



Another EMC resource
from EMC Standards

EMI Stories 1 to 95

Helping you solve your EMC problems

EMI Stories 1 to 95

1) **10MW power converters interfere with wired telephones over 12 miles away**

To cope with increased North Sea oil production, two new pumping stations with 6 MW adjustable speed induction motor drives were built and installed in Scotland, one in Netherly and one in Balbeggie. Soon after commissioning the local power utility and the telephone company received a flood of complaints. Geographically the complaints came from concentrated pockets spread over an area up to 12.5 miles away from the 33 kV overhead supply lines feeding the drives. A payphone over 4 miles away from the power line was noisy enough to be almost unusable, whereas just across the street a householder's telephone was relatively unaffected. Other symptoms included loss of synchronisation on TV sets (rolling pictures) and ringing on the supply to fluorescent lighting circuits.

Although the drives had been designed to, and met the supply industry's G5/3 harmonic limits, the problems turned out to be with higher order harmonics than it covered, up to the 100th in fact (i.e. 5 kHz). The problem became a public relations nightmare for all involved, and culminated in questions being raised at Government level. Remedial EMC work was urgently required and was in fact accomplished, although under extreme difficulties because the cost of any downtime of the oil pumping stations was so high.

(Taken from: "Harmonic filtering of large induction motor variable frequency drives" by M J V Wimshurst of Hill Graham Controls, High Wycombe, U.K., and Allan Ludbrook of Ludbrook and Associates, Ontario, Canada. Presented at the 7th International Conference on Harmonics and Quality of Power (IEEE) at Las Vegas, October 16-18, 1996, pages 354-359 in the Proceedings. Also presented at the "Sixth International Conference on Power Electronics and Variable Speed Drives", Nottingham, UK, 23-25 September 1996, IEE Conference Publication No 429, pp 24-29, <http://www.iee.org.uk/Library>.)

2) **PC proximity switches off bathroom shower**

A (CE marked) portable PC carried up the stairs in a domestic household whilst operating, reliably caused the "power shower" in the bathroom to turn itself off if it was in use at the time.

(Personal communication with Editor in 1997)

3) **RF interference in ambulance causes death**

Medical technicians taking a heart-attack victim to the hospital in 1992 attached her to a monitor/defibrillator. Unfortunately, the heart machine shut down every time the technicians turned on their radio transmitter to ask for advice, and as a result the woman died. Analysis showed that the monitor unit had been exposed to exceptionally high fields because the ambulance roof had been changed from metal to fibreglass and fitted with a long-range radio antenna. The reduced shielding from the vehicle combined with the strong radiated signal proved to be too much for the equipment.

(An article in the Wall Street Journal reported in Compliance Engineering Magazine's European edition September/October 1994, www.ce-mag.com.)

4) **Running Windows™ causes cat flaps to rattle**

Computers used in a room close to a door fitted with a high-technology (magnetic) cat flap caused the latches on the cat flaps to rattle continuously whenever Windows™ was loaded or a Windows™ application run.

(From the New Scientist magazine, 7th May 1997, www.newscientist.com)

5) **Poor power connections interfere with search and rescue satellite comms over large area**

The Langley (USA) Air Force Base Rescue Co-ordination Centre reported that its search and rescue satellite was receiving interference on its 121.5 and 243 MHz distress frequencies. The area over which interference was a problem was around 8 square miles, which was significant

because normal emergency transmitters on these frequencies can only be detected at ground level for about one mile. The problem was eventually traced to poor connections on an overhead power line.

(From an FCC Field Operations Bureau news release, 1994, also reported in Newswatch...EMC in Compliance Engineering European Edition January/February 1995, page 6.)

6) Desert Shield and Desert Storm suffered 'serious and significant' EMI problems

An advertisement for engineers for "The HERO Project" quoted Rear Admiral Roland T Guilbalt, Deputy Director, Electronic Warfare Division US Navy as saying that both Desert Shield and Desert Storm suffered from serious and significant EMI problems. We have no more information on this at present, but presume it was due to the very heavy use of high-tech civilian equipment used for the first time in a military situation.

(From EMC Technology magazine, 1993. HERO stands for Hazards of Electromagnetic Radiation to Ordnance.)

7) Mains harmonic currents increasing, causing overheating and other problems

Excessive mains harmonics in the London area, due mainly to the rapidly increasing use of personal computers, are causing overheating problem in AC power cables (including those that run under the Thames). In the offices where the computers are, it is increasingly common for the power-factor correction capacitors normally fitted to fluorescent lamps to blow (the electricians usually just remove the blown capacitors).

Damaged and overheated neutrals, and damaged electrical switchgear is increasingly seen as a result of harmonic mains pollution. In the US, fire insurance companies are being urged not to take on any new policies unless they have had the size of the neutral cables in the company concerned checked for their adequacy for the heating effects of harmonic currents.

(Personal communications with Editor, January 1998)

8) Hair dryer can be turned on spuriously by mains transients

Hartman Products of Los Angeles, California, has agreed to pay a civil penalty of \$60,000 to settle allegations that it failed to file a report regarding a defect in the 1992 Hartman Pro1600 hair dryer. The CPSC (a US consumer safety agency) believes that these hair dryers can turn themselves on even when the on/off switch is in the "off" position. While the dryers' heaters start, their fans do not, potentially causing internal components to overheat and cause fires.

(Compliance Engineering May/June 97, www.ce-mag.com)

9) Radio-activated car keys unreliable due to EMI

The AA and RAC estimate that around 9000 breakdowns they attended in 1996 were the result of remote key fobs being blocked by RFI. An AA spokesman said: "The number of cars being produced with radio-activated keys is standard now. If we're getting 9000 now, what will the problem be like later on?". *(Electronics Times 13th Oct. 1997, www.eetuk.com.)*

10) Desk toy wipes floppy discs and distorts monitors

We recently bought what looked like a fine new idea for an executive toy. It consisted of a very strong magnetic base with lots of ball bearings attracted to it, which it was possible to form into beautiful sculptures. What we did not realise at the time is that magnets and office desks are not cheerful companions. But we soon found this out when the discs with our accounts on them were mysteriously wiped, and the monitor screen went all the colours of the rainbow. It is now only possible to use our office desk toy when not at our desks, and well away from the office.

(Letter from Michael Fell in 29 November 97 issue of New Scientist, www.newscientist.com.)

11) Electric wheelchairs erratic due to EMI

Wheelchairs have come in for special scrutiny by the FDA (the US Food and Drug Agency). A few months ago, the agency ordered makers of wheelchairs to shield them and to educate users about the potential hazards of interference. The FDA acted after receiving "many reports of erratic unintentional powered wheelchair movements." These included sudden starts that

caused wheelchairs to drive off curbs and piers when nearby police, fire or CB transmitters were activated. Miraculously, no fatal injuries have been reported.

(But broken limbs have occurred as a result of such interference - editor.) (Compliance Engineering - European Edition September/October 1994, www.ce-mag.com.)

12) Railway signalling interferes with recording studio

Around 1990 Alan Little leased a derelict arch under the railway line in Camberwell from British Rail. He borrowed money to convert it into a two-level mix of recording and rehearsal studios. The total cost was pushing £50,000. Up until November 1991 it was popular with up-and-coming bands needing somewhere to rehearse and record. Then, one fateful Saturday morning, with three bands booked for the morning and three for the afternoon, disaster struck. All the studio equipment, and the bands' amplifiers, started warbling. The bands and studio crew thought at first that they had an equipment fault. Then other studios in other railway arches in the area began phoning each other. They all had the same problem. Alan Little phoned British Rail and on the Monday morning a BR engineer came round, listened and said the cause was a new signalling system installed by BR.

BR controls its track lights by feeding electric current through its rails. When a train runs over the rails it provides a short-circuit between them, triggering a red light behind the train. Recently BR has begun changing to the use of alternating current. The long rails act as a highly efficient aerial, radiating a powerful AC magnetic field (*this was actually around 1 Amp/metre over much of the studio - editor*). The AC is at audio frequency, using tones of between 1 kHz and 4 kHz. The tones are complex warbles, to safeguard the system from outside interference.

The effect was heard through the mixing desk, with pick-up from mains and connecting leads. It was even heard through unpowered loudspeakers (*even when they were disconnected from their cables and their terminals shorted - editor*). It was worst when an electric guitar is plugged into an amplifier. Guitar pick-ups are designed to convert their magnetic fields, modulated by the movement of the steel guitar strings, into sound. They cannot distinguish between magnetic fields from a BR signalling system and those from vibrating strings.

(Extracted from an article by Barry Fox in Studio Sound Magazine, June 1992)

13) Magnetic airline tray tables wipe hard drives

It was reported in the Sunday Times (15/2/98) and New Scientist (7/3/98) that Sabena Belgian World Airlines had installed magnetic tray tables in its new fleet of A340 Airbuses, to prevent the nuisance of rattling trays on their flights, but that these tray tables were apt to cause loss of data on PC hard disc drives.

New Scientist of 28 March reported that the story was untrue, but that tables of this sort had been discovered on a train from Frankfurt to Berlin. The conclusion seems to be that if you intend to use your PC in any kind of vehicle you should always carry a (steel!) paper clip and use it to check for magnetised tables.

14) Electromagnetic 'bombs'

High intensity radiated fields (HIRF) guns and electromagnetic pulse transformer (EMPT) bombs are already easy to build from off-the-shelf components. The effects of even hand-built HIRF or EMPT weapons can damage microprocessors at ranges of hundreds of metres. Possibly, in a few years, a van equipped with suitable electronics could cruise down Wall Street (or through Canary Wharf - ed.) and disrupt the information processing capability of thousands of computers without being detected by the local police.

