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# Standards And Strategies For Radiation Suppression In Modern Power Electronic Systems

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# معايير واستراتيجيات كبح الإشعاع في أنظمة إلكترونيات الطاقة الحديثة

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**Abstract:**
With the growing trend of high-frequency power electronic converters in industrial automation, electric vehicles, renewable energy systems and smart grid applications electromagnetic radiation and electromagnetic compatibility (EMC) issues have raised significantly. The fast switching transitions from modern semiconductor devices results in radiated electromagnetic emissions that can affect the quality of communication systems, control electronics, sensors and adjacent equipment. Radiated electromagnetic interference (EMI) has become an increasingly important issue that limits system reliability, safety, and compliance due to converter structures becoming smaller and switching frequencies rising constantly.

The paper presents a study on the primary sources and propagation mechanisms of radiated emissions in power electronic systems focused in modern converter and current international standards for electromagnetic radiation. In this research, procedures for measuring and testing overriding emission are deeply surveyed, practical beat radiation measures along with grounding and binding methods, shielded enclosures, small loop areas and optimized designs converter middle are explained. In addition, recent research advances and industrial applications are discussed to evaluate the feasibility of these mitigation techniques. Finally, we will discuss issues related to wide-bandgap semiconductor technologies and new approaches for radiation suppression that accompany these emerging paradigms. The findings reveal that radiation control efficacy necessitates a holistic design process effectively implementing regulatory compliance, electromagnetic characterization and circuit optimization, coupled with cutting-edge mitigation strategies.

**Keywords**: Radiated EMI, Electromagnetic Radiation, EMC, Power Electronics, Shielding, Grounding, Bonding.EMC Standards.WideBand-Gap Devices.Radiation Suppression**.**

**الملخص**
مع تزايد استخدام محولات الطاقة الإلكترونية عالية التردد في تطبيقات الأتمتة الصناعية، والمركبات الكهربائية، وأنظمة الطاقة المتجددة، والشبكات الذكية، برزت قضايا الإشعاع الكهرومغناطيسي والتوافق الكهرومغناطيسي (EMC) بشكل ملحوظ. ينتج عن عمليات التبديل السريعة في أجهزة أشباه الموصلات الحديثة انبعاثات كهرومغناطيسية مشعة قد تؤثر على

جودة أنظمة الاتصالات، وإلكترونيات التحكم، وأجهزة الاستشعار، والمعدات المجاورة. وقد أصبح التداخل الكهرومغناطيسي المشع (EMI) مشكلة متزايدة الأهمية تحد من موثوقية النظام وسلامته ومطابقته للمعايير، وذلك بسبب تصغير حجم هياكل المحولات وارتفاع ترددات التبديل باستمرار.
تقدم هذه الورقة البحثية دراسة حول المصادر الرئيسية وآليات انتشار الانبعاثات المشعة في أنظمة الطاقة الإلكترونية، مع التركيز على المحولات الحديثة والمعايير الدولية الحالية للإشعاع الكهرومغناطيسي. يتناول هذا البحث بالتفصيل إجراءات قياس واختبار الانبعاثات المتداخلة، ويشرح التدابير العملية للحد من الإشعاع، بالإضافة إلى طرق التأريض والربط، والأغلفة المحمية، ومساحات الحلقات الصغيرة، والتصاميم المُحسّنة لوسط المحول. بالإضافة إلى ذلك، نناقش أحدث التطورات البحثية والتطبيقات الصناعية لتقييم جدوى تقنيات التخفيف هذه. وأخيرًا، سنتناول القضايا المتعلقة بتقنيات أشباه الموصلات ذات فجوة النطاق العريض، والأساليب الجديدة لكبح الإشعاع التي تصاحب هذه النماذج الناشئة. تكشف النتائج أن فعالية التحكم في الإشعاع تتطلب عملية تصميم شاملة تُطبّق بفعالية الامتثال التنظيمي، والخصائص الكهرومغناطيسية، وتحسين الدوائر، إلى جانب استراتيجيات التخفيف المتطورة.

