EMC a problem for some - a challenge to many

- **Foetal heart monitor picks up cell phone conversation**
- **10MW power converters interfere with telephones 12 miles away**
- **PC switches off bathroom shower**
- **Hair dryer turned on by mains transients**
- **CNC machine interferes with travelling crane**
- **EMI causes signal failures to delay the introduction of Eurostar**

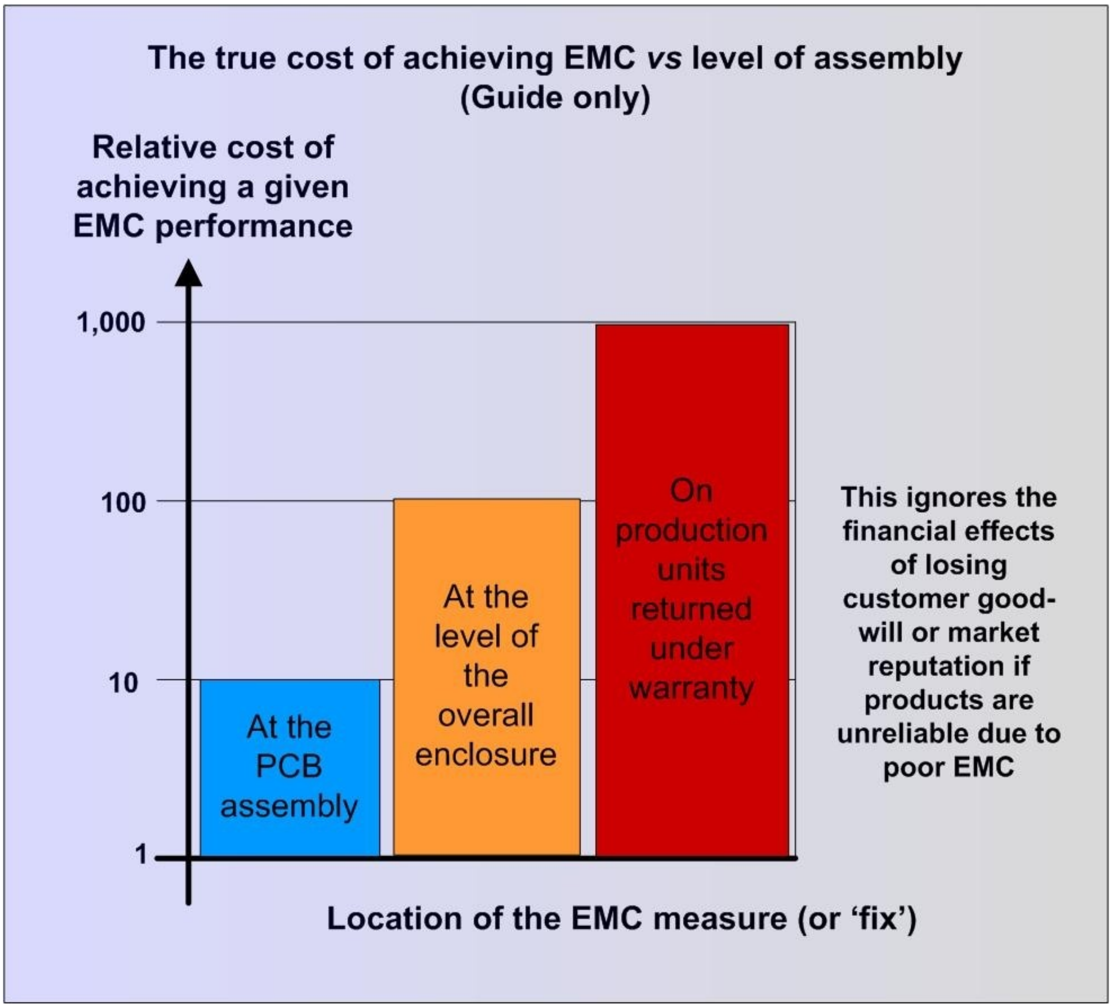
This is selection from the first few pages of The First 500 Banana Skins a compendium of EMC hiccups and disasters which challenge the unwary engineer. The chronicler of these often amusing, sometimes deadly anecdotes, Keith Armstrong of Cherry Clough Consultants, suggests this represents "just the tip of the iceberg" but with large, but unknown, costs for manufacturers and society.

