

Electromagnetic Interference (EMI)

What it is, and why we are concerned about it

*14th National Biomedical and Clinical Engineering Conference,
14th October 2010, National Motorcycle Museum, Birmingham*



Eur Ing Keith Armstrong CEng FIET SMIEEE ACGI
phone & fax: +44 (0)1785 660 247
keith.armstrong@cherryclough.com

What is EMI ?

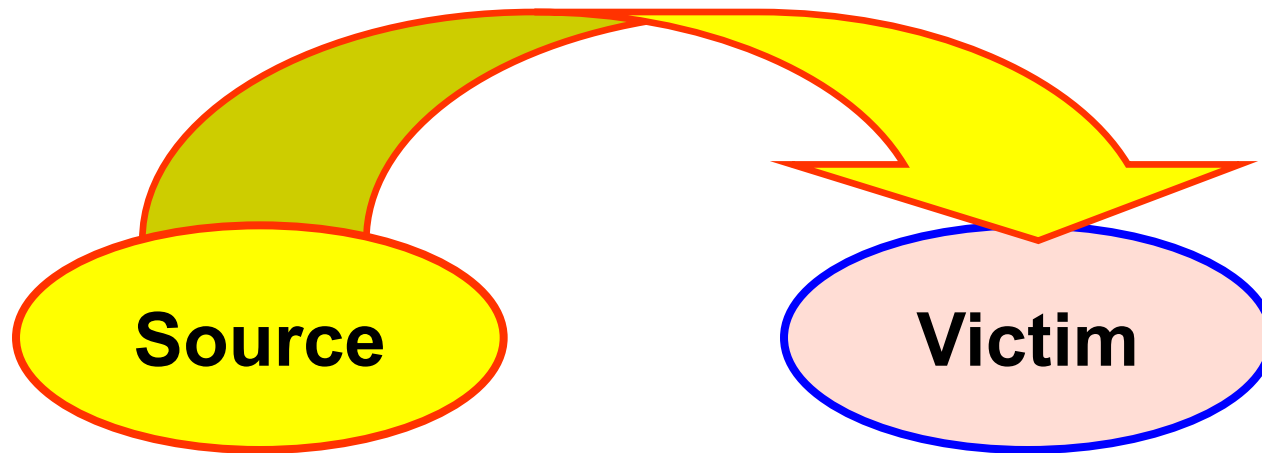
- **All electrical and electronic power and signals are *really* electromagnetic (EM) energy...**
 - one kind of EMI is when the noise in one circuit (e.g. the mains power supply)...
 - gets into an interconnected circuit (e.g. interfering with measurement, display or control)...
- **We call this *conducted EMI...***
 - and the 50Hz mains supply and safety earth systems are major pathways for it

But the EM energy does not all stay in the wires...

- they all “leak” their EM energy, emitting electric and magnetic fields into the air...
 - ◆ behaving as “accidental antennas”...
- and they pick up fields that are in the air, causing “noise” currents and voltages to appear in the wires
- We use this “antenna” behaviour for radio, TV, radiocomm’s, wireless telemetry, RFID, etc...
 - but when we don’t want it, we call it *radiated EMI...*
 - and it is generally worse when equipment and their wires are closer together

The three parts to every EMI event

- A source of EM energy (any electrical/electronic equipment, radio transmitter, electrical power distribution, etc.)
- An EMI victim (any electrical/electronic equipment)
- And at least one EM coupling path between them



- The control of EM emissions, coupling, and immunity is called EMC (electromagnetic compatibility)

Four types of EM coupling can occur singly, or in any combination

- **1 Common impedances**
 - all metalwork and conductors have impedance (e.g. metal structures, chassis, cables, PCB tracks, etc.)...
 - so when carrying a current due to one electrical or electronic circuit they develop a voltage ('noise')...
 - ◆ that can interfere with *other* circuits that are connected to the same metalwork or conductors
 - one consequence is that there can never be a perfect 'earth' or 'ground'...
 - ◆ so 'safety earths' can't prevent EMI, and in fact they are one way in which EMI spreads around a site

Four types of EM coupling

continued...