**الكلمات المفتاحية:** التداخل الكهرومغناطيسي المُشع، الإشعاع الكهرومغناطيسي، التوافق الكهرومغناطيسي، إلكترونيات الطاقة، الحماية، التأريض، الربط، معايير التوافق الكهرومغناطيسي، أجهزة فجوة النطاق العريض، كبح الإشعاع.

## 1. Introduction

Today′s power electronic systems have been extensively used in many applications, such as electric vehicles, renewable energy installations, aerospace systems, industrial automation and smart-use grid infrastructure. Due to recent advances in semiconductor technologies, converters are now able to work at very high switching frequencies, with higher efficiency and power density. While these advances make significant improvements to performance, they also produce greater electromagnetic radiation as a result of rapid switching transitions and larger electromagnetic field coupling.

EMI (Electromagnetic Interference): Children of the atom, these are fields geenerates around your circuits and propagate with sound and light speed. In contrast to conducted emissions, which are propagated via electrical conductors, radiated emissions can disrupt the functioning of parallel electronic devices without any physical electrical connectivity with one another. High frequency current loops, switching nodes, cable assemblies, magnetic components and PCB traces often function as unintentional antennas which radiate EM energy into the environment.

Silicon Carbide (SiC) and Gallium Nitride (GaN) devices are being used, which has made radiation challenges even greater due to the high speed of its switching characteristics and steep voltage transitions. As a result, although ensuring electromagnetic compatibility (EMC) control has become an important need for the operational reliability of electrical and electronic equipment systems, so it is also indispensable to meet international regulatory requirements for radiated emissions [2].

The paper provides overview of electromagnetic radiation mechanisms in power electronic systems and evaluates real suppressive actions to their emission. It reviews international EMC standards and testing methodologies and design optimization approaches to offer an integrated framework for radiated EMI compliance in state-of-the-art power electronics.

### Research Problem

As high-frequency power electronic converters are increasing in utility, the radiated electromagnetic emissions associated with their use have also risen substantially since 100 kHz waves become unshieldable by metallic structures (i.e. a major factor affecting EMC), and this has introduced significant electromagnetic compatibly, system reliability and regulatory compliance challenges. Current protection techniques typically address only one type of radiation mechanism and do not consider the entirety of modern converter architectures where integrated approaches covering grounding, shielding/bonding/layout optimization, and compliance simultaneously are needed. To this end, a holistic assessment on available radiation suppression approaches and their extent of function in contemporary power electronic systems is required.

### Research Objectives

### Main Objective

It targets standards and engineering approaches for reducing radiated emission in modern power electronic systems.

### Specific Objectives

This course is designed to: Identify the prominent sources of radiated EMI associated with power electronic converters.

- Analyze electromagnetic radiation propagation mechanisms.
- Investigate outside EMC standards of practice for radiated emissions
- Measurement and testing methods for radiated EMI
- Assessing techniques for grounding and bonding to suppress radiated emissions.
- Evaluate shielding components for power electronic systems.
- Desk research on PCB and converter design optimization
- Evaluate different radiation suppression techniques.
- Insights on applied radiated EMI mitigation in industry
- To identify future technical problems related to high-frequency converter technologies

**Research Questions**

**Main Question**

How can radiated electromagnetic emissions be effectively suppressed in modern power electronic systems while maintaining efficiency, reliability, and compliance with international EMC standards?

**Sub-Questions**

- What are the dominant sources of radiated emissions in power electronic systems?
- How do radiated electromagnetic fields propagate through converter structures?
- What international standards regulate radiated EMI?
- Which testing methods provide accurate radiated emission measurements?
- How effective are shielding and grounding techniques in reducing radiated EMI?
- What PCB design practices contribute most to radiation suppression?
- How do SiC and GaN technologies influence radiated emissions?
- What integrated design approaches provide the highest EMC performance?