(Extracted from an article in the IEE's Control and Computing Journal, April 1998 (page 52), www.theiet.org.)

15) More on radio activated key lock-out problems (Banana Skin No. 9)

Most radio activated key-entry systems have a manual override. Unlocking the door can be as simple as inserting the mechanical key into the lock and trying the lock according to the instructions printed in the car manual.

(From an Electronic Times article on 29th September 1997, www.eetuk.com. The trouble with this advice is that the manual will usually be locked inside the car – or are we supposed to carry it around with us at all times?).

16) More medical incidents:

The magnetic field caused by ground currents in a water pipe system made it impossible to use sensitive electronic instruments in part of a hospital.

A patient-coupled infusion pump was damaged by an electrostatic discharge, but thankfully the alarm system was not affected and a nurse was alerted.

An operation using a plastic welding machine caused interference with a patient monitoring and control system, causing failure to detect that the circulation had stopped in a patient's arm, which later had to be amputated.

(Taken from Compliance Engineering European Edition March/April 1998, ww.ce-mag.com)

17) Inadequate lightning protection led to serious explosion in oil refinery

At 1:23 pm on Sunday, 24th July 1994 there was an explosion at the Texaco Refinery, Milford Haven. Its force was equivalent to 4 tonnes of high explosive and it started fires that took over two days to put out. Shops in Milford Haven 3km away had their windows blown in. 26 people sustained minor injuries, and the fact that it was Sunday lunchtime and the site was only partially occupied meant it could have been very much worse. Damage to the plant was substantial. Rebuilding costs were estimated at £48 million. There was also a severe loss of production from the plant – enough to significantly affect UK refining capacity. The incident was initiated by an electrical storm between 7:49 and 8:30 am on the Sunday morning that caused a variety of electrical and other disturbances across the whole site.

(Taken from IEE Computing and Control Engineering Journal, April 1998, pp 57 – 60, www.theiet.org. There is an HSE report on this incident: "The explosions and fires at Texaco Refinery, Milford Haven, 24th July 1994" HSE Books, May 1997.)

Comments by the Editor: I have not read the HSE report, but understand from private conversations with HSE experts that the large explosion was caused by the electrical storm giving rise to power surges which tripped out a number of pump motors whilst leaving others running. As there was a great deal of panic and confusion due to the information overload caused by the numerous small fires and equipment outages from the time of the storm, it was not noticed that flammable substances which should have been flared off were accumulating in pipework and vessels. After five hours something ignited the total accumulation, resulting in the large explosion.

The general incidence of surges in the UK's AC power distribution network is quite low, and this often leads people to believe that qualifying the power surge immunity of their products, systems, or installations is not important. This belief is often supported by the observation that neither of the generic immunity EMC standards included surge testing in their normative sections. But it only takes a single incident such as the above in the lifetime of even a very large plant to make an excellent economic case for a proper preventative strategy. Suitable basic test standards include IEC 61000-4-5 or IEC 61000-4-12 (ring wave), both of which are intended to simulate the indirect effects of electrical storms on power networks.

Engineers are always under pressure to save costs, and the costs of preventative measures are easy to quantify. However, many engineers are uncomfortable with estimating the risks of infrequent and unpredictable events such as thunderstorms so do not effectively communicate the actual risk/cost and safety implications to their managers.

As someone said recently: Doctors kill people in ones, but engineers do it in hundreds. Careers and personal liability are also at stake here too, so it is always best to make an informed cost/risk case and get a written decision from management. There is no shortage of advice and assistance on this sort of thing – sources include:

The Institute of Risk Management: phone 0171 709 9808, fax 0171 709 0716, or visit IRMG@aol.com



The Hazards Forum; phone 0171 665 2158, fax 0171 233 1806, Email: torey_d@ice.org.uk, or visit www.ice.org.uk

The Safety and Reliability Society: phone 0161 228 7824, fax 0161 236 6977, Email secretary@sars.u-net.com, or visit www.sars.u-net.com

The British Safety Council: phone 0181 741 1231, fax: 0181 741 0835, Email bsc1@mail.britishsafetycouncil.co.uk, or visit www.britishsafetycouncil.co.uk

Health and Safety Executive: Infoline: 0541 545 500, fax 0114 289 2333, or HSE Books: phone 01787 88 11 65, fax 01787 313 995, or visit www.open.gov.uk/hse/hsehome.htm

The IEE Library: phone 0171 344 5449, fax 0171 497 3557, Email libdesk@iee.org.uk, or visit www.iee.org.uk/Library/libgen.htm

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The Engineering Council: phone 0171 240 7891, fax: 0171 240 7517, Email: info@engc.org.uk, or visit www.engc.org.uk

18) CE marked 8kA DC motor drive causes severe interference with monitors

A very powerful ($\pm 8,000$ Amps) DC drive was recently purchased and installed in an industrial plant. It was contractually agreed that it would meet and be declared compliant to the EMC Directive. A control room was also required (like most modern control rooms it was full of PCs and CRT-based VDUs) and the drive manufacturer said that it could be installed near their drive cabinets. When the drive was operated the images on the VDUs were squashed into 50% or less of the screen width. It was possible to tell the direction and loading of the drive directly from the movement of the VDU images, which of course were completely unreadable. The magnetic fields caused by the drive were of the order of $235\mu\text{T}$, and most CRT-based VDUs show image movement at greater than $1\mu\text{T}$ ($1\mu\text{T}$ is approximately equal to 0.8Amp/metre and to 10 milligauss).

The drive manufacturer claimed that his drive did meet the EMC Directive despite the fact that it caused interference with the control room VDUs. What they in fact meant was that it met the industrial generic standards, which do not include any limits for low frequency magnetic field emissions. They forgot that their EMC Declaration of Conformity binds them to not causing interference of *any* kind, and that compliance with a harmonised standard only gives a presumption of conformity.

The situation has been remedied by the use of LCD screens, which have only recently been available with a specification suitable for the SCADA system that was used. "Dog kennel" magnetic shields and active field cancellation devices were also investigated. The delay in the use of the control room was several months, and this had an impact on productivity far beyond the cost of the remedial measures.

(Submitted by an EMC Consultant who wishes to remain anonymous, May 1998.)

19) Bathroom fan triggers security lights, which then cause radio to switch on

We've learned to live with the condition that if we get up in the middle of the night to use the bathroom, when we turn the light on the fan timer starts. The fan will keep running for twenty minutes, and when it turns off it causes interference that turns on the outside security light (infra-red triggered 500W halogen) which then runs for its time period (15 minutes) whilst shining through the bedroom window.

Now you'll have difficulty believing this bit... Monty Python eat your heart out... before the 500W halogen lamp we had a high pressure sodium lamp with an inductive ballast. When this switched off it would cause interference which would sometimes start the bedside radio. So the scenario was this...

Get up at 2:00 am, go to bathroom, turn on light, turn off light, go back to bed, and after twenty minutes a bright light would shine through the window and wake you up. If you slept through that (or went back to sleep), fifteen minutes later when the light switched off the radio would start, and then you would wake again.

The moral of this story? If you have bad EMC immunity make sure you use the bathroom before you go to sleep.

(From Chris Dupres via emc-pstc@ieee.org, 8th July 1998)

20) Licensed TV transmissions interfere with intensive care, kills babies

While taking classes in the early 80's, my Professor got involved with a terrible incident down in New Jersey. Seems a hospital had a high incidence of infant deaths in the intensive care section of the maternity ward. Late at night, the alarms on the babies' monitors would go off for no apparent reason. Annoyed, the nurses would turn them off and do the rounds on foot.

After some preliminary investigations, my Prof found out that a nearby TV transmitter was allowed by their FCC license to increase their output wattage by some enormous amount after say midnight but had to reduce it prior to 6am, or some such arrangement. The cable interconnecting the nurses station to the various baby monitors sang like a lark with these frequencies and set off alarms with the induced voltages.

Not sure now of all the specifics except what I have related above nor the name of the hospital, but they lost something like 6 kids before fixing it.

(From Doug Mckean, via emc-pstc@ieee.org, 29th July 1998)

21) 'Impossible' 50% brown-out occurs for 8 hours in the UK

Undervoltage AC supplies (brown-outs) are common in underdeveloped countries, or where the AC supply network is incorrectly configured. Parts of Spain are known to experience around 150Vac for lengthy periods during the day, apparently due to network loading, despite an officially-specified mains supply of 230Vac $\pm 6\%$. I had never experienced a brown-out in the UK, except maybe for a second or so prior to a complete supply failure during a thunderstorm, and I used to think that it must not be possible because of the way the supply network is operated here.

On Sunday 26/7/98 around 5pm in Denshaw village, Lancashire, U.K., the supply dropped to around 140Vac RMS (40% below nominal), and stayed at that level for about three hours before shutting down completely as the engineers arrived to fix the problem. We switched off our fridge and other motor-driven appliances, mainly because they were making very strange noises. Our computers kept running, but the CRT screens blanked, making us concerned about what was happening to our data, so we switched them all off as well.

I am aware of electronic control equipment that can misoperate when operated considerably outside its specified AC supply range, and also understand that undervoltages can damage coils and motors. Apparently the motors can stall due to the low voltage, so they don't generate back-emf, so they draw excessive currents and overheat, damaging their insulation and suffering premature failure (if not electric shocks and fires).

Manufacturers of products for the developed world, and their safety test laboratories, usually do not test at supply voltages outside $\pm 10\%$ (sometimes $\pm 15\%$). Until Sunday 26th July I had not thought this important. So far we have not discovered any damage to appliances or to data.

(Submitted by Keith Armstrong, Cherry Clough Consultants, www.cherryclough.com.)