- **2 Electric (E) fields**
- 3 Magnetic (H) fields**
- 4 Electromagnetic (EM) fields**
 - **these all radiate through the air, and through other insulators such as plastic, wood, glass, etc...**
 - **coupling EM energy into *all* metalwork and conductors (metal structures, chassis, wires, cables, PCB tracks, etc.)...**
 - ◆ **inducing ‘noise’ currents and voltages into them...**
 - **which can then interfere with the electrical or electronic circuits they are connected to**

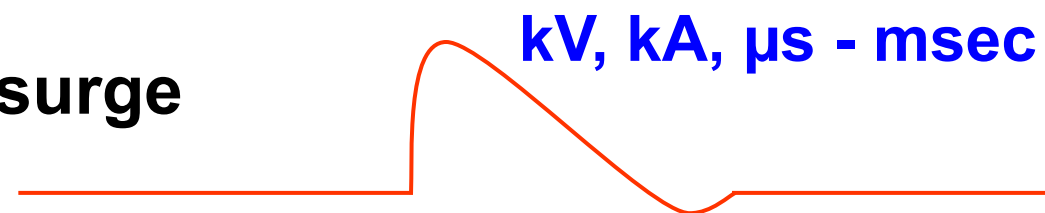
EM phenomena that couple into *all* metalwork and conductors

(metal structures, chassis, wires cables, PCB tracks, etc.)

■ Over-voltage transients and surges

from thunderstorms; fuses and circuit-breakers opening; and switching inductive loads such as motors (e.g. in pumps, fans, beds, tables, valves, etc.), solenoid valves, relay coils, etc...

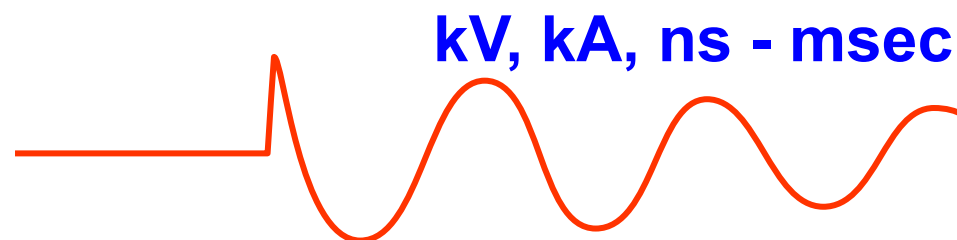
– example of unidirectional surge



– example of 'oscillatory wave'



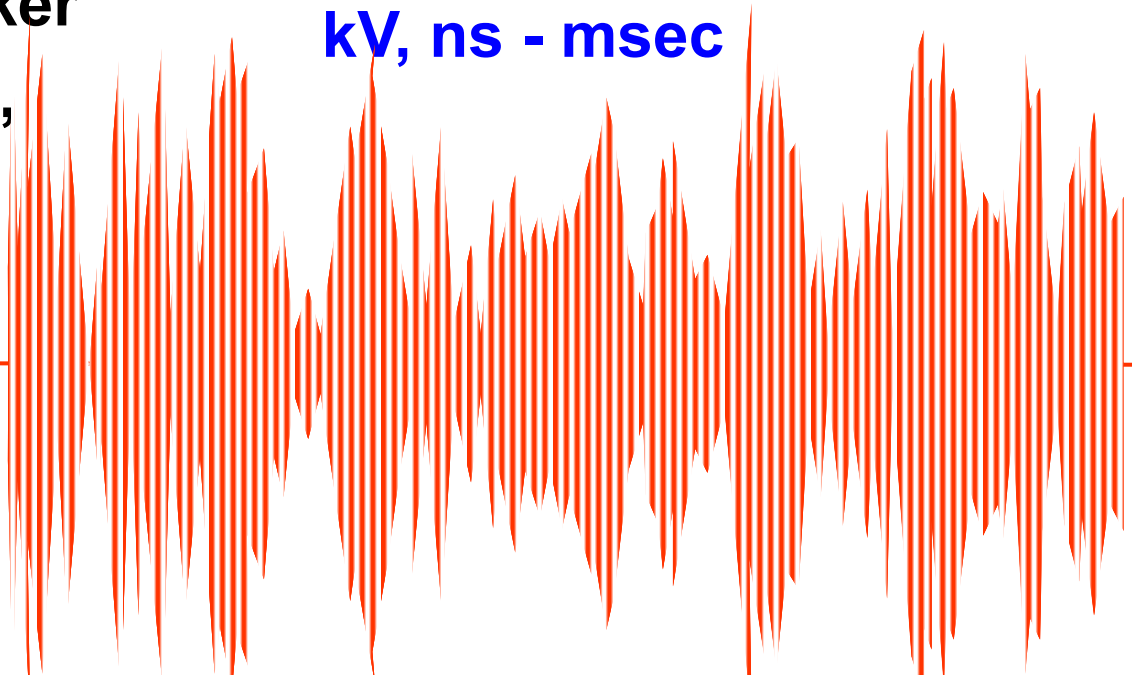
– example of 'ring wave'



EM phenomena that couple into *all* metalwork and conductors continued...

