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EMI and EMC: the present situation, and what the future holds - Wattnow Oct 2018

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EMI & EMC: the present situation, and what the future holds

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Introduction

There's an awful lot of myth, misunderstanding, and just plain rubbish talked about electromagnetic interference (EMI) and electromagnetic compatibility (EMC).

However, the rapid and unrelenting pace of development in electrical and electronic technologies since the 1950s has brought us to the point where achieving EMC (that is, ensuring freedom from significant EMI problems) is needed for the reliable operation of most products, applications, systems and networks.

As these developments continue into the foreseeable future, achieving EMC will soon become very important indeed for everything, up to the largest networks on the planet. Also, due to the rapid growth in *smart/autonomous* technologies (e.g. in automobiles, trains, mining, surgery, robotics, etc.), avoiding EMI over the complete lifecycle will soon become important for human safety.

EMI problems appear to be growing exponentially, especially as developments in semiconductor technologies are encouraging both more powerful processing of signals, data, and control; more powerful power conversion, and more wireless datacoms.

What this means, is that **for EMI and EMC, past experiences are not a reliable guide to the future**.

The high-tech future we are looking forward to will simply not happen without much closer attention being paid to EMI/EMC, and many more resources devoted to it, than has been the case.

First, a little background

Electrical power, radio/wireless communications, radiant heat, light, X-rays, etc., are all considered to be electromagnetic in nature, that is, they transfer various forms of power and energy by means of tightly-coupled electric and magnetic waves. But when we talk about EMI and EMC we are generally referring to waves having a frequency range from as close to DC (0Hz) as makes no difference, up to 300,000 MHz (300GHz).

When we talk about EMI, we identify the electromagnetic waves that are emitted by all electrical and electronic activities: signals, data, power, etc., from picoamps to Gigawatts. These emissions can be conducted and/or radiated and should not exceed levels above which other equipment in their operational environment cannot operate as their users need them to. The maximum emissions levels generally depend on the frequencies concerned and are especially a problem where the 'other equipment' is radio/TV broadcasting or wireless communications because of their high 'in band' sensitivity.

We also identify the propensity of electrical and electronic circuits to suffer noise, errors and malfunctions due to certain frequencies and levels of electromagnetic waves in their operational environments. This is called electromagnetic immunity, or its reciprocal – electromagnetic susceptibility.

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EM emissions are also created naturally, by electrostatic discharges such as the shocks we can get in very dry weather when touching metal objects, or lightning from thunderstorms. Rather less natural sources include nuclear explosions that create huge pulses of electromagnetic energy which can puncture the insulation of overhead power transmission lines several hundred kilometres away. Engineers specialising in EMI/EMC have a lot of ground to cover!

The present situation with EMI and EMC

The usual industry misperception of EMC is that it is a financial burden because it requires expensive testing to specifications; increases production costs; delays time-to-market and adds no value!

But there have long been problems with EMI in real life, and such problems are increasing because the rapid pace of developments in semiconductor devices are lowering their costs and increasing their power, so that they are increasingly being used everywhere. Electronics is increasingly replacing older technologies, such as pneumatics, hydraulics, mechanics, electro-mechanical devices, high-voltage transformers, synchronous electrical generators, even people.

Machine learning is finally making electronic artificial intelligence practical, especially in safety-critical applications such as cars and other forms of passenger transport, and the control of national utilities (water, electricity, gas, telecoms, etc.).

This rapid growth in electronics is causing correspondingly rapid increases in EMI problems, but the situation is worsened by the fact that the developments making semiconductors smaller, less costly, and more powerful, are causing them to emit electromagnetic noises to ever-higher frequencies.

The historical misperception of EMI and EMC has been encouraged by the fact that problems have only rarely identified as being caused by EMI, which adds hugely to the cost and delay in solving them. Even when companies discover and fix costly problems due to EMI, they (understandably) rarely publicise this, so everyone else continues to believe EMC is not important. One result is that large financial benefits are often being overlooked by many organisations.

There is the real-life example of a UK manufacturer who, in the early 2000s, spent 100,000 GB Pounds on improving the design of his products and testing them to ensure they complied with new versions of the European Union's EMC immunity test standards – whilst annoying the EMC test engineers by complaining bitterly about 'Brussels bureaucrats' the whole time, claiming they would be the death of his company.

In his first full year of manufacturing the modified products, his warranty claims were 2.7 million GB Pounds lower than had been usual. Why hadn't he identified this huge cost saving earlier? A 2,700% payback on investment *in the first year* is a truly excellent result, but EMC is usually overlooked as a good financial investment, as happened here.

Realising that this misperception was causing huge amounts of wasted time and money, I started a magazine column on real-life EMI stories in 1998: 'Banana Skins', in the UK's EMC Journal. People read my column to laugh at other people's mistakes (although some had deadly results and were not funny at all) and painlessly learned about the many real-life problems of EMI and the real engineering and financial need for good EMC. That magazine is no longer published, but all those EMI stories are still available from EMCstandards and are continually being added to: currently at Number 873.