22) Ball lightning during in-flight refuelling

There was film footage on TV some years ago of a British in-flight re-fuelling exercise where the tanker aircraft was hit by lightning, but there was no on-going discharge downwards, the implication being that the plane was left charged to 100kV - 1MV or whatever.

A few seconds later great balls of glowing gas came off the back of the fuselage and wing tips (where the fuel hose was) into the slip stream, presumably taking away a whole load of surplus electrons, or holes - whatever it was - as "ball lightning".

(From Chris Dupres via emc-pstc) (The Editor comments: New Scientist magazine recently reported that a theoretical basis for ball lightning may have been found, www.newscientist.com.)

23) Electrostatic charging of helicopters

Helicopter blades and bodies tribocharge as they swish through the air, and they don't have a convenient green/yellow wire handy. There are reports of an oil rig computer system crashing whenever a helicopter landed, due to its sudden electrical discharge into the metal decking, and there is a film which shows a crew-member getting an awful shock when he reached up to touch the skids of a hovering helicopter.

A US Coastguard Chief related to me that he had seen "arcs as bright as a welding stick" when an emergency pump was delivered to the deck of a freighter one night. He also told me that the Coast Guards' standards practice calls for NEVER lowering a flotation ring or sling to a person in the water; the person will automatically reach for the line! Instead, they dip the line into the water and drag it to the person.

(The above are from Chris Dupres, via emc-pstc@ieee.org.)

24) Interference with a travelling crane

A new CNC machine being installed in a factory had a spindle controller which was a small inverter drive in a plastic case. When the spindle was first operated emissions from the inverter caused a overhead travelling crane to start up and drag its chains down the length of the factory. Luckily, the 18 ton casting the chains had been attached to had just that minute been released.

(Submitted by Phil Hampton.)

25) Two more examples of interference with cranes

There was the famous case reported by the DTI in the early days of their EMC Awareness Campaign of the guy who was standing under his crane's load using his radio-control pendant when interference caused it to release its load, crushing him to death. Many recent crane incidents are due to the use of radio control, especially where crane radio-control systems share the same frequency bands as amateur radio and/or car radio-keyfobs. The soon-to-be-introduced TETRA system also shares some of these bands, and use 25W transmitters – so expect more wild cranes.

Just to prove that modern technology can't teach old technology any interference lessons, I once worked for a company that I was told had made the controls and drives for the first large-scale hovercraft testing tank in the late 1960's. It was in effect a sophisticated travelling overhead crane, which ran a gantry along overhead rails and towed a hovercraft shape along a large pool of water in an even larger building. In those days they used resistor-transistor logic which ran on a 40V rail to provide noise immunity. During commissioning the machine suddenly started up by itself and proceeded towards the far end of the pool – it had been set off by "some sort of mains transient". All the personnel on the site were standing by the access ladder to its gantry, but the only emergency stop button was on the gantry – but it and its ladder were moving just faster than running speed and they couldn't get to it. Since it was not operating according to its (hard-wired) programming, the crane ignored its limit switches and crashed clear through the end wall of the building. Luckily nobody was hurt. The next version had E-stops all around the building.

(Submitted by Keith Armstrong, Cherry Clough Consultants, www.cherryclough.com.)

26) Foetal heart monitor picks up cell phone conversations

A foetal heart monitor in a clinic in the UK in June 1998 picked up a cellphone conversation from elsewhere on the premises quite clearly. The visual output of the monitor was unaffected, but the staff tend to use the audio output, and the cellphone conversation was so loud that it swamped the heart signal they were listening for.

It must have been an analogue cellphone, and it must have been getting in via the audio stages, or else the visual output would have been distorted. Even slow opamps will demodulate 900MHz signals (as hearing aid wearers are only too aware!). In common with many healthcare premises, the use of cellphones on the premises was banned, but you can't rely on people to read or follow signs. *(Submitted by Ian Ball)*

27) RF welder fields set fire to bed 60 yards away

A 40kW RF welder (a dielectric welder for plastic materials) in use in a factory caused a mattress in a bed manufacturer's factory 60 yards away to catch alight. The bed springs must have just been the right length to make an efficient antenna at the frequency the welder was using.

(Anonymous submission, date of event not specified.)

28) Digital TV can suffer more from EMI than analogue

Digital TV is more likely not to deliver a programme to the viewer than the analogue TV services it replaces. It appears that this newer technology is less robust, and that its users will on average suffer a higher loss of service than they may have become used to.

Broadcast digital TV, which can be picked up with existing TV antennae, has a sharper cut-off in performance as signal strength declines. R.S.Sandell, a Fellow of the IEE writing in IEE Review November 98, is concerned that: "Whereas analogue viewers can live reluctantly with a picture that has to be viewed through varying angles of 'venetian blind' and alternating densities of 'boiling porridge', they can still follow the programme plot for most of the time. This dubious advantage may not be available for some members of the digital generation, who will be confronted by a blank screen. In particularly unfortunate reception location this condition may come and go with time as field strengths vacillate". Viewers using indoor aerials (the TV with the rabbit ear antenna in the kid's bedroom?) may find they need to invest in new external aerials or aerial amplifiers and splitters.

Satellite-delivered digital TV is very susceptible to lightning storms, both at the uplink and downlink ends. This leads to the odd situation, when watching digital satellite TV in South Africa during very fine clear weather that thunderstorms near the uplink in Europe can cause all 100 channels (or however many there are) to disappear all together for periods of several minutes. This phenomenon was well understood by the satellite broadcasters, who broadcast a little presentation on this topic every now and again.

(From Keith Armstrong of Cherry Clough Consultants, www.cherryclough.com.)

29) Jam GPS over 200km range with 4W pocket-sized Russian unit

GPS is another example of an advanced technology that everyone wants to use, but which has important susceptibility problems. The signals from the GPS satellites are very weak, so the receivers have to be correspondingly sensitive, which means they are readily swamped by interference from industrial sites. Even though they are at microwave frequencies, interference with satellite communications caused by such commonplace things as poor quality power line connections has been observed several times. Added to this, the need to "see" several satellites at once means that GPS is unreliable in the urban canyons of cities.

I was intrigued to see two items on GPS in the New Scientist magazine dated 10th January 1998. The first was an article about the concern of the US military about a Russian GPS jammer. With only 4W of power (about the same as a hand-held CB or security guard walkie-talkie) this device is claimed to prevent GPS systems from working over a 200km radius (yes, 200 kilometres!). Apparently any competent electronic engineer could build such devices from readily available components. The second item in the same issue was an advertisement from BT for their MoBIC mobility system for blind people. This uses a computerised map, speech simulator, and GPS to guide blind people to their destination. Quote: "Getting around the shops is much easier since I started using the US Military's Satellite Guidance System."

Designers building GPS into their products, especially where these are used for critical purposes, might like to consider the lack of robustness and ease of jamming of this system. I have visions of hordes of planes, cars, and pedestrians all milling around a factory until a certain machine is switched off, because their satellite navigation systems are blocked by its microwave noise.

(From Keith Armstrong of Cherry Clough Consultants, www.cherryclough.com.)

30) Rodent repeller interferes with Amateur Radio

Interference in the Amateur Radio 144MHz band traced to an ultrasonic rodent repeller.
(Brad Thomson, Editor of Test and Measurement World, Feb 95, www.tmworld.com.)

31) Domestic appliance interferes with surround-sound processor

The operation of a domestic appliance used to reset a surround-sound processor, causing a ½ second gap in the audio
(From Neil Gardner, Plantronics, August 98)

32) Taxicab radios interfere with control of Hi-Fi system

An advanced hi-fi system would change input selection due to taxicab radio transmitters when they called at a public house 100yards away.
(From a Technical Director of Lumonics, 1996).

33) Cell phone interferes with digital watch

A Tissot Two-Timer digital/analogue wrist-watch went into time-travel mode (about x 60) whenever a particular Motorola Micro-Tac portable phone nearby had someone actually speaking into the mouthpiece.
(Chris Duprés, 7th July 1998. *It was his watch!*)

34) Several examples of interference

With over 18 years in EMC I could go on listing interference incidents for a long time. Some examples this year already: My computer (FCC Class B) interferes with my cordless phones, to some degree on all 10 channels. My fax machine (FCC Class B) interferes with my TV and some channels of my cordless phones. My garbage disposal unit interfered with everything! My small personal fan destroys my monitor picture.
(From Derek at LF Research, 6th July 98, www.lfresearch.com.)

35) Microwave cookers interfere with car security

Domestic microwave ovens can activate the microwave security sensors fitted to some vehicles.
(From Terry Beadman, Motor Industry Research Organisation (MIRA), 6th November 1998, www.mira.co.uk.)

36) EMI implicated in two capsizes

The Canadian Centre for Marine Communications claim there is evidence that EMI may have contributed to two boat capsizes, via autopilot malfunctions. One was the 16metre fishing vessel the "Dalewood Provider" on August 17 1989, the other was the 64 tons "Martin N" on April 25th 1987. In the latter case three lives were lost. In both cases the concern is that the on-board VHF radiotelephone system interfered with the autopilot sufficiently to turn the rudder hard over. Staff at the Centre report that erratic alterations in a boat's course when autopilot is engaged and VHF radio used is commonplace, generally due to insufficient EMI suppression at the autopilot's interface and control cables.

(Extracted from: "Need for EMI/EMC Standards and Regulations on Small Boats: a Canadian Perspective" by Byron R Dawe and Albert Senior of the Canadian Centre for Marine Communications, and Peter Ryan of Fisheries and Oceans Canada, EMC Technology magazine, Nov/Dec 1998, pages 17-19.)