- **Fast transient overvoltage bursts, caused by any/all arcs and sparks....**
 - e.g. caused by switches, relays, contactors, motor commutators, poor connections, insulation breakdown, fuse and circuit breaker opening, arc welding, etc.

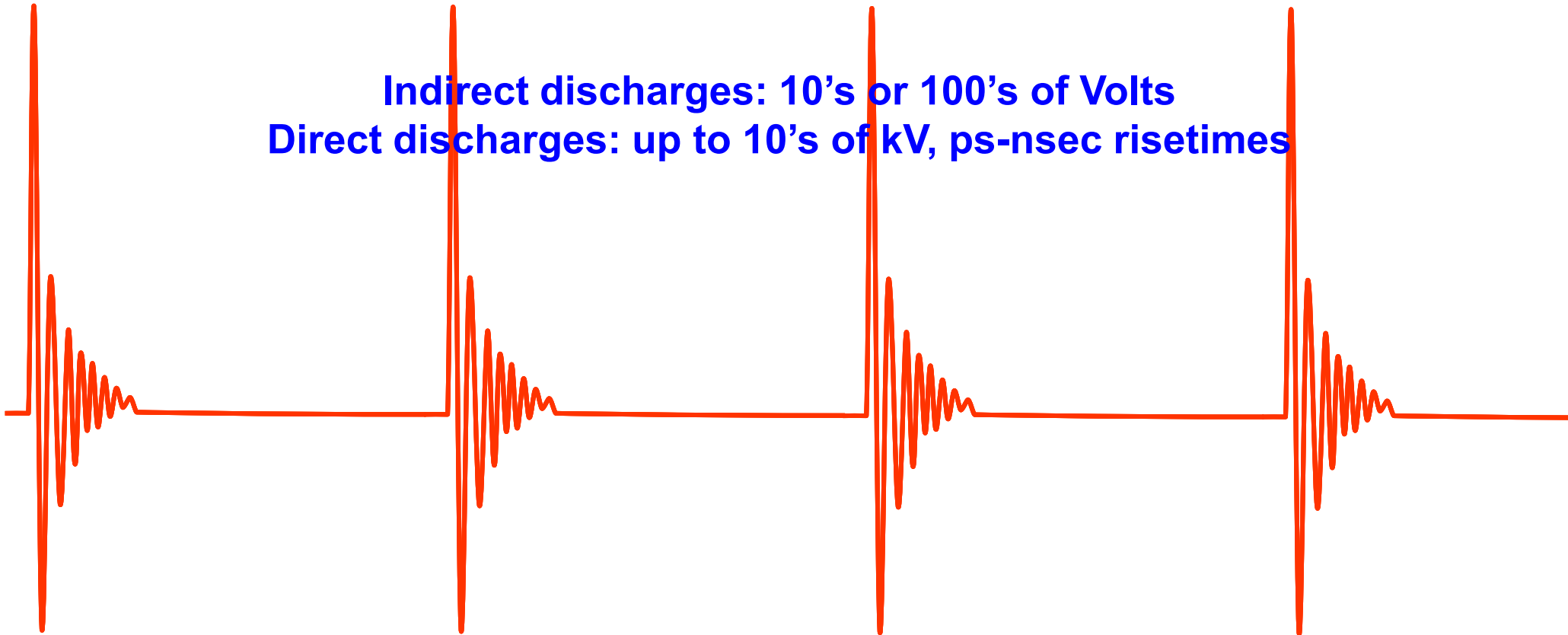
kV, ns - msec



EM phenomena that couple into all metalwork and conductors continued...

- Very fast transient overvoltages, usually caused by electrostatic discharges

Indirect discharges: 10's or 100's of Volts
Direct discharges: up to 10's of kV, ps-nsec risetimes



EM phenomena that couple into *all* metalwork and conductors continued...