The case for early identification of EMC problems
All electrical and electronic equipment sold in Europe must comply with the Electromagnetic Compatibility (EMC) Directive. The basic immunity test method listed in the Directive for radiated continuous radio-frequency (RF) is IEC 61000-4-3 and for conducted RF is IEC 61000-4-6.

For engineers, familiar with their product's life-cycle development, EMC is not a big issue and for others it's an issue that may be resolved as problems arise. However, for some engineers it's a black art with which to wrestle sometimes taking days, even weeks, to identify the cause of malfunction followed by costly remedial work and the expense and delay of re-testing. If failures occur in the field costs can spiral out of control.

David Goodway of dB Tech Limited argues the case for identifying potential malfunction due to RF and ESD at the earliest possible stage and that the engineer need not fear that there will be disastrous consequence during PCB level testing. The engineer should test for EMC compliance at all stages of design. In fact, the cost of not identifying problems as they arise, increases by a factor of ten at each level of intervention.

Keith Armstrong suggests in his recently published book, EMC for Printed Circuit Boards, that the true cost of controlling EMC increases by about ten-fold for each level of intervention. The relative costs might look like this:



From the graph we can conclude that it is likely to be about a thousand times more costly to rectify a malfunction in equipment returning from the field than at the initial design stage.

How do the problems arise – the basic principles

Fluctuating voltages in a conductor of any type create radiated electrical waves whilst fluctuating currents create magnetic waves. After travelling for about 1/6th of their wavelength, both electrical and magnetic waves have turned into electromagnetic (EM) waves. These waves pass through air, a vacuum and insulating materials creating EM fields. Every type of electronic equipment "leaks" some EM fields to some degree.

So, the electronic activity at radio frequencies in an item of equipment causes radiated EM fields to be created at those frequencies which we call RF fields. Radio, TV and Radar transmitters along with industrial, scientific or medical equipment that uses RF energy to perform direct functions can emit very powerful fields. Arcs and sparks at electromechanical contacts, electrostatic discharges and lightening cause transient RF fields that can also be quite powerful.

When conductors such as cables, connectors and PCB tracks are exposed to RF fields RF currents and voltages "noises" are coupled into them. Shielded cables and their connectors are often less than perfect, so even in these there is always some coupled noise. Sufficient levels of coupled RF noise can cause errors or malfunctions in an analogue or digital circuit or switch-mode power converter. Without adequate protection from RF fields few modern electronic circuits will behave reliably in real life operation. If the noise levels are high enough they can sometimes cause permanent damage.

Electrical and electronic equipment can be particularly vulnerable to electro static discharge (ESD) from people's fingers or metal objects. Static charges accumulate on a person where dissimilar materials are in rubbing or sliding contact, one of which will steal electrons from the other creating a voltage difference. This is known as "tribocharging". If the materials are then separated, so that the capacitance between them decreases, the charge on each remains the same, so the voltage difference must increase, sometimes up to many kilovolts, which can cause a breakdown of the air, resulting in a spark that we call an electrostatic discharge.

When to test for EMC compliance

Modern designs use ever-smaller ICs, but this is continually degrading both signal integrity (SI) and EMC emissions and immunity performance. RF emissions are increasing and RF susceptibility is worsening. Higher clock and power switching frequencies increase emissions but at the same time the trend to operating ICs on lower DC voltages worsens immunity.

The philosophy that EMC immunity measures are best "bolted on" at the end of the project is clearly refuted by the earlier graph. Identifying the potential for malfunction and fixing them at the design stage will significantly reduce the cost of modification, and the resulting delays, at the post-testing or pre-production stage.