37) Chlorine gas release caused by mains transients – prosecution

The HSE recently prosecuted the supplier of an item of equipment which led to a release of chlorine in a semiconductor plant. The equipment was not sufficiently immune to mains transients (and proven to be so by the HSE's own labs). They were prosecuted under section 6 of the Health and Safety at Work Act because the supplier, though aware of the problem, did not inform the users of the equipment. The company pleaded guilty.

(From Simon Brown of the UK's Health & Safety Executive (HSE), 13th January 1999)

38) Cell phones can interfere with pacemakers

The Therapeutic Goods Administration of Australia (TGA) continues to review findings of clinical and laboratory research indicating a potential for temporary interaction or interference between mobile phones and the operation of pacemakers and implantable defibrillators. The findings have indicated that interference may be caused by holding the phone within about 150mm of the implanted device, or in direct contact between the phone antenna and the user's skin. Interference can occur with the phone in standby mode, as well as in use. Some phones incorporate magnets, at least in their loudspeakers, and while held close to the implanted device these can cause them to go into their "magnet" mode, which for a pacemaker is a fixed pace.

Based on the most recent testing, simply moving the phone away from the implanted devices will return it to its correct state of operation. Recommendations for users of implanted pacemakers or defibrillators include: not keeping the phone in a pocket over the site of an implant; using the ear that is furthest away from the site of the implant when using the phone; and not allowing the phone antenna to touch any part of the body.

(From Compliance Engineering's European edition Jan/Feb 1998, www.ce-mag.com)

39) Pinball machines interfere with emergency services' radio comms

There is a story of how something was causing havoc with the emergency services' two-way radio communications in Nevada, i.e. police, fire, and ambulances. An exhaustive investigation led to one or more really noisy pinball machines at a roadside pub (editors note: I thought they had bars in Nevada instead of pubs). The owner was ordered to get rid of them. He got rid of them and the problem went away. However, it soon reappeared, as another pub owner wound up with the same machines.

(From George Alspaugh of Lexmark International, 7th July 1998.)

40) Kitchen fan triggers security lamps

I have a security floodlamp system for my backyard, equipped with a thermal motion sensor. I have found that I have a reliable, though unintentional, remote control capability simply by flicking the kitchen range fan on and off a couple of times. I told my wife that it's a special purpose, hard-wired, digital controller.

(From Ed Price of Cubic Defense Systems, San Diego, 8th July 1998, www.cubic.com.)

41) Eurostar north of London delayed by concerns over interference

Eurostar and Railtrack officials admitted this week the threat of EMI causing signal failures is delaying the introduction of European rail services north of London. EMI generated by overhead power lines can affect the trackside signals such that red lights are forced to green. A Eurostar spokesperson said: "In electrical terms, we have found with new trains, such as Eurostar, there tends to be a degree of stray electrical current. This can cause an interference with signalling and affect the integrity cause a signal to go from red to green." Railtrack, responsible for the track and signalling systems, is refusing to allow the trains to run commercially until Eurostar can demonstrate their safety.

"We are working hand-in-hand with to solve this problem as quickly as possible," Railtrack said. Eurostar engineers have designed an interference current monitoring unit. When it senses EMI, the motor is stopped and the train coasts to a stop. However, for the highest safety the unit must be set to maximum sensitivity. This could cause the train to stop every few miles.

(From Electronics Weekly October 23rd 1996) (Editors note: has anybody seen a Eurostar north of Watford Junction yet? How much has this cost our national economy, especially northern companies? I understand that all Eurostar trains have had TCFs done for them under the EMC Directive and that traditionally both British Rail and Railtrack always imposed stringent EMC immunity standards on their signalling equipment, using the RIA series of standards.)

Also see the Lords Hansard text for 14th July 1998 (180714-02) in which Baroness Hayman, Parliamentary Under-Secretary of State, Department of the Environment, Transport and the Regions stated:

“My Lords, the technical issues which prevent the operation of regional Eurostar rolling stock on parts of the existing network relate to electrical interference associated with track circuits. These matters have prevented the issue of safety clearances which are required before passenger services can be operated.”
(<http://www.parliament.the-stationery-office.co.uk/pa/ld199798/ldhansrd/vo980714/text/80714-02.htm>)

In October 2003 the interference problems still did not seem to have been solved. The editor has since been informed that plans to run Eurostar trains north of London have now been shelved.

42) Railway trains banned over interference

There are a number of railway trains that have been unable to be taken into service because they interfere with signalling.

(From Ray Garner of Datel Defence Ltd, November 98, quoting an earlier article in a national newspaper.)

43) Induction furnace interferes with high street store’s computers

A 1.5 MW induction furnace controlled in on/off time-proportioning mode (using large contactors to switch the current) interfered with the computers in a Marks and Spencer’s store ½ mile away.

(From Laidler Associates Consulting Services, June 1998, www.laidler.co.uk.)

44) Turbogenerator support distorted by heating from incorrect cable installation

A new large turbogenerator in a UK power station was designed to have its 20kA three-phase output busbars split either side of one of its support pillars, because of a lack of space. The support pillars were steel, part of a steel framework, and created a single-shortened turn around one of the busbars. In operation, the pillar (made of 2 inch thick steel members) got hot enough to blister its paint, and increased in height by 5mm, putting a bearing out of alignment and causing a terrific noise which caused the station workers to run for their lives. (*Editor’s note: a large turbogenerator up to speed and adrift from its bearings is a fearsome object!*) The cure was another shortened turn, this time around the pillar and made of ½ thick aluminium.

(Conversation at Mersey and District Club Européen, 28th January 1999.)

45) Further information on Banana Skin No. 37: Chlorine release

The case referred to was heard at Swindon Magistrates Court on November 25th 1998. The defendant entered a plea of guilty to a charge brought under S6 (1) (d) of the Health & Safety at work etc. Act, 1974. The magistrates imposed a fine of £5,000 and made an order for the defendants to contribute £7,000 towards HSE’s costs of £9,482. The case concerned a microprocessor based valve control panel used to control the flows of chlorine and nitrogen in a semiconductor plant. There had been a release of chlorine resulting from all of the valves in the control cabinet being set to an open position.

Investigation by the HSE found that the unit was susceptible to conducted transients on the mains supply. There were no precautions against electrical interference in the power supply and the microprocessor watchdog was not effective in ensuring a safe state following detection of a fault. The HSE inspector who dealt with this case was Eifion Davies in our Cardiff office.

(From Simon Brown of the HSE, 3rd March 1999)

46) Monitor image wobble caused by magnetic fields

Scenario: Large open-plan office in a publishing company. Lots of eager beavers with 21 inch displays on their MACs, doing all sorts of clever graphics things for page make-up and other arcane processes.

Problem: The displays on only some of the monitors oscillate sideways about 0.5 mm at most, at about 1 Hz.

Diagnosis (partial): The combined magnetic fields of mains cables under the floor and a power transformer on the floor below are sufficient to cause this very small effect. Unfortunately, once

you notice it, it keeps catching your eye and it eventually drives you mad! The 1 Hz is due to a beat between the third harmonic of 50 Hz and the second harmonic of the 75 Hz frame rate of the displays.

Solution: Move the transformer. Replace the large feeder cable to it by individual lower-current feeds to the loads served from it, spread out across the void below the office floor.

Continuing problem: Now that the sideways movement has been eliminated, an even more subtle “vertical” movement of the displays is discovered. Again, it’s difficult to see, but once you see it, you can’t ignore it. This effect is not continuous: it occurs for a few minutes and then disappears for about ten minutes or more.

Diagnosis: An air-conditioning unit is found to have an intermittent fault to earth, resulting in some 3 A flowing in the armour of the cable feeding it. This current is not balanced by currents flowing in the conductors of the cable, and creates a 50 Hz magnetic field with a horizontal component sufficient to cause the effect.

Solution: By turning a monitor through a right-angle, so that the strong horizontal component of the field is parallel to the electron gun axis, the movement disappears. However, it is obviously necessary to correct the potentially hazardous fault in the air-conditioner.

The main point here is that the tolerable amount of display movement is “very small indeed” when people are working on complex artworks on large-screen displays.

(From John Woodgate, 8th March 1999)

47) Mains spikes blow fuses in poorly-designed control panel

The relaxed attitudes of those times did not always pay off, however. Slightly later in my career, I moved to a company where engineering standards were, let’s put it politely, a little lacking. For example, interlocking between contactors in reversing pairs was considered an unnecessary expense, and no one would ever consider such niceties as interrupting capacity when selecting a fuse. If the current rating was right, the fuse was good enough for the job.

The error of these ways wasn’t long in revealing itself, however. In one mechanical handling job, we had around a dozen reversing starters, all protected with totally inadequate fuses. Even worse, the contactors were controlled by some very dodgy solid-state switches which had been “designed” in-house. Now, in those days, EMC hadn’t even been invented. The result was that even the slightest spike on the supply made these solid-state switches turn on – just for an instant – but long enough for all of the contactors to jitter. Frequently, both contactors in a reversing pair would close for an instant, placing a short-circuit across the supply. This meant a mighty bang as the inadequate fuses shattered and spilled their silica contents all over the floor of the enclosure.

After a lot of time on site, during which much wiring was re-arranged and many capacitors were added to the system, we managed to get the equipment working after a fashion but, ever since, I’ve been suspicious of control panels with a layer of silica sand in the bottom!

(Taken from “When I was a lad...” reminiscences by Keith Wilson, Panel Building Magazine, February 1999, page 17)

48) Screened leads that weren’t

I was testing an item of IT based instrumentation the other day that failed conducted emissions. We replaced its 3 metre long screened 25-way D-type lead, which had been purchased as a “fully screened cable” from a well-known distributor, with my own home-made 15 metre long 25-way D-type lead, which simply used a single braid cable and metallised plastic backshells. The conducted emissions problem (on the mains lead) went away. My customer is now trying to source cables which really are screened. So *caveat emptor*, even when buying from large distributors.