- **Low frequency voltage and current noises at the mains frequency and its harmonics (from AC-DC rectifiers, fluorescent lamps, etc.)...**
 - plus noise at *other* low frequencies caused by electrical power use, especially by variable-speed motor drives, electric traction (trams, trains, electric vehicles, etc.)

Up to 10's of volts continuously, possibly kV during electrical faults



EM phenomena that couple into all metalwork and conductors continued...

- Radio frequency (RF) noise voltages and currents from radio/TV broadcasts, radars, diathermy, electrosurgery, coagulators and cautery, switch-mode power control, variable-speed motor drives (pumps, fans, centrifuges, etc.)...
 - plus *nearby* cellphones, walkie-talkies, Wi-Fi, wireless telemetry, RFID, computers, etc.

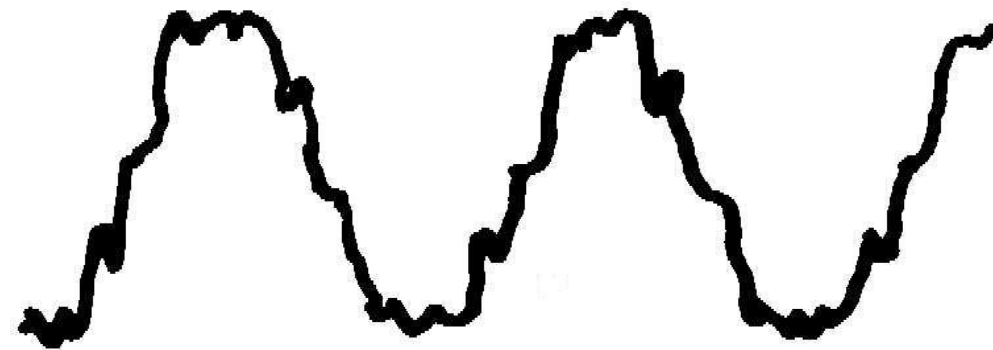
◆ often many frequencies at the same time

V, kHz - GHz



EMI issues concerning the quality of the mains power supply (“Power Quality”)

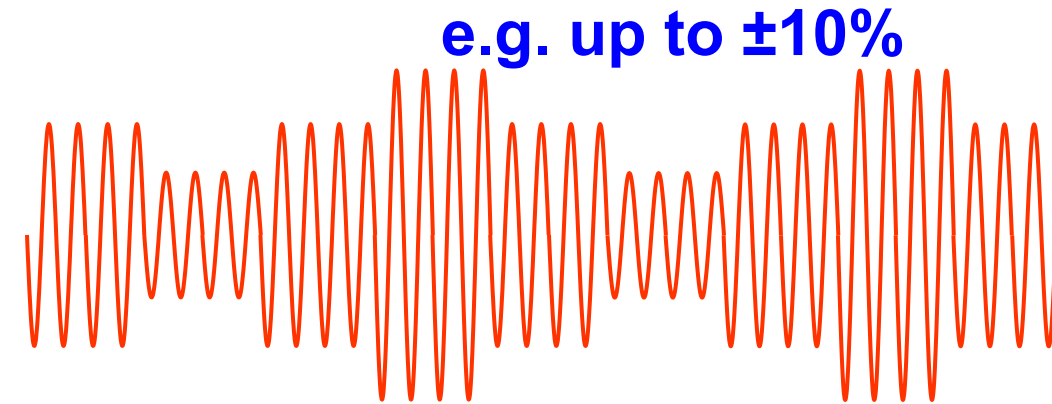
- **AC waveform distortion** (this example from Israel, 2000) **Up to 10% (possibly 30% on generator supply), 100Hz - 5kHz**