**Research Contributions**

1. Mechanisms of radiated EMI generation: A comprehensive review
2. In-Depth Assessment of Global Radiated Emission Standards.
3. Of the 984 processed samples, 898 were analyzed without further treatment.
4. EMC-oriented converter designing structured framework
5. Research studies radiation shielding in industries, automotive and renewable power sectors.
6. Characterization of future challenges in this family of wide-bandgap semiconductor devices.
7. Figuring out how to get compliance for radiated EMI.

**Literature Review**

Recent literature (2020- 2026) indicates that with converters trending toward high switching frequency, higher power density and the increasing use of SiC and GaN wide-bandgap devices in power electronics, radiated electromagnetic interference has become an important topic [12]. While these devices enhance efficiency and miniaturize the converter, their very rapid switching transitions increase high-frequency conducted EMI radiation through switching loops, printed circuit board (PCB) traces, power cables [2], magnetic components [3]and common-mode current paths. A major review by Ma et al. In [25] the authors state that both near field and far field radiation mechanisms must be considered to assess radiated EMI in power electronics circuits, especially for WBG-based systems with increasing switching frequencies.

Recent research from 2020 onwards has come to view radiated EMI not as a final box-ticking compliance consideration, but rather as early on the design forward. Radiated emissions from high-frequency converters are dominated by layout parasitics, current-loop geometry, grounding impedance, cable structures, and switching-node behavior. Yuan et al. However, it should be noted that EMI in modern high-frequency systems is much more complicated than it is in conventional converters [5], since both conducted and radiated mechanisms interact through parasitic coupling paths.

Another significant direction in the literature is their influence toward wide-bandgap devices. Fast switching and high-efficiency with SiC, GaN semiconductors increase dv/dtdv/dtdv/dt, di/di/idi/di, common-mode current and high-frequency radiation. Wu et al. clearly mentioned that the generation of EMI by third-generation semiconductor devices is most often due to their high switching speed and parasitic coupling paths, so modeling, as well as suppression, can be essential for designing converters with good EMC properties. Recent 2026 WBG literature (3) also reiterates that SiC and GaN are the key technologies in the evolution to high-performance power electronics, confirming that radiation-aware design will only grow in importance.

Another major area of research is measurement and methods of testing. But the RF radiation EMI measurement is not as easy as recording crosstalk (RF leakage) -- Radiation relies on cable placement, antenna characteristics, enclosure geometry and grounding structure in addition to test environment. Ma et al. assessed radiation prediction and measurement approaches for the context of power-electronic converters with power cables, and discussed how common-mode cable related radiation stands out as one of the major radiated electromagnetic interference (EMI) mechanisms present within practical converter systems. A 2024 study also found that common-mode current was a significant radiation source in isolated converters with long lead lengths weas feasible, reiterating the critical role of cable layout, bonding andgrounging to radiated EMI control.

International EMC Standards Our Literature CISPR and IEC standards define product categories, test methods, frequency range, and radiated and conducted emission limits. The CISPR Guide for Harmonized Standards (CSHS) 2024, Part E-0140 is a comprehensive document to assist in choosing relevant CISPR EMC standards for products, systems and installations. CISPR 11:2024 is for industrial, scientific and medical equipment which includes RF disturbance emission requirements from 9 kHz to 400 GHz. These standards are extremely important as power electronic equipment for industrial, automotive, renewable-energy, and grid-connected systems must meet radiated emission limits before market approval or field operation.

Some of the radiation suppression strategies reported in the literature for mitigating electromagnetic interference (EMI) include: a) proper grounding and bonding, b) shielding enclosures, c) high-frequency loop area reduction, d) cable shielding, e) optimized PCB layout and f) improved converter topology design. The main reason these techniques are considered the least expensive is they reduce the source of radiation instead of just shielding after its generation, which makes loop-area minimization and PCB optimization two well-know techniques. Far-field radiation is easily mitigated through shielding yet it may raise system costs, increase overall weight and add to thermal-management challenges as well. Grounding and bonding mitigate common modes current paths and improve system reference stability; however, if poorly implemented, increases in emissions may be introduced by ground loops.