The case for close field probe testing

Failure to use good EMC engineering techniques in PCB design and layout invariably increases the manufacturing costs. Close-field probing is a low cost EMC testing technique that will allow the design engineer to identify the potential for malfunction due to RF noise and ESD at an early stage. It does not require a special test chamber so can be used at the designer's workbench.

Designers can use close-filed probing to test for RF immunity as soon as they have "breaded boarded" a design. EMC performance can be improved by modifying the circuit board, moving components, re-routing PCB tracks and experimenting with board level filtering and shielding. Identifying these changes early in the design process, when the cost of change is low, helps keep down the cost of manufacture – not good news for the filter and shielding manufacturers but good news for the competitiveness of your product.

Significant delays can be experienced by failure to achieve EMC compliance – so improving confidence in EMC immunity at the design stage can also prevent costly delays in market introduction.

Test for EMC compliance at all stages of development and production
Earlier we explored the cause of EMC emissions and the difficulty of ensuring adequate immunity to RF noises and showed that close-field probing can help save time and money. Close-field probing can in fact be used at any stage of the design and manufacture cycle including:

- Proof of principle
- Proof of design
- Component selection
- Pre-testing compliance
- Post-testing compliance
- Goods in checking
- EMC checking after maintenance or repair, even in the field

How to locate the fault and what to use

EMC Compliance Testing
No EMC test standards use close-field probes so it is difficult, often impossible, to ascertain or pinpoint the reason for malfunction due to RF or ESD directly from the test. The primary function of the test is to confirm or deny EMC conformance to the standards not to identify causes of malfunction. So, not only is it important to brush up on your close field probe testing techniques during the development stage these are important skills to learn for those (hopefully) infrequent occasions when your design fails an EMC immunity test.

Generating a signal with which to test
Close field probe testing can identify design flaws before and after compliance testing or in production and in the field, but, how best to generate a signal with which to confirm immunity?

A variety of signal generators used with close field probes can be used to create localised magnetic or electric fields, these include:

- RF signal generators with modulation and frequency sweeping capabilities
- Transient generators for fast transient bursts or ESD

With conventional close-field probe testing great care is required to avoid blowing-up the equipment being tested and to avoid being electrocuted.

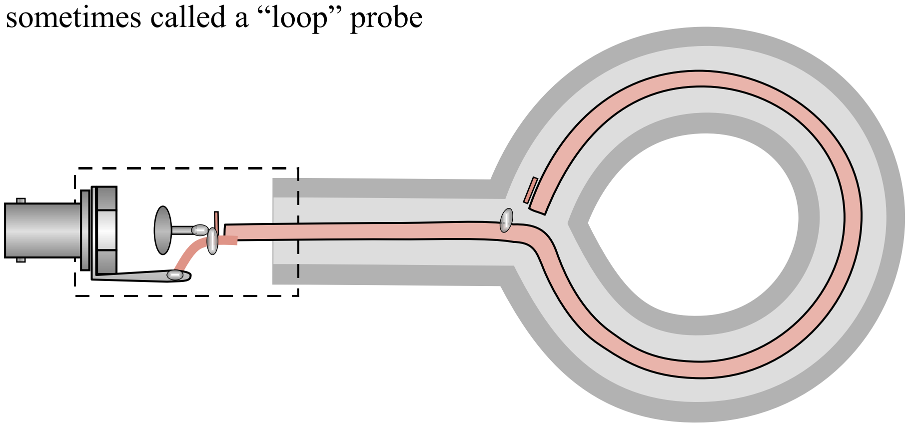
These are the obvious disadvantages of these types of test, but there can be many more. It can take a long time to find a good technique to replicate the failure and then identify the cause. It can also be difficult to precisely locate the signal causing the problem for example in fine pitch ribbon cable or high density PCB tracks.

Instruments with which to probe
Engineers can become quite adept using close field probes if they use them frequently. However, each design of probe behaves differently so expertise with one probe may not translate quickly into expertise with another. There are safe and sure

ways to locate the cause of an RF or ESD immunity test failure and the next section explores the options.