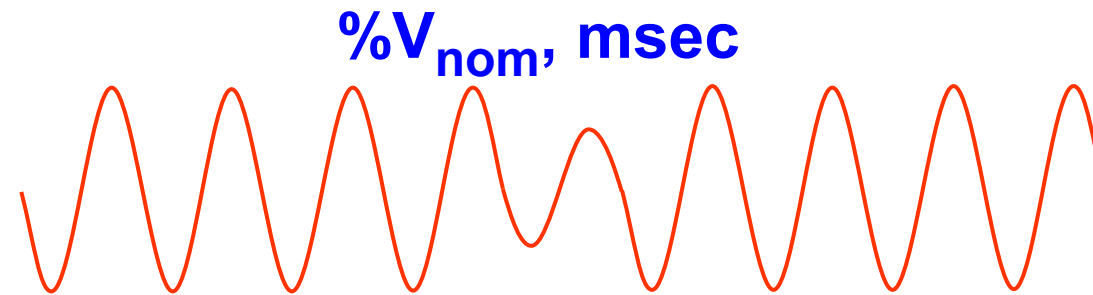
- the distortion can be *harmonic* mostly caused by AC-DC rectifiers and fluorescent lamps...
- and/or *interharmonic* (i.e. not related to the mains frequency) mostly caused by variable speed motor drives (pumps, fans, centrifuges, etc.)

Some more Power Quality issues...

- **Rapid fluctuations** caused by rapid fluctuations in the load



- **Voltage dips and flicker** from network control and fault-clearance

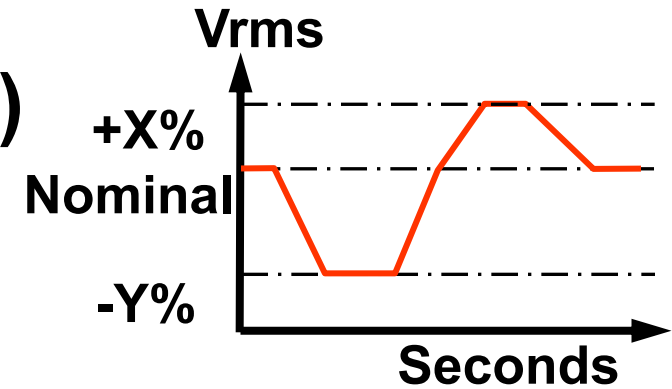


- **Dropouts / interruptions** from network protection and fault-clearance

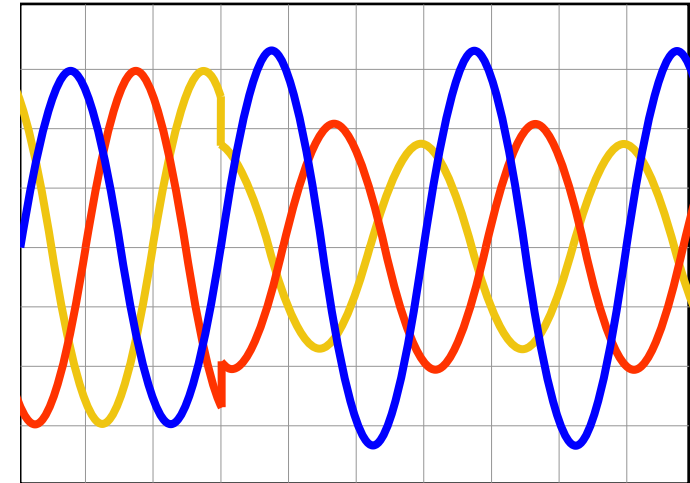


Some more Power Quality issues...

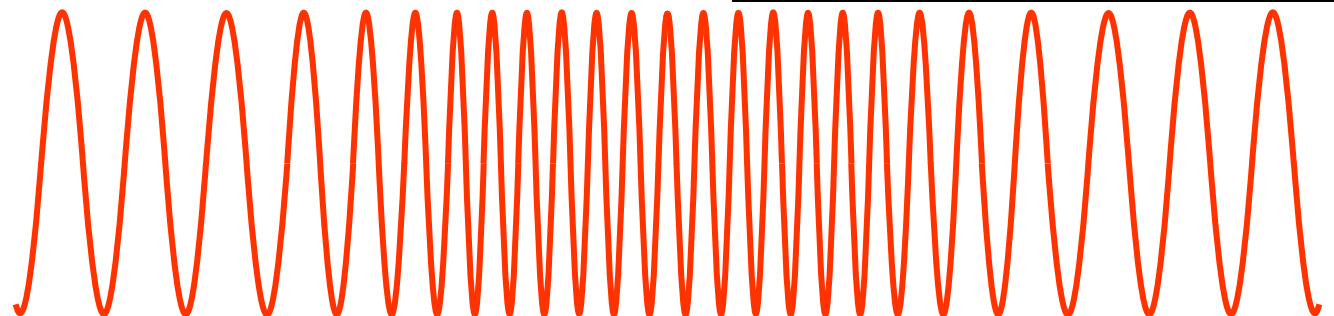
- **Slow variations (sags and swells)** caused by load variations



- **Three-phase voltage unbalance** caused by unbalanced loads, faults, etc.