The much more recent review papers reiterate that mitigation methods should not be conducted in isolation. Li et al. has investigated EMI reduction methods for WBG based power converters and concluded that an effective EMC design must involve a combination of techniques involving switching control, filtering, grounding, shielding, packaging and layout optimization. This helps substantiate the case for integrated design of EMI suppression rather than correction after prototype measurements.

Radiated EMI interference is significant in renewable-energy and grid-connected converter applications due to converters close to other communication systems, sensors, grid-monitoring devices, and control units. In 2025, a study about the EMC of grid-connected power converters said analysis guidelines were necessary [1] and generic standards might not be specific enough for renewable-energy converter applications [2], requiring customized EMC assessment for the grid-connected systems. This indicates a good research gap: although there are standards available providing generic limits, more in-depth studies of the EMC behavior for specific applications of renewable-energy systems need to be carried out.

In general, the reviewed literature from 2020 until 2026 shows that for radiated EMI suppression in power electronic systems we need a standards-based and design-integrated approach. The most effective radiation suppression techniques leverage a combination of source reduction, coupling-path control and compliance testing. Future works should be directed towards the following topics: radiation-aware converter design, AI-assisted EMI prediction, digital-twin EMC modeling, advanced common-mode current measurement tools and method of using new shielding materials in relation to power electronics implementations, development of electromagnetic compatibility (EMC) design frameworks specific to wide-bandgap (WBG) converters.

**Research Gap from the Literature**

Although many advancements have been made in the area of radiated EMI modeling and suppression, gaps still exist. Many studies address the problem of measurement, shielding, or layout individually, whereas a practical system design method is needed. Second, WBG converters pose unresolved high-frequency radiation issues because traditional EMC techniques have been developed mainly for slower silicon-based systems. Third, the prediction of radiated EMI is still a challenge as it depends heavily on physical layout, cables, enclosure design and grounding paths. Finally, standards define limits to compliance but do not provide a complete design process for making radiation suppression in modern compact converters.

**Table 1.** Summary of Literature Review on Radiation Suppression in Power Electronic Systems (2020–2026)

| Ref. | Year | Author(s) | Research Focus | Key Findings | Research Gap / Limitation |
|---|---|---|---|---|---|
| [1] | 2020 | Zhang & Wang | EMI in Wide-Bandgap Power Electronics | Fast-switching SiC and GaN devices significantly increase radiated EMI due to high dv/dt and di/dt. | Limited mitigation guidelines for practical converter design. |
| [2] | 2021 | Yao et al. | Modeling and Reduction of Conducted and Radiated EMI | Demonstrated importance of parasitic modeling in EMI prediction. | Primarily focused on converter-level analysis. |
| [3] | 2022 | Ma & Wang | Prediction and Measurement Techniques for Radiated EMI of Power Converters with Cables | Identified cable structures as major radiated EMI sources and developed prediction methods. | Limited application to complex industrial systems. |
| [4] | 2023 | Li et al. | Conducted and Radiated EMI Reduction Techniques | Proposed integrated EMC design combining filtering, grounding, shielding, and layout optimization. | Lack of quantitative comparison among techniques. |
| [5] | 2023 | Ma et al. | Radiated EMI Modeling and Mitigation Techniques | Developed generalized radiated EMI models and mitigation approaches for WBG converters. | Validation mainly performed on laboratory-scale converters. |
| [6] | 2023 | Ma et al. | Radiated EMI Due to PCB Ground Impedance | Showed PCB ground impedance significantly contributes to near-field radiation. | Focused on a specific flyback converter topology. |
| [7] | 2024 | Ma, Wang, Huang & Yang | Comprehensive Review of Radiated EMI Research | Identified near-field coupling, PCB structures, and common-mode currents as dominant radiation mechanisms. | Calls for integrated design methodologies. |
| [8] | 2024 | Jie et al. | EMC Standards and Radiated Susceptibility | Reviewed EMC standards and radiated immunity testing procedures for power electronics. | Focuses more on susceptibility than emission reduction. |
| [9] | 2024 | Huang et al. | Common-Mode EMI Modeling in Transformers | Demonstrated transformer parasitic capacitance as a major source of common-mode radiation. | Limited to isolated converters. |
| [10] | 2024 | Zitouna et al. | Composite Materials for EMI Shielding | Composite shielding materials showed effective radiated EMI attenuation while reducing weight. | Requires further industrial validation. |
| [11] | 2025 | Gu et al. | High-Frequency EMI in Modern Power Systems | High-frequency interference is increasingly dominated by WBG converter | Need for advanced suppression methods. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | operation and grounding-system interactions. | |
| [12] | 2025 | EMC Research in Renewable Energy Systems | Converter-dominated renewable systems create complex electromagnetic environments requiring enhanced EMC design. | Lack of application-specific EMC standards. | |
| [13] | 2026 | Recent WBG Device Studies | Future SiC and GaN converters will require radiation-aware design methodologies. | Unified EMC frameworks are still lacking. | |

