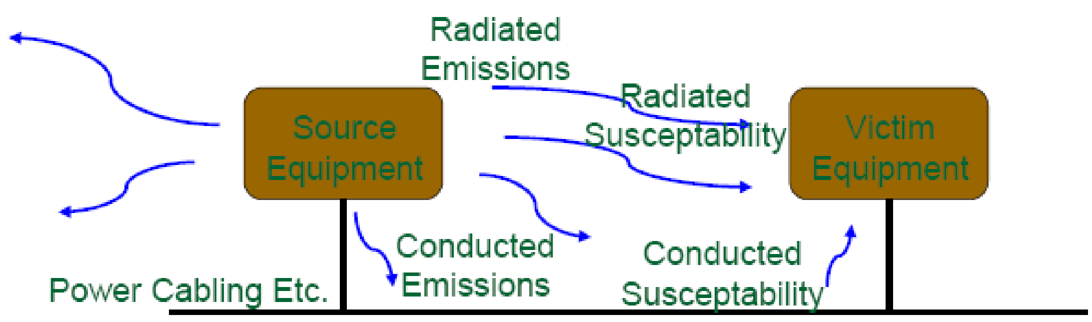
Interference, or noise, mitigation and hence electromagnetic compatibility is achieved primarily by addressing both emission and susceptibility issues, i.e., quieting the sources of interference and hardening the potential victims. The coupling path between source and victim may also be separately addressed to increase its attenuation.

1.2 Origin Of EMI :

The origins of EMI are basically -

• Radiated emissions (electric and/or magnetic fields)

• Undesired conducted emissions (voltages and/or currents).



EMS(Electromagnetic Susceptibility)

It is the ability of an electronic device/equipment/system to function satisfactorily in an electromagnetic environment.

EMC (Electromagnetic Compatibility)

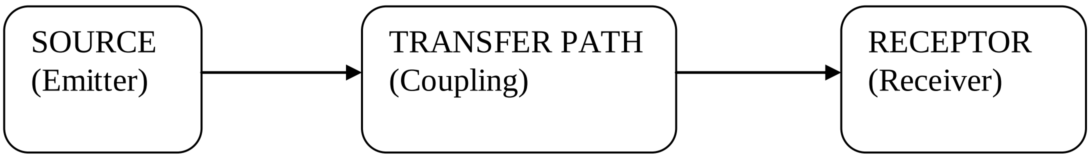
EMC=EMI + EMS

- It is the ability of an electronic device, equipment, system to function satisfactorily in its electromagnetic environment.
- At the same time it doesn’t introduce intolerable electromagnetic disturbance to any other device /equipment / system in that environment.

A system is Electro-Magnetically Compatible (EMC) if……

- It does not cause interference with other systems.
- It is not susceptible to emission from other systems.
- It does not cause interference with itself.

Composition of EMI/EMC



Man Made	***RADIATION***	***Man Made***
Radar Broadcast 2-way radio Arc Welders Microwave Oven	Far Field- Plane Wave Near Field-Capacitive Cross talk Inductive Cross talk conduction Power distribution Signal distribution	Broadcast receivers Radar receivers Amplifiers Biomedical sensors Industrial controllers Medical

1.3 Classification Of EMI:

EMI broad types:

• Intra system

•Inter system

Intra-system Interference

If the cause of EMI problem is within the system it is termed as Intra-system interference.

Intra-System EMI Causes:

Emitters	***Susceptors***
Power supplies	Relays
Radar transmitters	Radar receivers
Mobile radio transmitters	Mobile radio receivers
Car Ignition systems	Car radio receivers
Fluorescent lights	Ordnance

Inter-system Interference

If the cause of the EMI problem is from the outside of the system it is termed as Intersystem Interference.

Intersystem EMI Causes:

Emitters	***Susceptors***
Lightning Strokes	Radio Receivers
Computers	TV sets
Aircraft Transmitters	Ship Receivers
Power Lines	Heart Pacers
Radar Transmitters	Aircraft Navigation Systems

Types of EMI:

• Radiated Emission (RE)

• Conducted Emission (CE)

• Radiated Immunity/Susceptibility (RS)

• Conducted Immunity/Susceptibility (CS)

Other Types of EMI:

• Electrostatic Discharge (ESD)

• Electric Fast Transient (EFT)

• Surges (Lightning

Radiated Emission:

Radiated emission is the energy propagated through free space in the form of electromagnetic waves.

Conducted Emission:

Conducted emission is the energy propagated through a conducting media in the form of electromagnetic waves.

Radiated Susceptibility (Immunity):

Undesired potential EMI that is radiated into an equipment or system from hostile outside electromagnetic sources.

Conducted Susceptibility (Immunity):

Undesired potential EMI that is conducted into an equipment or system from hostile outside sources.

Popular Instances of EMI/EMC:

- Radiated Emission: From Nearby Radio Transmitters
- ESD (Electro-static discharge): Transfer of static charge between the application and something else.
- EFT: Electrical Fast Transient Power Disturbance to equipment.
- Surge: Lightning Indirect Strike of Lightning (Power Surge).
- EMP: Electromagnetic Pulse
- Intense electromagnetic wave caused by a nuclear detonation.

Chapter …..2

Wireless Communication

2.1 Fundamentals:

In 1895, **Guglielmo Marconi** opened the way for modern wireless communications by transmitting the three-dot Morse code for the letter ‘S’ over a distance of three kilometres using electromagnetic waves .

Wireless communications has developed into a key element of modern society. From satellite transmission, radio and television broadcasting to the now ubiquitous mobile telephone, wireless communications has revolutionized the way societies function.

Wireless communications relies on a scarce resource – namely, radio spectrum – the property rights for which were traditionally vested with the state. In order to foster the development of wireless communications (including telephony and broadcasting) those assets were privatised. Second, use of spectrum for wireless communications required the development of key complementary technologies; especially those that allowed higher frequencies to be utilised more efficiently. Finally, because of its special nature, the efficient use of spectrum required the coordinated development of standards. Those standards in turn played a critical role in the diffusion of technologies that relied on spectrum use.

It focuses on wireless telephony rather than broadcasting and other uses of spectrum (e.g., telemetry and biomedical services). Specifically, the economics literature on that industry has focused on factors driving the diffusion of wireless telecommunication technologies and on the nature of network pricing regulation and competition in the industry.

2.2 Spectrum Allocation:

Radio transmission involves the use of part of the electromagnetic spectrum. Electromagnetic energy is transmitted in different frequencies and the properties of the energy depend on the frequency. For example, visible light has a frequency between 4×10^{14} and 7.5×10^{14} Hz. Ultra violet radiation, X-rays and gamma rays have higher frequencies (or equivalently a shorter wave length) while infrared radiation, microwaves and radio waves have lower frequencies (longer wavelengths). The radio frequency spectrum involves electromagnetic radiation with frequencies between 3000 Hz and 300 GHz.

The tasks of internationally coordinating the use of radio spectrum, managing interference and setting global standards are undertaken by the International Telecommunication Union (ITU).