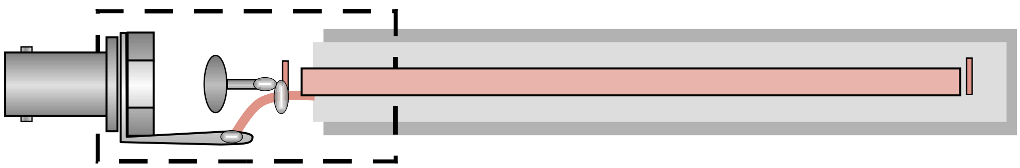
A variety of probes and instruments are available which can speed up the fault location process with varying success. Close-field probes can be made small to provide greater accuracy in pin-pointing the cause of the problem whilst passing a cable through a coil wound round a split ferrite will produce a different effect. It is possible to construct a wide range of close-field probes. However, it is difficult to make comparisons between the different results of differing designs. The engineer will need to explore the advantages and disadvantages of the various options.

A magnetic field probe – a "shorted turn" shielded from electric fields, sometimes called a "loop" probe



This probe would be improved with a CM choke or ferrite toroid.

An electric field probe – a very short "whip" antenna



This probe would also benefit from a CM choke or ferrite toroid

A simple DIY unshielded magnetic loop probe

A rectangular probe can be more convenient for testing flat items

A number of loop and pointed probes kits can be purchased off the internet. In researching this article we found a range of proprietary instruments specifically designed for locating EMC immunity faults. Prices range from a few hundred pounds to several thousand pounds. Most had a lot to commend them and made the engineer's task easier, but all have limitations. These included:

- An ESD field generator probe unsuitable for close field work
- A fast transient simulator which is expensive and required complex set up routines to perform each test
- An expensive fast transient generator unsuitable for probing sensitive areas
- A mini burst generator which cannot be used to sweep an area to locate fault
- A hand held "minizap" easy to operate but unsuitable for close field use and does not readily locate the fault.

There must be a better way!
In recognising that most of the available solutions had operational issues the author set out to find a better solution.

David Goodway, is the founder of dB Tech Limited, an R&D house through which a constant stream of new products flows. Frequently up against tough deadlines David needed a speedy and consistent way to locate electromagnetic immunity problems. Proving the age old adage that "necessity is the mother of invention", **Empulse** was the result, a unique hand-held instrument that provides a quick and repeatable way to locate ESD and RF design or construction problems.

Empulse is an EMC fault locator which can be used with confidence and safety in all situations from enclosed equipment right down to naked PCB level without fear of harmful effects to the equipment under test (EUT). Empulse creates a region of well controlled electrical and magnetic fields that will not harm devices.

So how does Empulse work?
Via a specially designed non-contact probe Empulse generates a localised voltage field which capacitively couples to the EUT whilst it also generates a localised magnetic field which inductively couples to the EUT.

Empulse enables you to simulate the effects of RF and ESD immunity testing and importantly it allows you to test right down to PCB level without fear of destroying the EUT. You can be sure that if a malfunction is due to RF fields Empulse will locate the exact position of the problem on the PCB. After just 10 minutes practice using Empulse, with its field calibration facility, selectable strength, polarity and repetition rates**,** it is even possible to find the exact troublesome conductor in fine pitch ribbon cable. Empulse, powered by a rechargeable battery, is immediately ready for use in the work place or out in the field.

Our research suggests that there is nothing similar to Empulse anywhere in the world and with Empulse you can be sure of saving time and money by avoiding the need to pay test laboratories for retesting and thus get your products to market quicker as a result.

Testimonials on the **Empulse** website www.empulse.co.uk illustrate the difficulty in locating the cause of EMC immunity problems and how this unique instrument can save time and money. It includes user comments and a short video demonstrating the instrument in use.

Our Thanks
This article borrows heavily from the work of Keith Armstrong of Cherry Clough Consultants who permitted the author to quote from his course entitled “Close Field Probing for Emissions and Immunity”. On that course Keith describes how different types of close-field probes are constructed and techniques that can be used to save time and cost at every stage in the product life-cycle.