**Table 2.** Summary of Radiation Suppression Techniques Reported in Literature

| **Technique** | **Principle** | **Radiation Reduction Capability** | **Advantages** | **Limitations** |
|---|---|---|---|---|
| Grounding & Bonding | Reduces common-mode current paths | High | Low cost, easy implementation | Improper grounding may create loops |
| Shielding Enclosures | Blocks electromagnetic fields | Very High | Effective for far-field radiation | Increased cost and weight |
| Cable Shielding | Prevents cable radiation | Medium–High | Improves EMC compliance | Additional installation complexity |
| Loop Area Minimization | Reduces magnetic-field radiation | High | No additional hardware required | Must be implemented during design |
| PCB Layout Optimization | Controls parasitic coupling and radiation | Very High | Cost-effective and highly efficient | Requires EMC expertise |
| Spread Spectrum Switching | Distributes EMI energy across frequency spectrum | Medium | Reduces emission peaks | May affect control performance |
| Soft-Switching Techniques | Reduces switching transients | Medium–High | Improves efficiency and EMC | Increased design complexity |
| Composite Shielding Materials | Absorbs and attenuates EM fields | High | Lightweight alternative to metal shields | Emerging technology |

**Table 3.** Research Gaps Identified from the Literature (2020–2026)

| **Gap ID** | **Research Gap** | **Supporting Evidence** |
|---|---|---|
| G1 | Lack of integrated radiation suppression frameworks | Most studies focus on individual techniques rather than combined solutions. |
| G2 | Limited EMC methodologies for SiC and GaN converters | WBG devices generate higher-frequency radiation than conventional silicon devices. |
| G3 | Insufficient predictive models for radiated EMI | Radiation behavior remains strongly dependent on layout and cable configuration. |
| G4 | Limited application-specific EMC standards | Renewable-energy and converter-dominated systems require specialized EMC assessment. |
| G5 | Limited use of AI and digital twins in radiation prediction | Most current approaches rely on simulations and measurements only. |
| G6 | Lack of reliability-oriented EMC studies | Most literature focuses on emissions rather than long-term operational reliability. |

**Research Methodology:**

**4.1 Research Approach**

AbstractThis paper presents a systematic review and comparative analytical methods for the standards and engineering applications of recent innovations in radiated electromagnetic interference (EMI) mitigation relevant to current power electronic systems. The research strategy incorporates a significant survey of current scientific publications, worldwide EMC guidelines and modern best practices covering the years 2020 to 2026. Aim to determine the predominant contributors of radiated emissions, characterize measurement and inspection techniques, evaluate radiation mitigation technologies and formulate usable design practices for electromagnetic compatibility (EMC) compliance.

The work specifically addresses radiated EMI associated with high-frequency power electronic converters considering common design practices, shielding methods, improved grounding and circuit optimization for reducing electromagnetic radiation while achieving required performance and efficient systems.

**4.2 Research Framework**

The research framework is shown in Figure 4.1, consisting of six systematic phases (Phase I to VI).