2.3 The range of Wireless Services:

Radio spectrum is used for a wide range of services. These can be broken into the following broad classes:

• **Broadcasting services**: including short wave, AM and FM radio as well as terrestrial television;

•**Mobile communications of voice and data**: including maritime and aeronautical mobile for communications between ships, airplanes and land; land mobile for communications between a fixed base station and moving sites such as a taxi fleet and paging services, and mobile communications either between mobile users and a fixed network or between mobile users, such as mobile telephone services;

• **Fixed Services**: either point to point or point to multipoint services;

• **Satellite**: used for broadcasting, telecommunications and internet, particularly over long distances;

• **Amateur radio**; and

• **Other Uses**: including military, radio astronomy, meteorological and scientific uses.

2.4 The Rise of Mobile Telephony:

The history of mobile telephones can be broken into four periods. The first (pre-cellular) period involved mobile telephones that exclusively used a frequency band in a particular area. These telephones had severe problems with congestion and call completion. If one customer was using a particular frequency in a geographic area, no other customer could make a call on that same frequency. Further, the number of frequencies allocated by the FCC in the U.S. to mobile telephone services was small, limiting the number of simultaneous calls.

2.5 Economic Issues in Wireless Communication:

Radio spectrum is a natural resource, but one with rather unusual properties. It is non-homogeneous, with different parts of the spectrum being best used for different purposes. It is finite in the sense that only part of the electromagnetic spectrum is suitable for wireless communications, although both the available frequencies and the carrying capacity of any transmission system depend on technology. The radio spectrum is non-depletable; using spectrum today does not reduce the amount available for use in the future. But it is non-storable.

Spectrum to produce wireless communications services can lead to synergies between services and between geographic regions.

The adoption of standards has been a long-standing issue in wireless communications. The International spectrum allocation system is a form of standardization – ensuring that certain frequencies are used for certain purposes on a regional or world-wide basis. Standardization, often with government involvement, has also been a key factor in the success of new wireless technology.

Chapter…..3

EMI Suppression Techniques:

The Three common means employed are:

1. Grounding
2. Shielding
3. Filtering

Each technique has a distinct role in system design proper grounding may sometimes minimize the need for shielding and filtering also proper shielding may minimize the need for filtering.

3.1 Grounding:

Grounding is the establishment of an electrically conductive path between two points to connect Electrical and electronic elements of a system to one another or to some reference point, which may be designated as Ground.

Purpose of grounding:

- Safety in power failures
- Path for Dissipation of electro static charge
- Protection against lightning
- As a reference point
- Ground as being a zero-potential surface may be appropriate at dc or low frequencies.

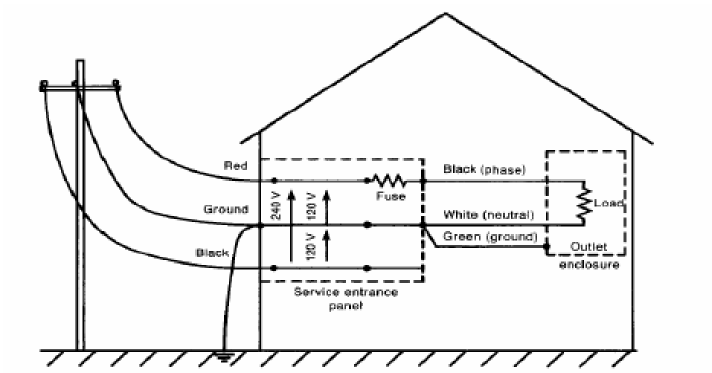
• A safety ground is normally required in order to provide protection against shock hazard. This safety ground is generally called “chassis ground.”

• Signal ground is referred to as return path for signal current to their source.

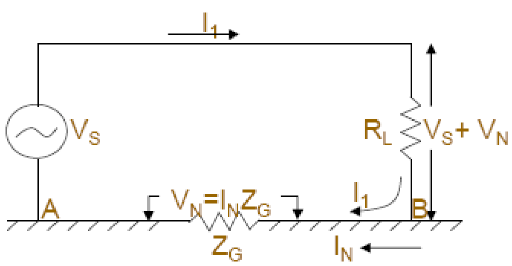
Grounding Tips:

- Select a solid ground point.
- Use a single point low impedance ground to avoid any ground loops.
- DC ground paths are very often high impedance RF grounds.
- Use ground planes whenever possible.
- Keep ground runs as short as possible.
- Avoid using thin wires for ground.

Safety ground and Signal ground:



Safety ground



Signal ground

3.2 Shielding:

Shielding is the primary means of protection of victim devices when the source of interference cannot be controlled.

Shield may be done in several ways.

1. Spatial separation
2. Orthogonalization
3. Metal barrier

Shielding Effectiveness

A Shield is characterized by its shielding effectiveness. The Shielding effectiveness is the number of decibels (db) by which the shield reduces the field strength by using the shield.

Shielding Effectiveness depends on the following:

1 Material of the shield

2 Thickness of the shield

3 Frequency of the incident wave

4 Distance of the shield from the emitter

Cable Shielding

Cable wrapping is used to shield cables or to harness even bundles of cables. Wrap shield is made as a tube so: two layers of knitted wire mesh, with a nominal thickness of 0.4 mm.

Benefits

- high flexibility
- high shielding performance
- wide range of applications
- easy to cut into the right shape

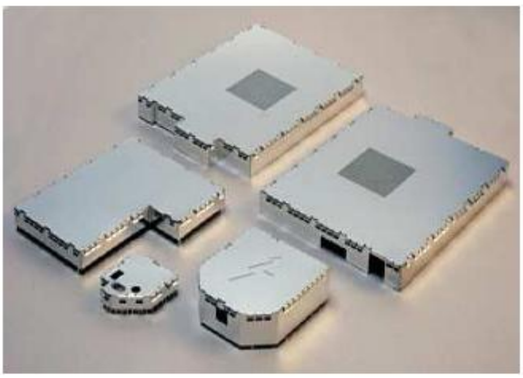
Shielded Honeycomb Filters

- Shielded Fan Filters provide a high and reliable level of shielding.
- Honeycomb blending process and Flexi-Shield gasket provide exceptional EMI shielding and EM bond.
- Flexi-Shield edge is tin/lead plated beryllium copper gasket. The honeycomb panel and frame are chem-film plated.
- Fan Filters can provide up to 80dB of shielding at 1GHz.

Standard Board Level Shielding

A standard two piece board level shield design incorporates a unique spring finger style attachment between fence and cover. To any possible configuration including rectangular, “L” shaped, “V” shaped, or even irregular shapes.

Brass, nickel silver, copper or cold rolled steel are used in manufacturing.



PCB Shielding:

With Broadband Ferrite Suppressor

The ferrite body offers a very high RF absorption, depending on circuit load and frequency up to 1.2 GHz with peak performance at 700 MHz.