(From Ian Ball of A. D. Compliance Services Ltd, which used to be Dedicated Micros EMC Test Centre.)

Items 49-52 below are four real-life case-histories of industrial projects that failed in a big way, due a failure to correctly appreciate EMC. The names and details that might allow identification of the companies concerned have been suppressed for confidentiality

These examples have been extracted from the paper "The Real Engineering Need for EMC" by John Whaley, General Manager of SGS International Electrical Approvals (UK), presented at the IEE event "Electromagnetic Compatibility in Heavy Power Installations", Teesside, UK, 23rd February 1999, www.theiet.org.

The other papers from this event will also be of value to anyone involved with industrial products and installations (not just heavy power applications). Contact IEE Sales and ask them to send you digest reference 99/066. These cost £20 each for delivery in the UK, and they normally require a cheque for the full amount before posting. An extra postage charge may be made for overseas customers. Phone +44 1438 313 311, fax +44 1438 313 465, or e-mail: sales@iee.org.uk.

49) Failure to correctly specify EMC performance

A large manufacturer of industrial fasteners, negotiating with a major customer, agreed to install a packaging cell containing an automatic weighing machine that filled plastic packets with fasteners and an RF welding machine to seal the packets. For cost reasons the two machines were purchased separately. No assessment of the electromagnetic environment took place, and the machine contract specifications included no EMC requirements other than "shall meet all legal requirements".

Both machines were supplied, installed, and tested successfully. Unfortunately when both were operated together the weighing machine suffered >25 % errors due to interference from the RF used by the welder (not an uncommon problem). In an 8 hour shift the cell should have packaged £20,000 of fasteners, but could have given away up to £4,000 of product in incorrect weights.

There was no comeback on the machine suppliers, whose products met specification. Both suppliers appeared willing to help, but when pressed blamed each other. Expert technical assistance was brought in and solved the problem. The fastening manufacturer lost 6 weeks production, suffered additional costs, and lost credibility with their major customer.

50) Over-specification of EMC

A machinery manufacturer needed a special inverter drive for a new range of machines, and out them out to tender. A manufacturer of AC inverters won the contract for this large project against stiff competition, but didn't notice that the specification required meeting military EMC standards. Their normal inverter designs failed the EMC tests, and their customer refused to accept them. Not having experience in military EMC, time and effort was wasted only to find that the redesigned inverters would not meet functional specifications.

As a direct result, the inverter manufacturer went out of business. Their customer's machine introduction was consequently delayed, leading to loss of revenue and loss of market credibility. The machinery manufacturer should have correctly assessed the electromagnetic environment of his product, and realised that military EMC standards far exceeded what he really needed.

51) A cost reduction exercise that didn't

A manufacturer produced high-quality industrial equipment sold throughout the world. New management thought that poor financial performance was because their products cost too much to make, so began a cost reduction exercise that included employing a production engineer to make design changes.

The designers had been using historically-generated design rules to give their products their famous reliability. These included EMC protection developed over many years of reacting to interference problems in the field. The design departments had no real understanding of EMC, did not realise what protection was lost by the changes, and were unable to suggest cost-effective alternatives.

A number of machines were built to the new design, and with a new price structure sold well in the UK and particularly well in the USA. Unfortunately the product was unreliable due to poor

immunity to real-life electromagnetic environments. The consequences included one customer rejecting a product, and the basing of a commissioning engineer in the USA for over one year, as well as loss of product reputation.

Reducing company profitability by employing cost-reduction techniques is not uncommon. *Cost-effectiveness* techniques should be used instead, taking account of all the consequences of change. In this case the history of the product should have made it clear that EMC expertise was required.

52) Mistakes with a cabling installation

A major manufacturer of automotive parts commissioned a series of robot controlled paint booths with a total project cost of over £2 million, and correctly specified their EMC performance. The successful supplier agreed to meet these EMC requirements, and accepted financial penalties in case of non-delivery. To save costs, it was agreed that the supplier would install his paint booths but the user would arrange for their cabling to be installed by local contractors.

When installed, the paint booths suffered apparently unconnected (and sometimes dangerous) faults and the user would not accept them. Investigations by both the user's and supplier's staff could not identify the problems. The user had problems meeting his production deadlines and had to employ extra painters, while the supplier started to incur financial penalties for late delivery. An independent consultancy quickly identified that the screens of all the interconnecting cables had been terminated in a daisy chain to a local earth (which was not the equipment earth), allowing interference with the control electronics.

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. Unfortunately there was no easy answer and 80% of the cables had to be replaced (using the correct screen terminations). The supplier picked up the bill.

Costs to the Customer	Costs to the Manufacturer
Loss of production	Financial penalties under the contract
Extra painting staff costs	Additional costs of investigation (staff)
Additional costs of investigation (own staff plus independent)	Additional re-wiring Costs.
	Loss of customer's confidence

The legal arguments about who was at fault continued for some time, but the lack of cable installation instructions from the paint booth supplier was the determining factor. Arguments that his staff normally installed his equipment were discounted, as he had agreed this would not happen on this contract.

53) Power dip problems solved using superconducting energy storage

The paper mill at Stanger (South Africa) has a modern electronic variable speed drive system rated at 1MVA. A thyristor-controlled rectifier controls the common DC bus voltage of the individual drives. The motors are independently driven, speed-synchronised units transporting the continuous paper web at high speed. Voltage dips of more than 20%, lasting in the order of 40 ms, are enough to upset the sensitive controls and shut down the drives. This tears the paper web and results in several hours of downtime for cleaning and re-threading.

The paper mill used to experience at least one or two such voltage dips a week in its power supply, but since the installation of a superconducting magnetic energy storage system in April 1997, configured as a voltage dip protector, not one shutdown has been caused by voltage dips on the supply from the feeding grid.

(Adapted from an article by R Schöttler and R G Coney in the IEE Power Engineering Journal June 1999 special feature on electrical energy storage, www.theiet.org.)

54) TETRA radio system interferes with car keyfobs

Ken Yard of the Radiocommunication Agency described the problems it had recently faced with the introduction of the TETRA services to the UK. Interference to car alarms and immobilisers had caused over 12,000 call-outs on roadside recovery services in the last year alone. He said that the problem was partly caused by TETRA base stations but the main cause was poor quality receivers (in the car system) with insufficient rejection of out-of-band transmitters. He hoped that this situation could be avoided with the new 868MHz band for car keyfobs.

(From the article "Compromise on 868 MHz", page 14 of Low Power Radio Association News May 1999, describing a meeting on March 23rd 1999, www.lpra.org/news/index.php. If your present car keyfob uses 418MHz, you could easily suffer from TETRA during the coming months and afterwards. If it uses 433MHz you may escape - if your receiver is of good quality.)

55) New kidney dialysis machines very susceptible to power quality issues

Power quality is especially critical in hospitals, where life sustaining processes demand clean reliable electrical supplies. This was recently highlighted at Glan Clwyd Hospital in North Wales where a problem became apparent on the renal dialysis unit during the testing of emergency generators. The switch from mains power to generator power was causing the newer, computer-controlled dialysis machines to close down and generate an alarm. This caused distress to patients and problems for staff who needed to reset several machines quickly before their blood began to coagulate.

Resets were generally successful, though occasionally a unit would not respond so a patient would need to be moved onto a spare machine. The problem was solved with uninterruptible power supplies to provide continuity of operation at the hospital during generator testing. Ten 2.5kVA UPSs are now used in the dialysis unit and one on a treadmill in the cardiovascular unit to safeguard patients from injury should power failure cause the treadmill to stop suddenly.

(Extracted from page 121 of IEE Review, May 1999, www.theiet.org. Take care: not all UPSs appear to be as reliable as we might wish!)

56) Aircraft carrier interferes with garage doors in Hobart, Tasmania

Hobart in Tasmania suffered an unusual blight earlier this month. Residents all over town found themselves trapped in their garages when the remote controls that operate the garage doors suddenly failed to function. Roll-a-door companies were flooded with calls from angry garage owners and were at first completely nonplussed by the problem.

Then the explanation emerged: the aircraft carrier USS Carl Vinson had just cruised majestically into the town's docks, equipped with navigational radar employing the same frequency as the remote controls for the town's garage doors. According to the local newspaper *The Advocate*, an apologetic Lieutenant Dave Waterman, the ship's public affairs officer, said that the problem would only occur when the ship was arriving and leaving.

(New Scientist, 24th April 1999, page 100, www.newscientist.com.)

57) Screening cable helps engine run smoothly

A control cable to the engine management system of a motor car was damaged, and repaired with a terminal block. But the engine ran rough. Wrapping the repair all over with EMC copper tape (conductive adhesive) made the engine run smooth again.

(Arthur Harrup, Chief Engineer, William Tatham Ltd, Rochdale, 16th Feb 1999)

58) Three examples of interference from UK Trading Standards

Some robotic toys interfere with TVs. Some touch-controlled lamps interfere with long-wave radio, even when their light is turned off. An illuminated (battery powered) yo-yo interfered with a Porsche.

(Jim Rackham, Principal Trading Standards Officer, 23rd February 1999)

59) Chart recorder runs at double speed on Saturdays

During the 1980s we used a French make of chart recorder, which often ran at double speed on Saturdays. This turned out to be due to the increased numbers of TVs and radios in use on a Saturday, whose power supplies injected second harmonic currents into the mains supply. The synchronous motors in the chart recorders were able to latch up to the resulting 100Hz voltage distortion, and consequently ran twice as fast.