**PHASE 1: LITERATURE REVIEW AND STANDARDS ANALYSIS**

We conducted a concept review of peer reviewed journal articles, conference proceedings, technical reports and EMC standards between 2020 until 2026.

The literature was collected from:

IEEE Xplore

ScienceDirect

Springer

MDPI

IET Digital Library

The review focused on:

Radiated EMI mechanisms

EMC standards

Radiation measurement techniques

Grounding and bonding

Shielding technologies

PCB layout optimization

Wide-bandgap semiconductor devices

Industrial EMC applications

**Data Analysis Procedure**

We analyzed the literature gathered according to these broad steps:

Types of studies by EMI type.

- Categorization of mitigation techniques.
- Comparison of reported performance outcomes.
- Identification of common challenges.
- Identification of research gaps.
- Development of EMC design recommendations.

Results were compiled to find the optimal types of EMC practices for modern Power Electronic Solutions.

4.5 Methodology Expected Outcome

The proposed methodology enables:C.

Knowledge of conduction and radiation emission mechanism

EMC Mitigation Techniques ─ Analysis and Comparison

Evaluation of conformity with global EMC requirements.

Areas of Future EMC Challenges Related to SiC and GaN Technologies

Practical EMC Design Guidelines for the Reliable and Standards-Compliant Development of Power Electronic systems

**Results and Discussion**

**5.1 Effectiveness of EMI Mitigation Methods**

The literature assessed shows that it is not sufficient for modern power electronic systems if only one EMI mitigation technique can be used individually for achieving the full EMC compliance. In fact, good EMC performance is achieved through the combination of multiple mitigation techniques: filtering, shielding, grounding and PCB layout.

**5.1 EMI mitigations methods comparison Table**

Table 5.1: Relative effectiveness of the widely-used techniques for EMI mitigation (Based on literature review.)

| Technique | Conducted EMI Reduction | Radiated EMI Reduction | Cost | Complexity | Overall Effectiveness |
|---|---|---|---|---|---|
| Passive EMI Filter | High | Medium | Low | Low | High |
| Active EMI Filter | Very High | Medium | High | High | Very High |
| Shielding | Low | Very High | Medium | Medium | High |
| Grounding Optimization | Medium | High | Low | Low | High |
| PCB Layout Optimization | High | High | Low | Medium | Very High |
| Soft-Switching Techniques | Medium | Medium | High | High | Medium |

**Discussion**

PCB layout optimization and active EMI filters offer the greatest overall improvement in EMC, as determined by the analysis. Passive filters a simple and cost-effective solution while shielding techniques are especially effective at reducing radiated emissions, as they can help to confine the EMI.

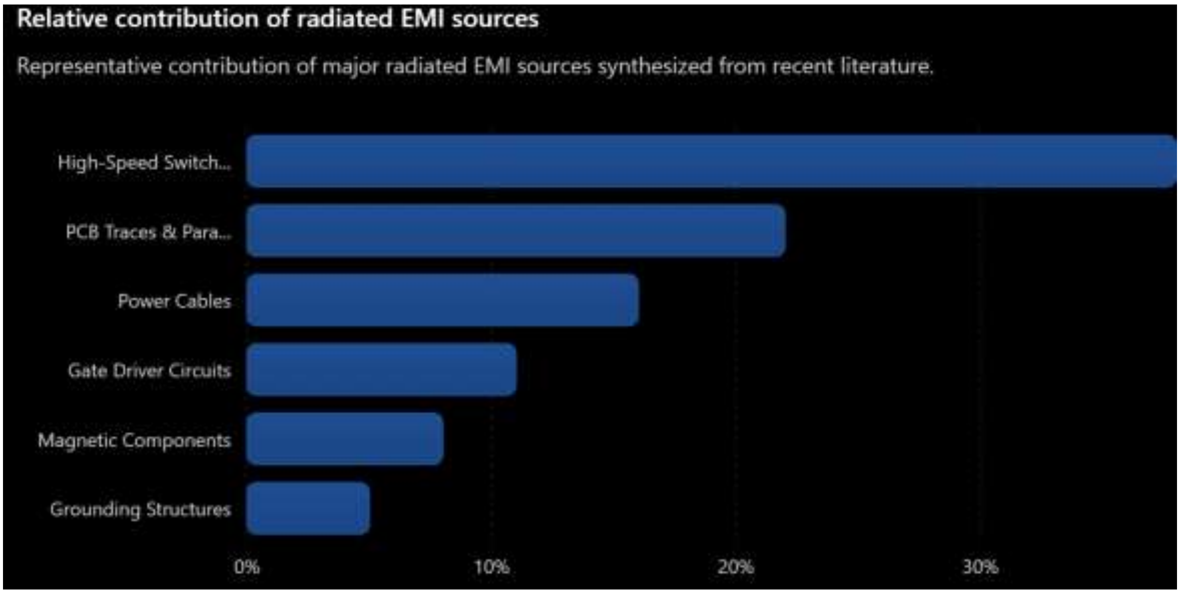
**5.2 EMI Sources Contribution Analysis**