- This PCB shield embodies the highest performance of board level shielding and RF attenuation from 40 MHz to 5.0 GHz. .
- Absorption of RFI right at the source.
- Much wider broadband performance, up to 1.2 GHz for the ferrite body.
- Integral mounting hardware, standard through hole or optional surface mount.

Specific Absorber Shielding

The Absorber Shield method deals with the unwanted Radio Wave (RF) energy right at the source and prevents re-radiation and reflection of the signals so that neighbouring components are unaffected and higher order harmonics are reduced.

Shielding in EMI Test

Anechoic Chamber:

- Anechoic chambers are used to study or test electromagnetic interference (EMI).
- Specialized walls to absorb and reflect waves of electromagnetic radiation.
- Chamber walls are lined with an absorbent material, such as carbon-impregnated foam shaped into pyramids.
- Also uses hybrid absorbers of both ferrite tile and unique polystyrene.

Chapter…..4

Experiments Performed:

Variation of field strength of radiated wave with distance from the transmitting antenna.

The variation of field strength of radiated wave with distance from the transmitting antenna has been carried out by taking different kinds of antennas under two different conditions; one when the near by systems (computer system, CRO's) were in OFF mode and other when the system were in ON mode.

4.1. Yagi (4el) and Yagi (3el) Antenna

Equipments used:

- Antenna transmitter, receiver and stepper motor controller.
- Yagi (4el) and Yagi (3el) antenna.
- Antenna Tripod and stepper pod with connecting cables.

Experimental Theory & Procedure:

1. The both tripods were placed at a minimal distance of 1m from each other, centre to centre using measuring tape. The minimal distance ensured that the antennas were tested in the far field region.

2. The RF signal transmitted from Yagi (4el) antenna was intercepted by Yagi (3el) and was send to receiver. The level was measured on receiver in dbμv.

3. Further readings were taken at distances 1m, 1.5m, 2m, 2.5m, 3m and 3.5m.

4. These readings were plotted on Cartesian plane with distance between antennas on x- axis and signal level in db on y-axis.

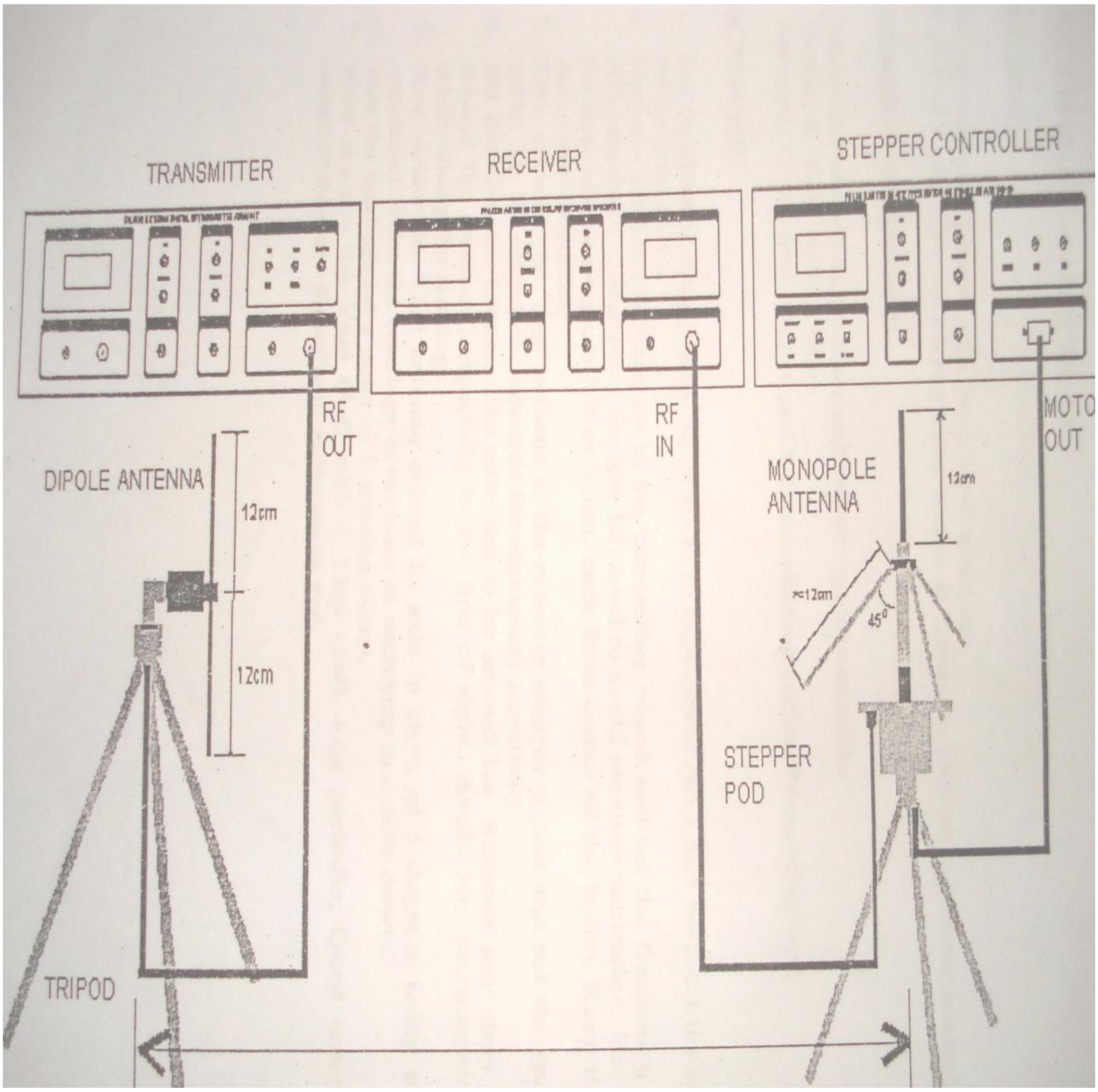
Tabulation:

Serial No.	*Distance in meters*	*Field strength (dbμv)*	
		With systems in OFF mode	*With systems in ON mode*
1	1.0	89.9	76.1
2	1.5	89.6	75.8
3	2.0	85.2	75.5
4	2.5	82.8	74.8
5	3.0	83.8	75.8
6	3.5	78.8	73.4

4.2. Folded Dipole and Whip/Monopole Antenna

Equipments used:

- Antenna transmitter, receiver and stepper motor controller.
- Folded Dipole and Whip/Monopole Antenna.
- Antenna Tripod and stepper pod with connecting cables.



Experimental Set up

Experimental Theory & Procedure:

1. The both tripods were placed at a minimal distance of 1m from each other, centre to centre using measuring tape. The minimal distance ensured that the antennas were tested in the far field region.

2. The RF signal transmitted from folded dipole antenna was intercepted by monopole antenna and was send to receiver. The level was measured on receiver in dbμv.

3. Further readings were taken at distances 1m, 1.5m, 2m, 2.5m, 3m and 3.5m.

4. These readings were plotted on Cartesian plan with distance between antennas on x- axis and signal level in db on y-axis.