Here are a few EMI stories from that archive. Any experienced EMI/EMC engineer can tell many similar stories – but usually don't, for confidentiality reasons.

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Inadequate EMC specification: A manufacturer of industrial fasteners negotiated a contract with a high-street DIY chain, which required a new production cell containing an automatic weighing machine which filled plastic bags with just the right number of fasteners, and a high-frequency plastic welding machine to seal them. The two machines were purchased separately, and their purchasing contracts had no EMC requirements other than 'shall meet all legal requirements' (CE marking, in other words).

The checkweigher and the bag sealer were supplied and installed and tested successfully *when operating one at a time*, but when operated together the weighing machine suffered errors of more than 25 % due to EMI from the sealer. There was no comeback on the suppliers, because their products met both their legal (CE) and their contract specifications. Both suppliers refused to try to solve the problem, blaming each other. EMI/EMC experts solved the problem, but not before the fastener manufacturer had suffered significant financial losses due to the delay in fulfilling the contract.

Such interference from high-frequency plastic sealers/welders is not uncommon, and is well-known to EMI/EMC experts, because the applicable EMC emissions test standard (CISPR11 / EN55011) permits very high levels of emissions at frequencies reserved for 'Industrial, Scientific and Medical' (ISM) purposes, such as this. Radio broadcasting and communications that must be protected from EMI do not use ISM frequency bands, for that reason.

This is one example of a very commonplace situation that has caused, and continues to cause, large financial losses: we should never assume that we can construct a system or installation that is free of reliability problems caused by EMI, merely by assembling together individual items of equipment that are each fully compliant with all their relevant EMC standards, even if we follow their manufacturers' EMC installation instructions to the letter (which almost no wiring contractors or installers do anyway).

Trying to avoid this sort of problem by over-specifying EMC can also be financially ruinous. An industrial machinery manufacturer needed a special inverter drive for a new machine range. His EMC expert specified military EMC standards for these new drives, and the contract to supply them was put out to tender. The drive manufacturer who won the contract didn't appreciate the financial risk issues created by the tough EMC requirements (which – in my experience – is usual 'Sales Team' behaviour).

They designed the new inverter using their normal methods, it failed its 'MIL SPEC' EMC tests, and the customer refused to accept it. Time and effort was spent learning new design techniques to comply with the EMC specification, only to find that the redesigned inverters would now not meet their *functional* specifications!

As a direct result of this failed contract, the inverter-drive manufacturer went out of business. The machinery manufacturer eventually had to revise the drive's EMC specifications and find a new supplier, and lost a great deal of money because their new range of machines were very late to market.

Here's an example of inadequate design. A very well-established manufacturer produced high-quality industrial machines that were sold world-wide and renowned for their high reliability. A new management team decided that their poor financial performance was because their products cost too much to make – so began a cost reduction exercise.

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The machines had achieved their famous reliability by using EMI protection measures developed over many years of simply reacting to actual EMI problems in the field. Nobody in the design department had any real understanding of EMI/EMC, or any recollection of why these protection measures had been added in the first place, so – when the cost reduction exercise proposed removing the components with no obvious functionality – they were unable to prevent this.

With their historical reputation and new low price, the new machines sold well, but they were unreliable due to poor immunity to their real-life electromagnetic environments. One customer rejected his machine, and a commissioning engineer had to be based in the USA for over a year solely to 'baby-sit' some others. The excellent world-wide reputation the company had slowly built up over many years was lost in just a few months. A very costly EMI/EMC mistake for them.

Next, an example of incorrect EMC installation. A major manufacturer of automotive parts commissioned a series of robotic paint booths with a total project cost of over 2 million GB Pounds. The EMC specifications for these robots was correct, and the chosen supplier agreed to comply with them and agreed to pay financial penalties for late delivery. To reduce costs to help win the contract, the supplier's sales team agreed that their customer would have his own contractors install the robots' cabling.

The robotic paint booths suffered apparently unconnected (and sometimes dangerous) faults, and the customer would not accept them. Investigations by both the customer's and supplier's staff could not identify the problems. The customer had to employ extra painting staff to meet his production quotas while the supplier was incurring financial penalties for late delivery. An independent EMI/EMC consultancy quickly identified that the screens of the interconnecting cables had been terminated by long 'daisy chained' wires, ruining their shielding and allowing the control electronics to suffer EMI.

The supplier normally used its own trained installation staff to install its products and had no written instructions on the correct termination of the screened cables, so the customer's cabling installers had just terminated their screens any old how. There was no 'quick fix', and 80% of the cables had to be replaced (using correct screen termination methods). The supplier picked up the bill for the re-wiring as well as paying the penalty clauses in the contract.

Even if the robotic paint booth manufacturer *had* supplied their customer's wiring contractors with complete instructions, other real-life case studies show that this can have huge financial risks too, when the instructions are ignored by low-bidding contractors who don't have sufficient assets to make it worthwhile suing them through the courts.