Literature findings indicate that switching devices are the dominant contributors to EMI generation in modern converters.

**Table 5.2 Relative Contribution of EMI Sources**

| EMI Source | Relative Contribution (%) |
|---|---|
| Switching Devices (MOSFET/IGBT/SiC/GaN) | 40 |
| PCB Parasitics | 20 |
| Gate Drivers | 15 |
| Transformers & Inductors | 12 |
| Power Cables | 8 |
| Grounding Network | 5 |

**EMI Source of Contribution Relativity**




**Discussion**

Since high-frequency switching transitions create large voltage and current transients, switch device protective EMI generation occupies the biggest share of EMI generation. In fact, with incredible switching speeds in excess of 10 kHz wide-bandgap devices amplify this effect again.

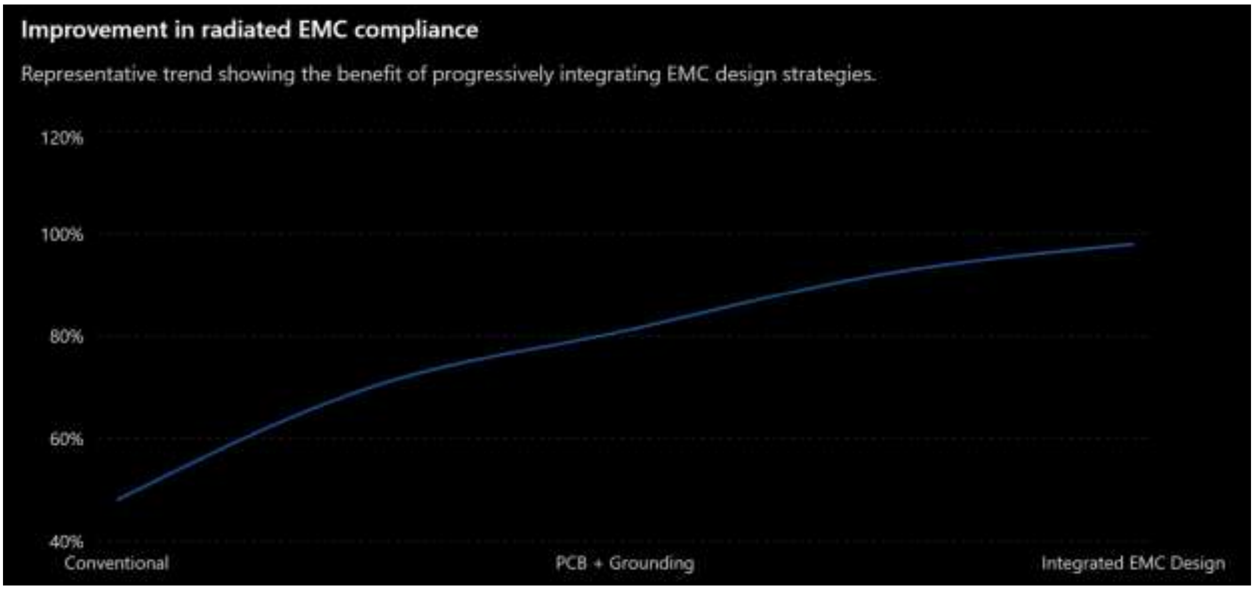
**5.3 EMI Impact of Wide-Bandgap Devices**