Tabulation:

Serial No.	*Distance in meters*	*Field strength (dbμv)*	
		With systems in OFF mode	*With systems in ON mode*
1	1.0	75.0	73.8
2	1.5	61.5	64.6
3	2.0	63.2	58.0
4	2.5	58.0	59.0
5	3.0	53.5	53.0
6	3.5	51.0	44.0

4.3. Log Periodic and Yagi (3el) Antenna

Equipments used:

- Antenna transmitter, receiver and stepper motor controller.
- Log periodic and Yagi (3el) antenna.
- Antenna Tripod and stepper pod with connecting cables.

Experimental Theory & Procedure:

1. The both tripods were placed at a minimal distance of 1m from each other, centre to centre using measuring tape. The minimal distance ensured that the antennas were tested in the far field region.

2. The RF signal transmitted from log periodic antenna was intercepted by Yagi (3el) and was send to receiver. The level was measured on receiver in dbμv.

3. Further readings were taken at distances 1m, 1.5m, 2m, 2.5m, 3m and 3.5m.

4. These readings were plotted on Cartesian plane with distance between antennas on x- axis and signal level in db on y-axis.

Tabulation:

Serial No.	*Distance in meters*	*Field strength (dbμv)*	
		With systems in OFF mode	*With systems in ON mode*
1	1.0	75.5	75.4
2	1.5	66.9	72.5
3	2.0	75.0	73.5
4	2.5	74.0	74.6
5	3.0	73.4	75.4
6	3.5	72.8	73.1

Inferences:

- ✓ From the experiments performed, it is concluded that the field strength of the radiated wave decreases with increasing distance from the transmitting antenna.
- ✓ The field strength of the signal of the radiating/transmitting antenna is found to be higher when the nearby equipments/system is in OFF mode, than they are in ON mode. This is due to the electromagnetic interference between the antennas and the nearby systems.
- ✓ Hence the experiment so performed has proved that the level of interference is higher when the nearby equipments/system is in ON mode.
- ✓ There has been some error in readings which is of course because of the interference of radiating antenna with nearby working and/or standstill equipments/systems and also because of the reflection from the wall of the laboratory room where the experiment was performed, otherwise the result would have simply followed the inverse square law.

Chapter…..5

EMI Assessment of Wireless Handsets to Aircraft Navigation Radios

5.1 Approach

Ideally, the most effective way to assess the potential for electronic equipment to interfere with aircraft systems is to exercise a representative unit in all modes of operation, at the location of installation, and monitor all critical and essential aircraft systems for unwanted effects during their operation.

In the case of wireless phones carried aboard aircraft by passengers, this process quickly becomes impractical. Passengers routinely carry wireless handsets ranging from brand-new to over a decade old. The product design cycle for consumer electronics products is measured in periods of months. It is simply not possible to test every device or even representative models of every device for potential EMI to all aircraft systems. In addition, wireless handsets can potentially be present in any passenger cabin or cargo bay location.

To access the potential for wireless handsets to interfere with aircraft systems, it is necessary to separate the analysis into an elemental, rather than in-situ approach. In the figure, it graphically outlines the three required elements of any EMI problem, as they pertain to evaluating the wireless phone threat to aircraft radios. This section will address each of the three elements of the EMI threat assessment from wireless handsets. The threat power at the connector of a particular aircraft radio receiver (P(rcvr threat), dBm), due to spurious radiated emissions from a PED (P(ped), dB), can be described as PPED, less cable, propagation and antenna loss occurring between the PED and aircraft radio connector (Interference Path Loss, IPL, dBm).

In equation form:

P(rcvr threat) = P(ped)-IPL

To function without interference, the interference threshold power at the aircraft radio connector (P(rcvr_IT), dBm) must be greater than P(rcvr threat).

P(rcvr_IT) > P(rcvr threat).

The analysis herein focuses upon the following flight-essential aircraft navigation radio receivers: Instrument Landing System (ILS) localizer, ILS glide slope, VOR, and GPS. The potential for interference with flight-essential VHF and satellite communications, Distance Measuring Equipment (DME), Traffic Alert and Collision Avoidance System (TCAS), Air Traffic Control Radio Beacon System (ATCRBS), transponder systems, or flight critical propulsion, flight controls and display systems is not addressed.

5.2 Spurious Radiated Emissions from Wireless Handsets

Regulatory Limit

In the US, the Federal Communications Commission (FCC) provides guidance for allowable signal emissions from consumer device.

FCC contains the regulations for Public Mobile Services and provides the emission limitations for cellular handsets, with graduated emissions masks depending upon the frequency offset from the unmodulated carrier frequency. In summary, on any frequency removed from the carrier frequency more than 90 kHz, the mean power of emissions must be attenuated below the mean power of the unmodulated carrier (P) by at least 43 + 10logP dB. Thus, for a 1 watt unmodulated carrier frequency, a cellular handset could radiate 0.05 milliwatts (or -13dBm) in any aircraft communication or navigation radio frequency band. It should be noted that specifically prohibits airborne operation of cellular telephones. This regulation applies as soon as the aircraft is no longer touching the ground, and is intended to prevent interaction with multiple cell base stations and possible interference with other calls.

FCC contains the regulations for Personal Communications Services. It provides the simple emission limit statement in paragraph (a) "On any frequency outside a licensee's frequency block, the power of any emission shall be attenuated below the transmitter power (P) by at least 43+10log(P) dB. Thus again, for a 1 watt unmodulated carrier frequency, a cellular handset could radiate 0.05 milliwatts (or -13dBm) in any aircraft communication or navigation radio frequency band.

5.3 Measurement Process for Spurious Radiated Emissions:

5.3.1 Semi-Anechoic Chamber

Standard radiated emission measurements collected in open area test sites, shielded rooms, and semi-anechoic chambers produce data in terms of electric field intensity. This is a point of significant concern when applying the data to devices that are not typically used in such controlled environments.

We proposed that measured field intensity be converted to units of power, by approximating the PED as an isotropic radiator. This should be considered conservative because an electrically-large PED could focus more power toward the measurement antenna than elsewhere, thus producing an artificially high measurement result. Ideally, the device should be re-oriented when measured at each frequency, such as to provide maximum power transfer to the measurement antenna at all frequencies. The isotropic approximation is certainly more valid in a semi-anechoic room than the passenger cabin of an airplane, and allows radiated emission data to be more accurately applied to the measured path-loss data between passenger cabin and aircraft radio receiver antenna.