(Stan Lomax of RTM Group Ltd, Altonham, March 99)

60) Cable TV interferes with aircraft navigation and radio comms

The German economics ministry is considering restricting cable TV networks because of mounting concerns about their possible impact on air traffic safety. Frank Krueger, an economics ministry spokesman, says that the possibility that interference from household cabling will interfere with aircraft navigation and ground communication systems has prompted the government to propose regulations. "It is possible that, in individual cases, certain stations will have to be closed down after a review of the dangers posed by their frequencies." said Krueger. According to the European Cable Communications Association, the discussion about cable broadcasting and air traffic safety is not confined to Germany.

Similar safety issues are currently being discussed by the Benelux states and the Nordic countries. The UK Radiocommunications Agency says that, as far as it is concerned, the only debate surrounding clashing transmissions relates to avoiding potential interference with other European broadcasters. *(From the lead article on page 1 of Electronics Times, April 1999, www.eetuk.com.)*

EMC consultant Diethard Hansen has written: "In spite of using coaxial cables in the TV distribution systems there is a lot of shield leakage, based on technical imperfections and ageing. Catastrophic emissions in the aeronautical security bands are jamming Germany."

(From: "Megabits per second on 50Hz power lines", Diethard Hansen, IEEE EMC Society Newsletter, January 2001, <http://www.ewh.ieee.org/soc/emcs>.)

61) Millennium Wheel installation delayed by interference from microwave comms

The Millennium Wheel on the Embankment in London was supposed to be lifted on September 12th 1999. One of the delays was caused by an EMC problem. *The Daily Telegraph*, Saturday

September 11th 1999 (page 6) said: “The operation had fallen victim of the publicity that it had generated because the satellite dishes on the fleet of television vans covering the event interfered with the laser signals monitoring the cables pulling the wheel upright.”

The Guardian, September 11th 1999 said: “Work was initially delayed when satellite dishes on media vehicles interfered with electronic equipment used to monitor the lift, and further hampered when a stabilising cable had to be re-routed.”

The Engineer, 17th September 1999 (page 2) chose to ignore the EMC issues altogether and focussed instead on the problems with the stabilising cable and its wheels, brackets, and lateral pins.

62) Copying machine interferes with CAD system

An engineering company invested heavily in a networked computer-aided design (CAD) system. However, the system’s many advantages were overshadowed by the all too regular problems it suffered. The system would crash unexpectedly, sometimes hours of work were lost or corrupted and circuit failures seemed to be almost a monthly event.

At first these were assumed to be just “teething troubles” but as time went on, and design work slipped further and further behind schedule, relations with the system’s supplier became increasingly difficult. Only when one of the engineering team read an article in a professional journal, did they realise that the problem might not be the system, but the environment. They soon observed that the system’s failures coincided with the operation of a large drawing copying machine, which was injecting switching transients onto the ring main.

(Furse Electronic Systems Protection Handbook, 1996, page 15, www.furse.com.)

More on this topic....

Transient faults (*in computer systems*) are triggered by environmental conditions such as power-line fluctuation, electro-magnetic interference, or radiation. These faults rarely do any lasting damage to the component affected, although they can induce an erroneous state in the system. According to several studies, transient faults occur far more often than permanent ones, and are also harder to detect.

Curiously, most computer failures are based on either software faults or permanent hardware faults, to the exclusion of the transient and intermittent hardware types. Yet many studies show these types are much more frequent than permanent faults. The problem is that they are much harder to track down.

(Taken from “Fault injection spot-checks computer system dependability” by J V Carriera, D Costa, and J G Silva, IEEE Spectrum, August 1999, pages 50 and 51, www.spectrum.ieee.org.)

63) Radio and radar transmitters interfere with early electronic flight control systems

Earlier analogue flight control systems have experienced malfunctions when overflying radio/radar transmitters—the new generation digital systems are very much more robust and can meet the very stringent EMC requirements.

(Taken from “Fly by Wire” by Dick Collinson of Marconi Avionics, Computing & Control Engineering Journal, IEE, August 1999 page 152, www.theiet.org.)

64) PC EMC compromised by non-compliant components

Computer manufacturers and others are finding it impossible to meet the EMC Directive because of non-compliant CE marked motherboards and power supplies, according to test house EMC Projects. The company tested 12 different motherboards for a client recently and found that every one of them failed to meet EN55022 limits, according to the company’s MD Mike Wood. Failures ranged from a few dB to 20dB over the limit line. None was accompanied by instructions about how the boards should be installed to meet EMC regulations. “I feel very sorry for companies trying to meet standards when they use these boards,” Wood said. “It is almost impossible for them to comply.” He pointed out that any manufacturer relying on CE marked components to justify compliance without testing is likely to have severe problems.

(Approval, Jan/Feb 99, page 5)

Talking to a representative of Intel Corporation (UK) of Swindon about this general issue in 1998, he said that they always tested their motherboards to make sure they were EMC compliant in a variety of different manufacturers' PC enclosures, and that this took approximately two weeks. He claimed that this was one reason why none of the "hottest" machines reviewed in the computer trade press used Intel motherboards – given the fast pace of the computer industry, taking the time to properly qualify a motherboard meant taking second place in the performance stakes to those who were less careful of their legal and ethical obligations.

(Keith Armstrong, Cherry Clough Consultants, October 1999)

65) Investigations into possibility of cell phones interfering with implanted medical devices

According to the Cellular Tele-communications Industry Association's web site www.wow.com: researchers have found that analogue phones have no effect on pacemakers, although some digital phones do. Already, doctors advise pacemaker wearers to exercise caution around electromagnetic devices such as MRI machines. Digital phones should be approached in the same way.

Wireless Technology Research Ltd conducted tests involving over a thousand pacemaker patients. They found no clinically significant interactions with the phone in the normal position at the ear. Some interference was noted in 20% of the tests with the phone 6 inches from the pacemaker. But even then, only 6% were clinically significant. Regular operation resumed once the phone was removed. The Food and Drug Administration (USA) believes pacemaker wearers should avoid placing phones next to the implant, as in shirt or jacket pockets. When using the phone, patients should hold it to the ear opposite to the side of the body where the pacemaker is located.

Other cardiac patients use implanted cardiovascular defibrillators (ICDs). The University of Oklahoma's Wireless EMC Centre investigated the effects of all the analogue and digital wireless phone technologies operating in the US and Europe on ICDs from four manufacturers. No interactions were found between phones that operate in the 1800 and 1900MHz bands.

Only one unnamed company's ICDs were affected, and these effects were only caused by TDMA-11 Hz which is only used in specialised operations, and even then no permanent ICD reprogramming occurred. Still, doctors say that additional research is necessary, and researchers say that ICD patients should follow the same guidelines as pacemaker wearers.

(Extracted from Electronic Design magazine, October 18th 1999, page 32H, www.elecdesign.com.)

66) Twenty-eight examples of interference with medical devices

During the past decade, the U.S. Food and Drug Administration (FDA) has received more than 28 medical device reporting incidents of adverse interactions between medical devices and electronic article surveillance (EAS) systems, metal detectors, and security systems. Several case reports and four peer-reviewed studies document adverse reactions between EAS systems and implanted pacemakers, implanted automatic cardiac defibrillators, implanted neurostimulators, and other ambulatory medical devices.

Anecdotal reports and newspaper articles suggest that many more device interactions have occurred and gone unreported. Each year millions of people enter establishments protected by EAS systems. Because more people are using electronic implants and ambulatory medical devices, adverse interactions with EAS systems are of increasing concern.

(Extracted from an article in Compliance Engineering magazine's European Edition, September/October 1999, Page 32, www.ce-mag.com. The article does not draw any conclusions for wearers of implanted devices in the way that item 65) above does.)

(Editor's Note: The number and variety of implanted medical electronics devices is rapidly increasing. Stevie Wonder (the musician) is apparently soon to receive an artificial retina chip. Some very serious people are talking about implanted personal enhancements which are not

for medical purposes. EMC takes on a whole new dimension when parts of your body or mind can suffer interference from common electronic technologies.)

67) Digital TV broadcasts interfere with critical medical telemetry

The Critical Care Telemetry Group submitted a petition document (to the USA's FCC), ET Docket 95-177, 10/97 covering new channels from 470 to 668 MHz for powers of 200,000 $\mu\text{V/m}$ at 3m at the same time as the digital TV group submission. This resulted in some confusion and a case where in March 1998 at Baylor University Hospital some medical devices failed due to the DTV broadcast. The FCC and the FDA produced a fact sheet stating that the DTV operators must co-ordinate with the regional hospitals before broadcasting. (Details can be found on the FCC web pages, <http://www.fcc.gov>.)

(Extracted from ERA Technology's Safety and EMC Newsletter, Supplement to Issue 47, October 1999, page 12, http://www.era.co.uk/Services/safety_and_emc.asp. This was reporting on a paper by Art Wall of the FCC presented at the IEEE's International EMC Symposium in Seattle, August 1999)

68) Plane crash nearly caused by portable CD player

In early February a DC-10 was entering its final landing approach at New York's JFK airport when it suddenly banked sharply to the left, nearly causing a crash. NASA and FAA experts concluded that the plane's flight controls were upset when someone in first class turned on his portable CD player. Apparently, newer planes are more heavily computerised and vulnerable to interference. Of particular concern is interference to frequencies used by the VOR (Visual Omni-Range) network, because flight control systems use these navigation beacons for autopilot operation and instrument landing.

(Taken from Compliance Engineering Spring 1993, page 92, itself commenting on an article in Time, Feb 22, 1993, www.ce-mag.com.)