What the future holds

Wi-Fi was designed to be very low-cost and easy to use anywhere in the world without licensing by using 2.45 GHz and 5.8 GHz bands reserved for ISM frequencies (see earlier). But now that Wi-Fi has been so wildly successful, and so many businesses depend on its reliable operation, that fact that it relies upon frequencies that *cannot be protected from EMI* for example from microwave cookers, or neighbouring buildings, creates significant financial risks.

All of the semiconductors used to create modern electronics are continually being die-shrunk to make them faster and cheaper, fuelling a rapid rise in increasingly sophisticated electronic control – for which the current media favourite is autonomous cars. We have already seen a dangerous malfunction of an autonomous car caused by EMI (luckily, without accident). Autonomous mining

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machines are already operating, autonomous agriculture is now available, and autonomous road trucks are being advertised.

Within a few years there are expected to be several million autonomous personal care robots in Japan alone, feeding and washing people who are too ill or old to manage by themselves, before carrying them safely to bed. Quasi-autonomous robotic surgeons are already being used; and new electronic technologies are seen as the only way of being able to continue to deliver affordable healthcare.

Future electrical power distribution systems will be 'Smart Grids' that will operate 'Virtual Power Plants'. Industrial robots now work alongside people *without safety screens*. And the big debate over autonomous battlefield robots, at the moment, is whether they should be permitted to kill without permission from a human.

All of these near-future developments use much more complex electronics than we have yet deployed, and they are usually systems of systems (increasingly: systems of systems of systems) about which no single person can understand everything. On top of this increase in complexity, the very die-shrinking that makes this brave new world affordable also makes semiconductors switch faster, which means that – all things being equal – emissions are continually increasing up to ever-higher frequencies.

Developments in power semiconductors, particularly wide-band-gap power switching devices are rapidly increasing the use of variable speed motor drives to reduce energy consumption, to help save both money and the planet. These are now cost-effective for motors in all domestic appliances, and at the other extreme switching power converters are making it possible to operate high-voltage DC (HVDC) electricity distribution, which doesn't suffer from losses caused by AC coupling with the soil. Unfortunately, every aspect of these developments is causing greater levels of harmonic distortion of AC mains waveforms, and increasing the electromagnetic noise emissions from all mains power distribution networks at every voltage level (UHV, EHV, HV, MV and LV) up to ever-higher frequencies.

Air-Gap Wireless Power Transfer (WPT) is a new application that uses switching power converters to generate magnetic fields to supply electrical power without using cables, to everything from cellphones through electric cars to passenger buses and trams, by using magnetic fields. This is a very rapidly growing area and, at the time of writing, WPT chargers at up to 7kW are already being trialled. It is envisaged that car parks will be fitted with 3kW (or more) WPT chargers in every single parking slot. Because this technology uses an air gap that cannot help but 'leak' magnetic fields – it will increase the likelihood of EMI.

The radio spectrum is already very crowded, and DSA methods are increasingly being adopted to use 'quiet' parts of the spectrum. Powerline telecommunications use a building's mains wiring to carry high-speed data, and the result of both will be higher levels of noise across more of the spectrum, increasing EMI.

The Internet of Things (IoT) and the Industrial Internet of Things (IIoT) are important modern developments that promise many benefits to many applications, old and new. The US Government is mandating what we might call the Internet of Road Vehicles (IoRV?), more properly known as V2V Communications. However, these huge – and hugely distributed – systems, estimated to have a trillion nodes by 2035, will mostly communicate by wireless datacoms. All this additional radio noise will increase the average RF noise levels experienced by all electronics, almost everywhere, causing more EMI.

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International commercial and industrial EMC standards are already incapable of coping with the modern world, and the pace of international standardisation has been much too slow to keep pace with technological progress in electronics since before 2000. So we cannot look for help from that direction, and to cap it all, Intentional EMI (IEMI) is a growing threat to national security and infrastructures from criminals, terrorists and the disaffected.

Conclusions

EMI is already a significant cause of financial risks and losses in almost all industrial sectors, although because it is invisible and hard to reproduce in real life it is usually not recognised as such. These risks and losses are mostly due to decreased operational efficiency and unreliability, but safety is also a concern.

Developments in all areas of electronics and electricity are making the likelihood of EMI ever-greater, in an ever-expanding area of applications.

With the control of all aspects of our lives, including safety, increasingly being entrusted to immensely complex – and often totally autonomous – electronic systems of systems, the risks of EMI to human safety are increasing very rapidly too.

All of our previous experience of EMI and EMC cannot provide us with a reliable guide to the future, and – if we want to survive – we will not be able to continue to overlook EMC.

Keith Armstrong and MESA Solutions (Pty) Ltd will be teaching a series of short courses on low-cost design techniques for achieving good EMC for products, equipment, systems and installations of any type or size. These will be held near Grabouw, Western Cape Province, RSA, in October/November this year, contact Mesa Solutions for details.

Keith will also deliver the plenary talk at GEMCCON 2018, to be held 7-9 November in Stellenbosch, Western Cape Province, RSA, this year. The subject will be: '*Techniques & Measures to Manage Functional Safety and Other Risks With Regard to EMI*'.

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