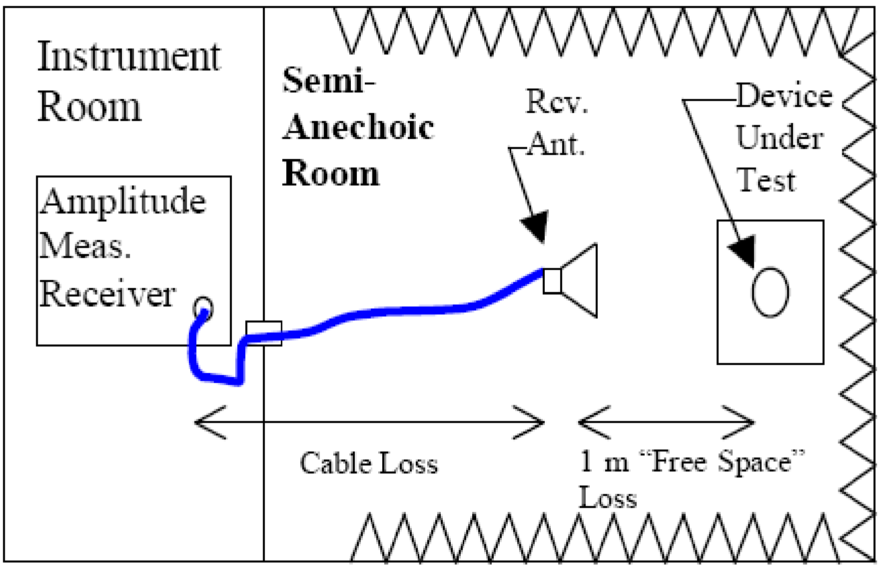


Diagram of Semi-Anechoic Chamber radiated emission measurement setup

To calculate effective isotropic radiated power (EIRP, in dBm) of a PED, at a given frequency, the following formula can be applied to the measured data:

P(ped)= P(meas) + **α**RcvPath + AF

where :

P(meas)= Power measured at amplitude measurement receiver. [dBm]

αRcvPath= Cable loss from Rcv. antenna connector to amplitude measurement receiver.

AF = Antenna Factor from Manufacturer relating field intensity at antenna to voltage measured at antenna connector.

5.3.2 Reverberation Chamber:

Radiated emission measurements in reverberation chambers produce data in terms of EIRP [Equivalent isotropic radiated power], so the isotropic radiator approximation is not required. A peak-radiated-power measurement is particularly useful when evaluating the EMI potential of devices that may be used in multiple locations that are electromagnetically complex.

This situation is certainly applicable to wireless phones used in aircraft passenger cabins. The measurement process utilized the same amplitude measurement receiver and antennas as those used in the semi-anechoic chamber.

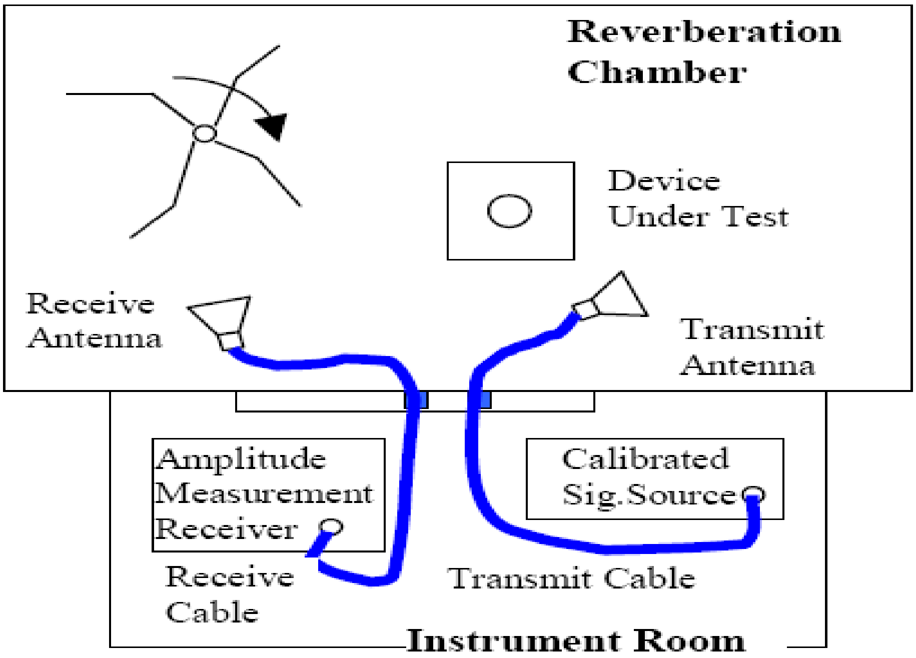


Diagram of Reverberation Chamber radiated emission measurement setup

The standard formula for measuring PED EIRP (dBm) in a reverberation chamber is:

P(ped)= P(meas) + αCbr + αRcvCb

where:

P(meas) = Power measured at amplitude measurement receiver.

αRcvCb = Cable loss from Rcv. antenna terminals to amplitude measurement receiver.

αCbr = Camber Loss,

αCbr describes the relationship between the power transmitted into the reverberation chamber and the power coupled out through the receive antenna connector.

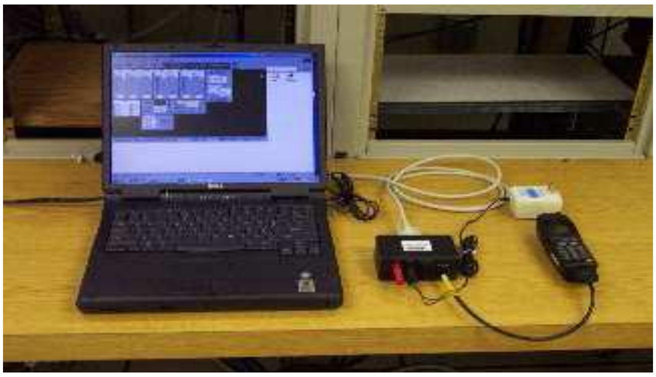
This definition includes the power lost as the signal travels through the chamber, reflecting off the walls and paddle-wheel, and coupling to and re-radiating from anything else contained within the chamber. It also includes reflection and resistive loss contributed by the receive antenna. It is important to note that αCbr varies with paddle-wheel position. For the testing described herein, all measurements were obtained with the paddle-wheel rotating continuously. This is often referred to as "mode-stirred" testing. The paddle wheel should be rotated fast enough to complete at least one rotation during each measurement period, but slow enough for the measurement receiver to complete each frequency sweep over a small fraction of the paddle wheel rotation. The rotation rate should not be a multiple of the frequency sweep time.

5.4 Interactive Control Wireless Handsets:

Measurement of radiated emissions from wireless phones is significantly more complex than from other PEDs. Unlike PDAs, laptop computers, music players, televisions, games and CB/FRS radios, wireless phones require physical-layer interaction with a base station in order to exercise the breadth of their functionality. This interaction allows control of handset transmit parameters likely to influence the spurious radiated emissions from the device.

In the laboratory, transmitter control can be accomplished either with base station simulators, proprietary keypad entry codes (supplied by the manufacturer), or a proprietary cable interface that connects between the phone and a programming device.

Keypad Programming



Test Harness Interface Programming

Base Station Simulator

The University of Oklahoma (U of OK) Wireless EMC Centre has provided operating modes analysis with a standard protocol for spurious radiated emissions.