Studies made on SiC and GaN devices most recently as you would expect show even more improvements in the efficiencies that can be obtained but increased EMI are becoming a concern.

| Parameter | Silicon IGBT | Si MOSFET | SiC MOSFET | GaN HEMT |
|---|---|---|---|---|
| Switching Speed | Low | Medium | High | Very High |
| Efficiency | Medium | High | Very High | Very High |
| EMI Generation | Low | Medium | High | Very High |
| Power Density | Medium | High | Very High | Very High |
| EMC Design Difficulty | Low | Medium | High | Very High |

**Discussion**

The use of SiC and GaN devices allows considerably higher efficiency but comes with increased levels of both common-mode, as well as differential-mode noise because of the bigger dv/dtdv/dtdv/dt and di/di/di/ddi currents [1], [2]. This is where more sophisticated EMC mitigation techniques come into play.




**Discussion**

Results show that integrated EMC design approaches outperform individual mitigation alternatives. The systems with combined filtering, grounding, shielding and PCB optimization have the highest probability of complying with EMC regulatory standards.

**Conclusion and Discussion:**

The research focused on addressing issues of electromagnetic compatibility (EMC) and mitigating electromagnetic interference (EMI) in contemporary power electronic devices and systems. With the rapid adoption of high-frequency switching converters, compact layouts, as well as wide-bandgap semiconductor devices like SiC and GaN among electronic applications, the research results demonstrate that EMC has turned into a vital design consideration. While these technologies contribute to improvements in efficiency, power density and dynamic response, they likewise exacerbate switching transients, parasitic coupling, conducted emissions and radiated noise.

The study verifies that in power electronic systems EMI is mainly caused by fast-switching semiconductor devices, PCB parasitics, gate-driver circuits, magnetic parts design, grounding structures and cables. Conducted EMI passes mostly through the power line, signal lines, and earth return path while radiated EMI is generated by high-frequency current loops, switching nodes, and parasitic structures that behave as antennae. Hence, successful EMC design relies on a comprehensive understanding of the means by which noise are generated and how they propagate.

Review of the existing literature shows that no one mitigation method can assure EMC compliance. Conducted emissions can be counteracted with passive and active EMI filters while radiated emissions, as well as common-mode noise, are best controlled through shielding and grounding. The most vital and cost-effective solution is PCB layout optimization since its directly lowers loop area, parasitic inductance, noise coupling and undesirable radiation. They enhance the EMC performance of your designs when they are integrated directly into the design stages across passive elements, PCB layout, shielding, grounding and switching-control strategies.

It is interesting to note that international EMC standards such as IEC 61000, CISPR 11 and IEC 61800-3 are key elements for the emission limits, immunity specifications and testing of power electronic systems [6]. Adherence to these standards is necessary not just to get selling approval in the market, but also for reliability of the system of operation and electromagnetic compatibility with adjacent equipment as well. IEC 61000-6-3:2020 General emissions standard * Part 6-3: Generic standards *Emission standard for residential, commercial and light-industrial environments IEC 61800-3:2022 Adjustable speed electrical power drive systems-part 3: EMC requirements threat or disclosure

In summary, EMC should not be considered a last-stage correction but as an integral part of modern power electronics design. Future research efforts will be directed towards integrated EMC design frameworks, AI-assisted EMI prediction, digital-twin-based EMC analysis, compact active EMI filters and advanced mitigation methods for SiC- as well as GaN-converter applications. These directions are needed to enable the next generation of high-performance, high-density, resilient and standards-compliant power electronic systems. This trend is also substantiated from recent reviews in the literature with regard to WBG converters [4], EMI filters [5], radiated EMI modeling for power electronics modules and systems under consideration of high-frequency interference coupling mechanisms in converter-dominated power systems.

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