69) Use of CD players banned by some airlines

With reference to Lufthansa's "weird" ban on CD-ROM drives (Letters, 28 March, p.64), the airline is probably extending an existing ban on personal CD players to computers. In the only documented case of interference from personal electronic equipment that I am aware of, an early CD player jammed the instrument landing system on an airliner in the mid-1980s. Because CD players are optical devices, some of the cheaper models did not include any shielding against radio-frequency (RF) interference from the logic devices in their controllers and were therefore quite noisy in the RF bands. *(Allan Gibson)*

In the feature "Do portable electronics endanger flight?" in IEEE Spectrum (September 1996), the reason given for the ban on equipment containing CD players is that "portable compact disc players have an internal clock of 28MHz", which "produces harmonics at 56, 84, and 112MHz – and 112MHz is a VHF aircraft navigation channel" for aircraft. *(Kevin Connolly)*

(These two items both appeared on the same page (56) in New Scientist 25 April 1998, www.newscientist.com.)

70) Airline check-in desks ban mobile phones

Earlier this year, at Paddington railway station in London, I saw this sign on the door of the airlines' check-in area (operated by BA, American Airlines and British Midland) for customers travelling by rail (Heathrow Express) to the airport: "Please do not use mobile telephones in the area as it interferes with the equipment." (I'd love to know more. I'd speculated -- wild guess! -- that it was US-built check-in equipment that had not been tested for immunity to GSM phones...).

(from Glyn Garside, Director, Engineering Services, Adept Technology Inc., San Jose, California.)

Reply from Jim Rackham of Warwickshire Trading Standards (one of Trading Standards' four EMC Specialists): If the use of a mobile phone is likely to cause any risk to Health and Safety, then the business would have a duty to warn anyone entering the premises not to use it. On a more general note as shops are usually on 'private property' then the owners would have the

right to lay down reasonable conditions on what actions were acceptable within the premises. If in certain circumstances mobile phones could interfere with equipment then it might be reasonable for them not to be used - some equipment could still predate the regulations. However, as installations should comply with the protection requirements and if it is reasonable that mobile phones could be used in the vicinity of CE marked equipment, that equipment should be reasonably immune from their interference.

(From Keith Armstrong of Cherry Clough Consultants): An EMC specialist from a major IT company told me that their computer systems only achieve 1V/m immunity although built from equipment that individually meets 3V/m. 1V/m is equivalent to a GSM hand-portable at around 5 metres, in a strong signal area without reflections from nearby metal structures. In weak signal areas (or standby mode) with no reflections, this would instead be around 7 metres. For this reason they generally ban the use of cellphones and walkie-talkies in the computer rooms they build.

71) Robot Wars interference problems

The robots used on the Robot Wars TV show apparently suffer terribly from interference. They are radio-controlled (R/C), often using hobbyist gear. Here are some comments extracted from the "Robot Wars: Tip Swap: weapons idea centre", soon after a robot ran amok and injured someone. The 'failsafes' they are talking about are supposed to shut down all robot activity except when valid R/C is established. *(From Bill Armstrong of PC Help.)*

(Saturday, January 8, 2000)Despite what the Reg's state hardly any of the failsafes on the robots were in a working condition. Remember that an awful lot of robots were suffering from radio interference problems, this I find odd, as personally all the robots that have been built here in my workshops have never had a problem. As for the question of failsafes, most of them are definitely not failsafes and don't work.one common problem on lots of commercial units is because the unit tries to detect an output pulse from the receiver, this works well in a normal environment but in studio conditions this is not the case, interference can (and will) cause 'spikes' on the output and it will assume that is the correct signal and fail to shut it down. Some of the more expensive models actually measure the pulse width and if it falls outside the normal pulse width they then fail safe.(*Sunday, January 9*) In my opinion, the biggest safety problem is with the failsafe system. Having run 27MHz R/C cars for years, I am used to how easily control is lost even in friendly RFI/EMI conditions. Most people use commercial RC aircraft failsafes (the little orange thing), which is fine when you are flying a plane outside, in friendly EMI conditions, and signal is completely lost (e.g. transmitter battery fails).....They are not meant to deal with conditions of huge RFI/EMI interference present at Robot Wars - indeed our electronics guy laughed at the simplicity of the circuit when he took apart the failsafe we bought. It would bypass the majority of interference, and render the robot uncontrollable (and unpredictable). ...Also I have to suspect the method of testing at the auditions. According to the test is simply to switch off the transmitter - and if nothing happens, then the robot passes. But aren't the auditions held in a quiet warehouse, with friendly RF (i.e. little interference), making them totally unrealistic? (*Sunday, January 9*)....the only problem is that a failsafe on some robots may be irrelevant. There are plenty of home-made speed controllers out there with home-rolled micros running the show that could go rogue regardless of whether they have an input at all. Even if PCM is used (*for the R/C*), there are some being controlled with relays and home made interface circuits that are not too stable irrespective of input. It certainly needs a more technical look at the way people are controlling their motors and weapons.....(*Monday, January 10*)The lack of failsafes on weapons channels scares me - I've been near a couple of robots when the weapons channel has fired for no reason.... (*Wednesday, January 12*)Just a quick note on the orange failsafes mentioned further back on this thread, I've done some investigating, they come in two varieties. The FS-1 (the one with undervoltage monitoring) works beautifully, the other, the FS-2 is not suitable for use on robots. As mentioned further back, it lets through most interference. There is no external difference in appearance between the two units, other than the number printed on the label.....(*Wednesday January 12*)...The problem we have is when the receiver loses its signal,

it holds its last state for 1.5 seconds before it fails safe, i.e. the robot does the last thing it was doing for 1.5 seconds after its signal was lost.

72) Trams fitted with inverter drives interfere with hospital equipment along their route

The Helsinki City Transport (HKL) rolling stock is ageing fast. The most recent trams were built 20 years ago. Hitherto, all auxiliary equipment, such as ventilator fan motors were DC and the maintenance of these units was becoming something of a nightmare. Spares were costly and it was a very labour intensive process keeping them in service.

In each HKL tram there were six ventilation fans with DC motors cooling the passenger compartment, brake resistor, and traction motor. The thinking was that one big inverter supplying six AC motors was going to be cheaper than several smaller inverters supplying one motor each, so a 15kW unit was mounted in the main electrical panel of one of the trams. The existing cabling was retained because of cost considerations and this connected the various motors in parallel. EMC problems very quickly surfaced. Not only was the vehicle's own radio system badly affected, but –crucially – third party electrical equipment also suffered interference, including that of a hospital on the tram's route.

The problem was solved in the end by siting individual inverters close to the motors they controlled.

(From an article by Les Hunt in dpa Magazine, March 99, Drives Supplement page 29, www.dpaonthenet.net.)

73) Solar storms black out Canada in 1989

Every 11 years violent storms on the surface of the Sun cause massive amounts of energy – in the form of protons and electrons – to be thrown out into space. After a few days, this energy reaches Earth, interferes with the planet's magnetic field and generates huge currents – particularly in the polar regions. These induced currents can subsequently induce massive surges in (*power distribution*) transmission lines, damaging transformers and causing high-amplitude harmonics. In the space of just 2 minutes in March 1989, six million people in Quebec, Canada, suffered a complete blackout because of a severe storm from space. In the UK the problems were less severe, but some were experienced.

(From Electrical Review, 20 July 1999, www.electricalreview.co.uk.)

The first space weather prediction system for electric power grids has been completed in the UK. The main problem for networks is losing control of voltage regulation, but with the new system certain regions can be highlighted as being particularly at risk and necessary precautions taken. So far in Solar Cycle 23 – the name for the current bout of activity – longer-term forecasts have given two clear warnings of potential disruption.

(From Electrical Review, Vol. 233 No 5 p 10, www.electricalreview.co.uk.)

74) Walkie-talkie interferes with ship steering, causes minor collision

There was a minor collision between a supply vessel servicing a semi-submersible offshore oil and gas installation. The vessel experienced a sudden power increase brought on because of interaction between radio signals from a portable VHF radio and the joystick control. This caused the joystick to execute commands not requested by the operator and resulted in contact between the vessel and the installation. The interaction caused minor damage (though it could have been far worse).

The incident occurred outside UK waters and was reported in a safety notice issued by an offshore operator. The safety notice was seen by an HSE inspector on a bulletin board on an offshore installation, dated 30 September 1999, which referred to the incident as having happened 'recently'.

(From Simon Brown of the HSE, 14th and 15th February 2000.)

75) EMI problems and shipping

"NOTING the growing number of problems experienced with equipment that is susceptible to electromagnetic interference, which can result in dangerous situations,....."

(Extracted from IMO Resolution A.813 (19):1995, "General Requirements for EMC for all Electrical and Electronic Ship's Equipment")

76) Class D amplifier launch delayed by EM emissions

National Semiconductor plans to begin shipments of Class-D audio amplifier ICs before Christmas. The delay of the launch, which was first reported by NE in June this year, has been attributed to the design of the development board. Class-D amplifiers, while efficient, require careful layout to prevent EMC problems from the internal 50kHz oscillator.

(From New Electronics magazine, 14th December 1999, p 8, www.newelectronics.co.uk.)

77) Faulty central heating thermostats can interfere with radio and TV

Faulty thermostats can cause annoying interference to radio and TV broadcast reception. They cause short bursts of interference that may recur at intervals. Thermostats in central heating systems, fridges or freezers switching on and off have all caused interference problems. Our experience shows that the thermostat found in the central heating system is most often the source of the interference. Often the offending thermostat is found in the house receiving the interference, although the agency is aware of cases where the source of the interference was some distance away.