The U of OK Wireless EMC Centre provides procedures and instrumentation to control RF Power output level, Puncture Rate, and VOCODER Rate for wireless handsets. Keypad entry codes were limited in their ability to control puncture rate and VOCODER [word voice encoder] rate.

The Base Station Simulator could control the handset RF transmit power level by initiating a call in a closed-loop mode, whereby the handset transmit power would automatically increase with a specified decrease in simulator transmit power.

The test harness interface could control all three parameters, with RF power control based upon a numerical entry into a proprietary software package running on a personal computer.

It is necessary to experimentally determine equivalent handset transmit power levels depending upon base station simulator versus test harness interface commands.

5.5 Radiated Emission Measurement Data:

Radiated spurious emission data was measured for wireless handsets, as affected by

- Operating mode
- Programming method
- Antenna retraction & extension
- Handling & manipulation,
- Battery charge level
- Interactions (intermodulation) with other transmitting handsets.

Nearly all data was acquired using the reverberation chamber measurement process to gain advantages of reduced time and lower noise floors. Reverberation versus semi-anechoic chamber measurement comparability was established by operating a particular wireless phone in the same operational mode, when measured in each facility.

5.5.1 Operating Mode Data

A primary objective for the measurement project is to determine which operating mode can be described as "worst-case", in terms of wireless handset spurious radiated emissions. Each handset was operated in extensive combinations of operating modes using available command capability, to gain insight into configurations resulting in highest emissions. While the operating mode often resulted in discernable differences in the spurious radiated spectrum, dominant spectral components did not vary appreciably due to mode changes. Operating mode did not appear to result in significant differences in Emissions in the aircraft RF navigation frequency bands.

The ON-OFF testing did not require any keypad codes, base station interaction or test harness interface.

Repeatedly turning the handset power on-and-off caused the most significant changes in the spurious radiated spectrum; however these changes did not impact the highest emission levels.

5.5.2 Programming Method Data

Operating modes of wireless handsets can be controlled via keypad entry codes, base station simulator, and test harness interface. This approach is based upon the assumption that the handsets would respond the same regardless of which control method is based.

5.5.3 Phone Handling and Manipulation Data

All spurious radiated emissions measurements discussed so far can be obtained with the wireless handset antennas extended, with the unit placed upon a Styrofoam dielectric support, 80 cm in height, with no objects touching the unit during operation (Free Standing). In practice, however, people need to handle their devices in order to operate them. It is conceivable that specific signals may radiate more or less to the surrounding environment depending upon electromagnetic interaction with the user.

5.5.4 Antenna Retraction and Extension Data

Antenna position influenced spurious radiated emissions in aircraft radio frequency bands, spurious radiated emission data should be compared with antennas extended and retracted. For the most part, emission variations due to antenna position are only a few dB.

5.5.5 Battery Charge Level Data

The functionality of the data acquisition software is to be extended to allow unattended measurement of emissions at specified time intervals. This allowed periodic sampling of handsets configured to transmit continuously until their battery is completely discharged.

5.5.6 Intermodulation Data

Signals from multiple handsets could potentially interact to produce additional spurious radiated emissions, all phones should be simultaneously set to simultaneously radiate at maximum power in the reverberation chamber. Significant additional spurious radiated emissions occurred.

5.6 Aircraft Interference Path Loss:

In order to approximate a PED radiating spurious signals in a particular aircraft radio frequency band, we propose a test setup.

1. A reference antenna (approximating the PED).
2. A particular aircraft radio receiver terminal connector.
3. Amplitude measurement receiver.

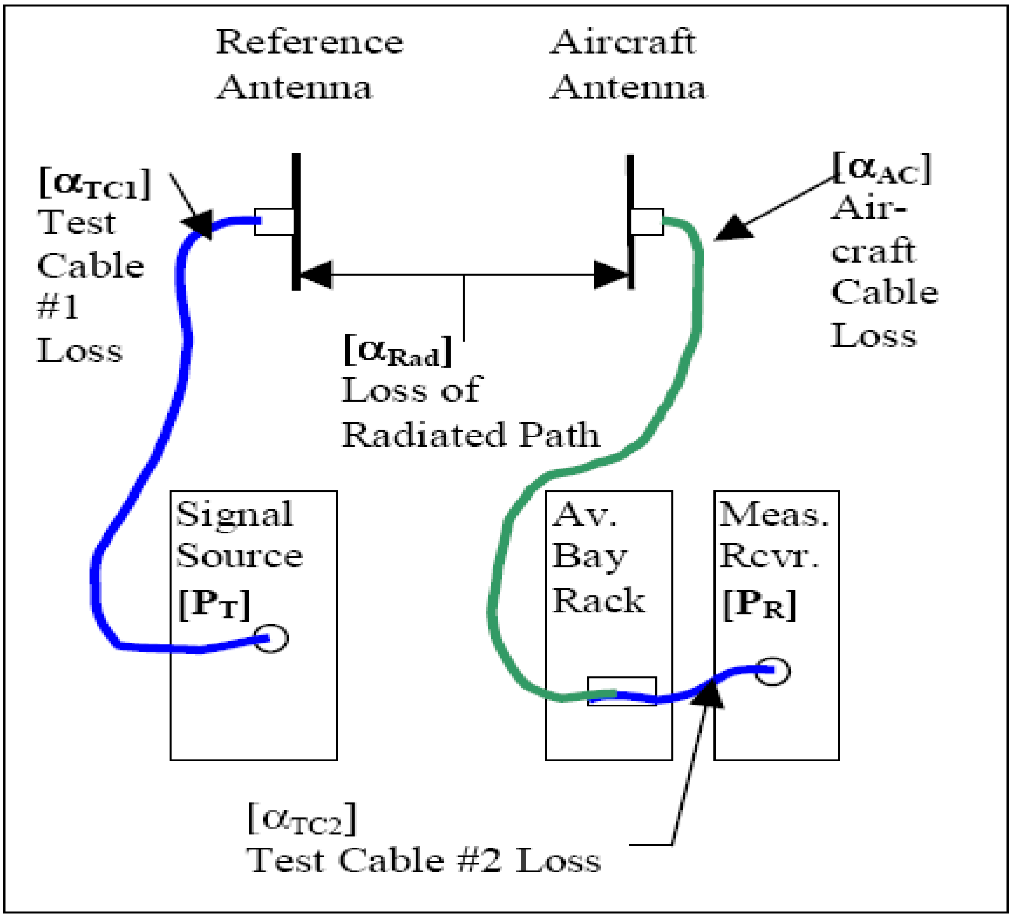


Diagram of IPL measuring variables

In the test setup aircraft Interference Path Loss [IPL] is defined as the loss between a reference antenna (approximating the PED) and a particular aircraft radio receiver terminal connector. (The aircraft radio needs to be removed to allow connection of the measurement receiver to the aircraft antenna.) .

Alternately IPL can be described as the loss between a calibrated signal source and measurement receiver, less any test cable losses. In equation form:

IPL = $\alpha Rad + \alpha AC$

$$= PT - \alpha TC1 - \alpha TC2 - PR$$

Where:

PT= RMS power amplitude transmitted by the CW signal source (dBm).

PR= RMS power amplitude measured at the test receiver (dBm).

αRad= Radiated path loss between the test antenna connector and the aircraft antenna connector (dB).

αAC= Aircraft cable loss. (dB)

αTC1= Loss of Test Cable #1, between the signal source and reference antenna connector (dB).

αTC2= Loss of Test Cable #2, between the aircraft radio receiver rack location and the measurement receiver (dB).

5.7 Aircraft Radio Receiver Interference Thresholds:

A significant part of the threat assessment is to determine the minimum interfering signal power, delivered to the RF connector of each aircraft navigation radio that would be required to cause unacceptable performance.

If the threshold power of the aircraft antenna is greater than the threat power of the portable electronic devices (PED), then there won’t be any interference in aircraft navigation, and if it is lesser or equal then interference will occur. The threshold power is similar to the susceptibility limit of the aircraft radios.

Chapter…..6

Shielding Techniques

6.1 Board-Level Control

Radiated emissions can be minimized through proper circuit design and board layout. Using multilayer printed circuit boards with separate ground planes and avoiding needlessly fast clock-waveform rise times can also be effective. However, with wireless operating frequencies of 800 MHz and higher, wavelengths are so short that many board circuit traces have lengths that make them act as efficient one-quarter or one-half wavelength antennas. Thus, board level emissions reduction does not eliminate the need for enclosure-level EMI shielding.

Board-level shielding often involves mounting a can or cover over radiating or susceptible components on a pc board. Stamped metal cans soldered onto boards are a common and effective shielding approach and can be integrated into pick and place component loading systems. However, soldered cans make it difficult to access the shielded components

6.2 Board-Level Shielding

For shielding at the PCB level, one of the most promising new shielding techniques uses a small metal-plated plastic shielding cover. The cover is mounted over troublesome circuits directly onto one end of a PCB. It features an integral conductive elastomer mounting gasket, which deflects sufficiently to maintain a continuous low impedance path. The elastomer gasket is moulded directly onto the plastic cover's nickel-copper-plated flange area.

This board shield provides EMI isolation and prevents the escape of radiated emissions. It can also replace the use of one or more metal shielding "cans", which are typically mounted into fences that are soldered onto PCB ground traces - a system that can be both pricey and time-consuming.

Specially formulated elastomers are also being precision-moulded onto thin-wall plastic spacer frames to provide grounding of circuit boards inside small wireless packages. In these applications, ground traces on a pair of cell phone boards are aligned, and the conductive elastomer gasket makes a continuous ground connection.

The choice of an EMI shielding system is greatly influenced by mechanical packaging issues. Compression-deflection properties, environmental requirements, mating surface finishes, and gasket installation methods are among the most important. As wireless devices and equipment become more densely packaged, and as operating frequencies increase, manufacturers of EMI shielding materials will continue to be challenged to develop satisfactory and low-cost new product systems.

Cans and covers:

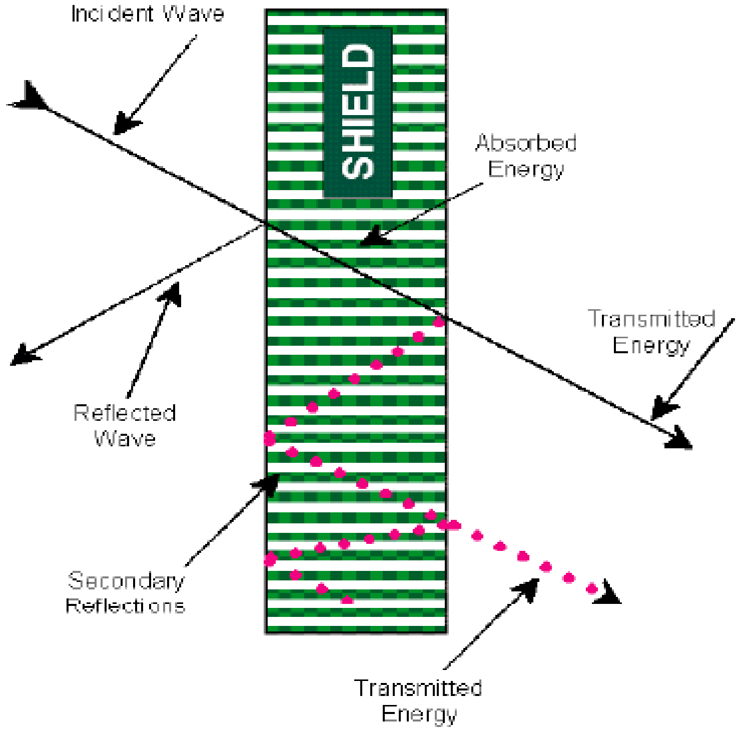
A shield might be used on a single-board phone, where components such as oscillators and high speed ICs must be shielded from each other. Board level shielding is often provided using a conductive can or cover mounted over radiating or susceptible PCB components. Stamped metal cans soldered onto boards are a common shielding approach. These are typically made from tinplated sheet steel, and can be integrated into pick and place component loading systems. While solder mounted cans hinder component access, versions with removable lids are now

available. However, like similarly mounted components, the solder is susceptible to cracking from tension or shock on the circuit board. Because of this, metal cans may be less compatible than other shielding solutions with phones designed for back-pocket flexibility. New molded plastic covers provide greater flexibility and easy pin mounting. These covers have a conductive coating or plated surface and feature integral conductive elastomer gaskets for shielding components or entire cell phone PCBs. The gaskets mate with board traces and, together with a PCB's conductive back plane layer, they provide a 360-degree shielding solution
(called a Faraday shield).

In place of plating or paint, a thin, continuous layer of molded-in-place conductive elastomer can provide a shielding surface. The elastomer can also be molded into detailed wall patterns for isolating components from each other under the cover.

The Role of Shielding

EMI shielding of electronic enclosures works on the theory that a highly conductive metal, inserted between the source of EM emissions and circuits needing protection, will attenuate the radiated E-field by reflecting and absorbing a portion of its energy. The type (reflection or absorption) and amount of attenuation will depend on factors such as the frequency and wavelength of the emissions, the conductivity and permeability of the metal, and its distance from the source. At high frequencies, thickness of the shield is not much of a factor.



Attenuation of Electromagnetic Interference (EMI) by a conductive shield.

An enclosure shield in a wireless device might be a simple metal sheet or foil layer (often called a "shadow shield"), or a six-sided metal or metalized plastic enclosure. In wireless systems Faraday shields are most common. These shields must be electrically bonded to the enclosure's chassis ground to be effective. To serve as a Faraday shield, a plastic housing can be metalized by applying a conductive coating, typically using an HVLP (high-volume, low-pressure) spray system. Conductive coatings are commonly formulated from an acrylic resin filled with metal particles. Metal plating provides another system for shielding plastic enclosure parts.