(From the Radiocommunication Agency's publication RA 272 (Rev3) May 1999, <http://www.ofcom.org.uk/radiocomms/ifi/glines/interference/148207>.)

78) EMI dangers of using mobile phone handsets while driving

Millions of motorists are risking their lives every time they use mobile phones while driving. New research has revealed (that) signals sent from mobiles can disrupt sophisticated electronic control units fitted in most modern cars. And it is feared that in some instances this could scupper vehicles' braking and engine systems. One major manufacturer has also warned that the transmissions from mobiles could trigger air bags fitted to the car.

The alert over making calls in the car was given by the AA following research into the problem. The motoring organisation is now urging drivers to ensure they stop their cars before making any calls. Last night an AA spokesman said: "It is the same as aircraft operators asking people to switch off their mobiles while on a plane. The mobile is transmitting all the time and there is the possibility of interference with electronics in the car. You might get a misfire or your braking system might not operate. The answer is to only use the phone when you are stationary or to install an outside aerial."

(From an article by Bill Caven in the Daily Record, 10th Jan 2000, p 23. Also see an article by Ian Fletcher in the Sunday Mirror 9th Jan 2000, p 9. Both were sent in by Dai Davis, then Head of IT, Communications and New Media Group at Nabarro Nathanson, now with Brooke North LLP, Solicitors, www.brookenorthllp.co.uk.)

Five examples of EMI from Art Wall of the FCC. *Items 79 through 83 below are taken from comments by Art Wall (Associate Chief of the Policy and Rules Division of the USA's Federal Communications Commission) during an EMCTLA seminar on FCC requirements on the 18th May 2000, www.emctla.co.uk.*

79) Radio remote controlled garage door openers are short-range devices which use a part of the spectrum also used by the military. People got fed up with their garage doors opening every time a military jet flew over, so the manufacturers added coding to their signals.

80) Retail shops use anti-pilferage devices (the hoops that are to either side of their doors) which operate in the USA between 510 and 1705 kHz. The goods to be protected have a small label stuck on them that resonates at the appropriate frequency and disturbs the field produced by the hoops, allowing detection. It was found that heart pacemakers were susceptible to the anti-pilferage fields, so pacemaker manufacturers had to improve their designs to make them less susceptible.

81) There used to be a lot of problems with light dimmers interfering with AM broadcasts. The manufacturers added suppression to their products to satisfy customers and maintain sales levels (and not because of any regulations or standards).

- 82)** A plywood laminating machine in Kentucky used 1.6 MW at 6 MHz to speed up the drying of the laminating glue. Operators removed a door which had a perforated metal screen so that they could see the inside of the machine better – subjecting themselves to hazardous levels of RF field. (Incidentally, Art claimed that more RF energy is used world-wide in manufacturing, for processing materials, than is used in broadcasting.)
- 83)** Diathermic knives are electro-surgical units used by surgeons to cut tissue whilst sealing blood vessels using RF energy. Although they pass the FCC limits of 10 $\mu\text{V}/\text{m}$ at 1 mile distance, they can generate 1000 V/m (1kV/m) at the surgeon’s head.
- 84) Mobile phones can cause interference to aircraft electronics**
Evidence of interference to aircraft had been anecdotal, with many reports by pilots suggesting that mobile phones were the source of the problem. The UK’s Civil Aviation Authority (CAA) safety regulation group conducted tests on the ground on a Virgin Atlantic 747 and a British Airways 737.
The conclusion was that “transmissions made in the cabin from portable telephones can produce interference levels that exceed demonstrated susceptibility levels for aircraft equipment approved against earlier standards.” Faults attributed to mobiles included noise of the flight crew headsets and false triggering of warning signals, which could have a ‘cry wolf’ effect meaning crews might ignore a real warning.
(*Electronics Weekly, May 31 2000, page 2, www.electronicweekly.com*)
- 85) CATV system re-radiates interference**
In a recent radio interference case, a cable television (CATV) system was found to be causing radio interference. Upon investigation it was found that this was due to the CATV system picking up the interference from a buried cable in a parallel duct (and re-radiating it).
(*Peter Kerry, “EMC in the New Millennium” IEE Electronics and Communications Engineering Journal, April 2000, Page 47, www.theiet.org.*)
- 86) Fluorescent lamps can interfere with mobile phones**
People have learned to live with problems such as their mobile phone not working near the fluorescent light.
(*Peter Kerry, “EMC in the New Millennium” IEE Electronics and Communications Engineering Journal, April 2000, Page 47, www.theiet.org.*)
- 87) Spikes can cause insulation breakdown even at low levels**
I was intrigued by the article by Prof. Yacamini *et al.* Relating to overvoltages at the terminals of downhole pumps supplied by variable speed drives (February 2000 PEJ, p.29). In the 19602 there was a series of faults on a group of cross-bonded 132 kV cables in the London area which were never satisfactorily explained, despite extensive on-site measurements using foils embedded in the joints, the last fault occurring shortly after the measuring instruments had been disconnected. These faults were located in joints at about one-quarter or half-way along the routes, successive faults occurring at the same joints, despite very careful repair by an experienced cable joiner. No serious overvoltages were measured.
Much investigation into surge voltages on cables and overhead lines has shown how steep-fronted waves can impose overvoltages, particularly at discontinuities such as exist at motor terminals. The continual overstressing of insulation by the spikes every half-cycle can lead to progressive failure, even if the overvoltage is not sufficient to cause immediate breakdown.
(*H. J. Langley, Letters to the Editor, IEE Power Engineering Journal, April 2000, page 48, www.theiet.org*)
- 88) Aluminium smelter’s underground cables interfere with power metering**
Working for Ferranti in the mid 1970s, we had a problem with the power metering in a power station near Loch Lomond. Every now and again (once every few weeks) we got totally ridiculous readings. Neither the readings or their occurrence was predictable or consistent. We tried various earthing schemes and surge suppression, but then discovered that there was an

aluminium smelter close by – and its huge power cables ran 3 feet underground the power station’s control room. The fields from these cables were powerful enough to magnetise wristwatches. The problem was solved by filtering the electronics of the kWh meters.

(From *Dave Dunn, Senior Applications Engineer, IMI Norgren, Manchester.*)

89) US\$1.5 billion computer downtime caused by power quality problems

In 1994, studies revealed that the total cost of computer downtime to U.S. businesses had climbed to an all-time high of over \$3 billion. “Power-related problems” was the number one cause of computer downtime, amounting to over 45% of occurrences and resulting in losses of \$1.5 billion. Many of the power-related problems could be traced to the most basic element of the computer network: the wiring and grounding of the host building.

(From *“Networking Equipment and Downtime: Caught in the Middle” by Tony DeSpirito, Electronic Design magazine, April 1997, pp 42-48. We wonder what the 1999 figures were.*)

90) xDSL technologies could increase radio noise floor

Recent developments in broadband data access methods over existing telephone or mains wiring will cause unintentional RF emissions which may adversely affect the established radio noise floor.

(From report AY3525 produced by York EMC Services for the Radiocommunications Agency on the effects of ADSL, VDSL, and power line technology such as HomeLAN. This and many other interesting documents may be found by hunting around the (legacy) Radiocommunication Agency’s website hosted on Ofcom’s site at: <http://www.ofcom.org.uk/static/archive/ra/rahome.htm>.)

91) Electromagnetic ‘bombs’ – the perfect weapons?

It sounds like the perfect weapon. Without fracturing a single brick or spilling a drop of blood, it could bring a city to its knees. The few scientists who are prepared to talk about it speak of a sea change in how wars will be fought. Even in peacetime, the same technology could bring mayhem to our daily lives. This weapon is so simple to make, it wouldn’t take a criminal genius to put one together and wreak havoc. Some believe attacks have started already, but because the weapon leaves no trace it’s a suspicion that’s hard to prove.

The perfect weapon is the electromagnetic bomb. The idea behind it is simple. Produce a high-power flash of radio waves or microwaves and it will fry any circuitry it hits. At lower powers, the effects are more subtle: it can throw electronic systems into chaos, often making them crash. In an age when electronics finds its way into everything bar food and bicycles, it is a sure way to cause mass disruption.

(From *“Just a Normal Town...” the cover story in New Scientist’s July 1st 200 issue, pp 20-24. The article goes on to quote a researcher who claims that modern computers and their systems are easier to crash with EM weapons than older models.*)

Seven examples of EMI from Anita Woogara. Items 92 to 98 below are taken from “Study to predict the electromagnetic interference for a typical house in 2010” by Anita Woogara, 17 September 1999. This and many other interesting documents may be found by hunting around the (legacy) Radiocommunication Agency’s website hosted on Ofcom’s site at: <http://www.ofcom.org.uk/static/archive/ra/rahome.htm>.

92) Hearing aids operate between 200 – 4000Hz. Manufacturers have to comply with the Medical Devices Directive and the IEC118-13 ‘Immunity of hearing aids from interference with cellular phones’. However, due to the interference experienced, it is not felt that these are adequate for those (hearing aid) users who also wish to use items such as mobile phones.

93) Mobile phones and passing taxi radios have been known to interfere with Anti-skid Braking Systems (ABS) and airbags, causing drivers to lose control of the car.

94) Railways cover most of the country and can pass quite close to residential buildings and hence affect the equipment inside them. Additional immunity constraints are placed on the users of information technology equipment in the near vicinity. However, it is unclear how suppliers know



that their users will be situated near railway systems. (*The study makes similar comments about tram systems, and the problem is their low-frequency magnetic field emissions.*)

- 95)** Mobile phones are becoming so popular that in America it is difficult for people to have a phone call without being cut off due to interference. This is leading to people suing mobile phone companies for not providing the advertised service.