6.3 Using EMI Gaskets

Designers have a growing choice of economical EMI gasket types and applications methods. Conductive elastomers, based on silver- or nickel-plated filler particles, are commonly used where small, precise cross sections are needed. These materials are available formulated for outdoor applications requiring both environmental sealing and EMI shielding. Knitted wire mesh gaskets are often used in die-cast housings due to their ability to bite through surface oxides and contaminants. Knitted or woven conductive fabrics with soft foam cores are useful where gaps are relatively large and closure force is low. And beryllium copper (BeCu) spring fingers are typically used in door seams where shear forces are a concern.

Depending on the gasket type, installation can be accomplished with pressure sensitive adhesive (PSA) tapes, clip-on strips, friction fit into grooves, vulcanizing onto covers or plastic retainer frames, or through robotic form-in-place dispensing.

For EMI gasketing of enclosure parts, such as wireless handsets, one of the more recent applications of conductive elastomers is in automated form-in-place EMI gasketing systems. These robotic systems dispense conductive elastomer compounds onto metal or metalized plastic housings with exceptional accuracy and strong adhesion. Dispensing systems are programmable in three axes, compensating for uneven surfaces on injection moulded plastic or cast metal housings.

Foam-based EMI gaskets include conductive fabric, metal foil or wire mesh over soft foam cores to provide shielding under low closure forces.

The small cross sections of robotically dispensed gasket beads allow their use on flanges as narrow as 0.030 inch (0.76 mm) wide. This allows tighter package designs, providing more space for circuit board components. Form-in-place EMI gaskets can be applied with height tolerances of just ±0.004 inch (±0.10 mm) onto the most common wireless housing substrates.

Hollow or solid extruded conductive elastomers are typically used along the perimeters of wireless enclosure doors, covers and panels. These gaskets can serve as both EMI and environmental seals, making them especially suited for outdoor applications. Elastomer extrusions accommodate low closure forces and many mounting systems. Versatile conductive elastomer formulations include UL 94V-0 flammability rated and corrosion resistant materials. Certain conductive fillers can bite through thin surface oxides or chromate conversion coatings on cabinet flanges, providing better electrical contact.

For applications where cabinetry closure force is limited or large gasket deflection is required, the EMI gasket of choice is often a foam core product. Foam based EMI gaskets generally feature a core made from open or closed cell urethane or thermoplastic EPDM. A conductive jacketing material surrounds the foam core. Jacket materials now are use includes plated woven fabric, knitted silver-plated nylon yarn, fibreglass-reinforced foil, and knitted wire mesh.

Foam core EMI gaskets are becoming as versatile as conductive elastomers. They can be formed in a wide variety of shapes, including continuous strips and intricate die-cut patterns for shielding I/O connector panels. Versions are available with UL 94V-0 flammability ratings. Foam-based gaskets are typically supplied with pressure-sensitive adhesive backing, simplifying their application. Like elastomers and metal spring fingers, they can be supplied as peel-and-stick pads for grounding applications.

Knitted wire mesh gaskets, long proven in thousands of shielding applications, continue to be adapted to wireless shielding design needs. Gaskets knitted from tin-plated steel wire provide a spring-like resilience when groove-mounted in cast metal enclosures. Today's wire mesh gaskets can deflect 80% under low closure forces, allowing the use of less expensive enclosure fastening systems.

Metal finger stock gaskets combine high levels of EMI shielding effectiveness with spring-finger wiping action and low closure properties. Typically made from beryllium copper (BeCu), these gaskets use linear serrated fingers and are available in gasket strips or in individual pieces for grounding applications. Finger stock gaskets are highly resilient and resistant to compression set. They are commonly used on base station doors where shear forces are encountered.

6.3.1 Spacer gaskets:

In multiple board phones, a common shielding approach uses spacer-type EMI gaskets of plastic and conductive elastomer. Spacer gaskets provide an EMI barrier between components to protect against cross talk. They also act as a ground path between a PCB and another board or a metallised cover. The molded elastomer gasket mates with board traces or other conductive surfaces. Using tools such as finite element analysis (FEA), the gasket profiles are designed with deflection and compression ranges that provide maximum performance.

A typical spacer gasket's conductive elastomer provides shielding effectiveness of 100 dB at 500 MHz and 80 dB at 10 GHz. The elastomer material is especially durable for high speed molding equipment and for installation procedures. Prototypes of plastic/elastomer spacer shields can be created within days.

6.3.2 Form-in-place gaskets:

For limited spaces and high volume applications, automated form-in-place EMI gaskets of conductive elastomer can be applied in very small cross sections. The gaskets are robotically dispensed on metal or metallised housing flanges as narrow as .030 inch, with placement accuracy of 0.001-inch. The most capable of these dispensing systems feature non-stop, 3-axis motion to accommodate the uneven surfaces common in casting or injection molded parts.

A variety of FIP conductive elastomers are available to accommodate different requirements. Moisture cure material can be handled in hours and cures overnight. For substrates (e.g., housing parts) that tolerate elevated bake temperatures, complete gasketed parts are ready to ship in less than a half-hour. Shielding performance is typically 75 to 10 dB from 200 MHz to 10 GHz.

Conclusions:

- Electromagnetic compatibility is the ability of electronic equipment to be able to operate properly despite interference from its internal and external intended electromagnetic environment and equally important, not to be a source undue interference to other equipments intended to work in same environment.
- Susceptibility is the capability of a device or circuit to respond to the unwanted electrical (conducted or radiated). The susceptibility level of a circuit is the noise level up to which the equipments/systems can operate satisfactorily.
- Even after applying these shielding techniques, interferences cannot be completely stopped. So the system should be compatible to work in the given environment.
- The susceptibility limit of the system should be higher than the emissivity limit of the other nearby system which might interfere with the former working system. So if the susceptibility limit of the system is higher than the emissivity limit of the other nearby system, then there won't be any interference in the working of the system, and if it lesser or equal to it, then interference will occur.
- PCB shielding is mainly for conducted EMI, for radiated EMI where system has antennas, it should be compatible.
- Electromagnetic interference and compatibility is an emerging area of research now a day. Several experiments/case studies have been carried out to detect the presence of EMI from various systems in different situations. Therefore the manufacturers now a day are spending a lot to alleviate the above situations since it has been the key problem for them. They are giving more attention on

rectification of EMI problems only because to get EMC certification without which their whole purpose is unproductive.

- In India also manufacturers are giving more attention on EMI/EMC issue and they are taking care through authorized certification. Therefore Scientists/ Engineers in India should come forward for the research in the field of EMI/EMC and they should concentrate much on design aspects so that equipments will be compatible in all kinds of environment.
- Problems of EMI/EMC have got a lot of applications in military, scientific and medical research. Similarly there are some regulations also particularly in this regard from strategic point of view.
- Therefore the whole purpose of the study of this topic is that an equipment/system in a functioning state should not disturb other working equipments/system nor it should be disturbed by others.

Due to limitations of scope in our local environment more detailed studies on the above topic could not be done, otherwise better results would have been produced and presented.

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