- **Frequency variations** caused by significant load fluctuations on the generator



EMI Victims: *Analogue devices*

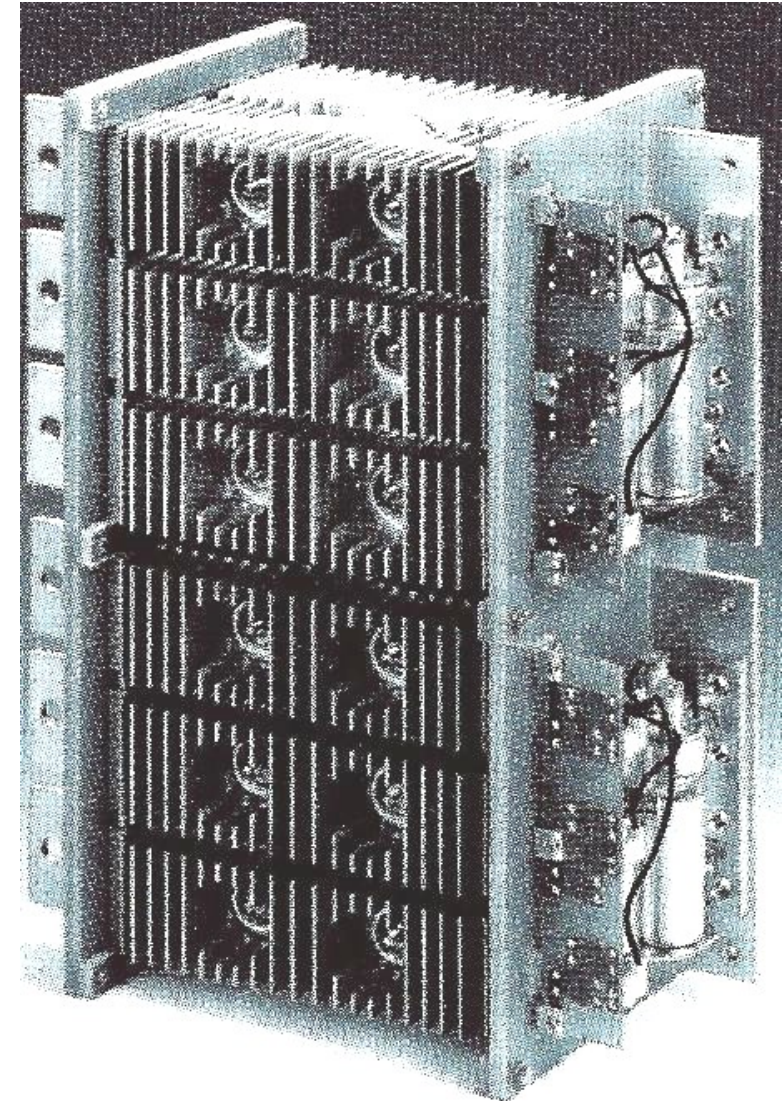
- **Suffer from signal distortion and zero-shift errors (up to full-scale), causing problems when measuring...**
 - pulse rate, temperature, other physiological parameters, nerve impulses, chemical reactions, sound, light, colour, pressure, weight, flow rate, angle, level, position, velocity, acceleration, etc.
- **Electron-beam devices (photomultipliers, cathode ray tubes, etc.) suffer image distortion**
- **Analogue devices are easily destroyed by overvoltages, especially from surges and ESD**

EMI Victims: *Digital devices* **(including the software that runs on them)**

- **When the EMI's magnitude passes a threshold, a variety of operational malfunctions can occur...**
 - **false key-presses; errors in datacomm's and control (video noise, operational errors (e.g. drug pumps), etc.)...**
 - **incorrect software operation (e.g. continually repeating an inappropriate activity)...**
 - **stopped operation (e.g. a 'freeze' or 'crash')...**
 - ◆ **which can cause control outputs to assume states that can have undesirable or unsafe consequences...**
 - **and they are very easily destroyed by overvoltages**

EMI Victims: Power semiconductors

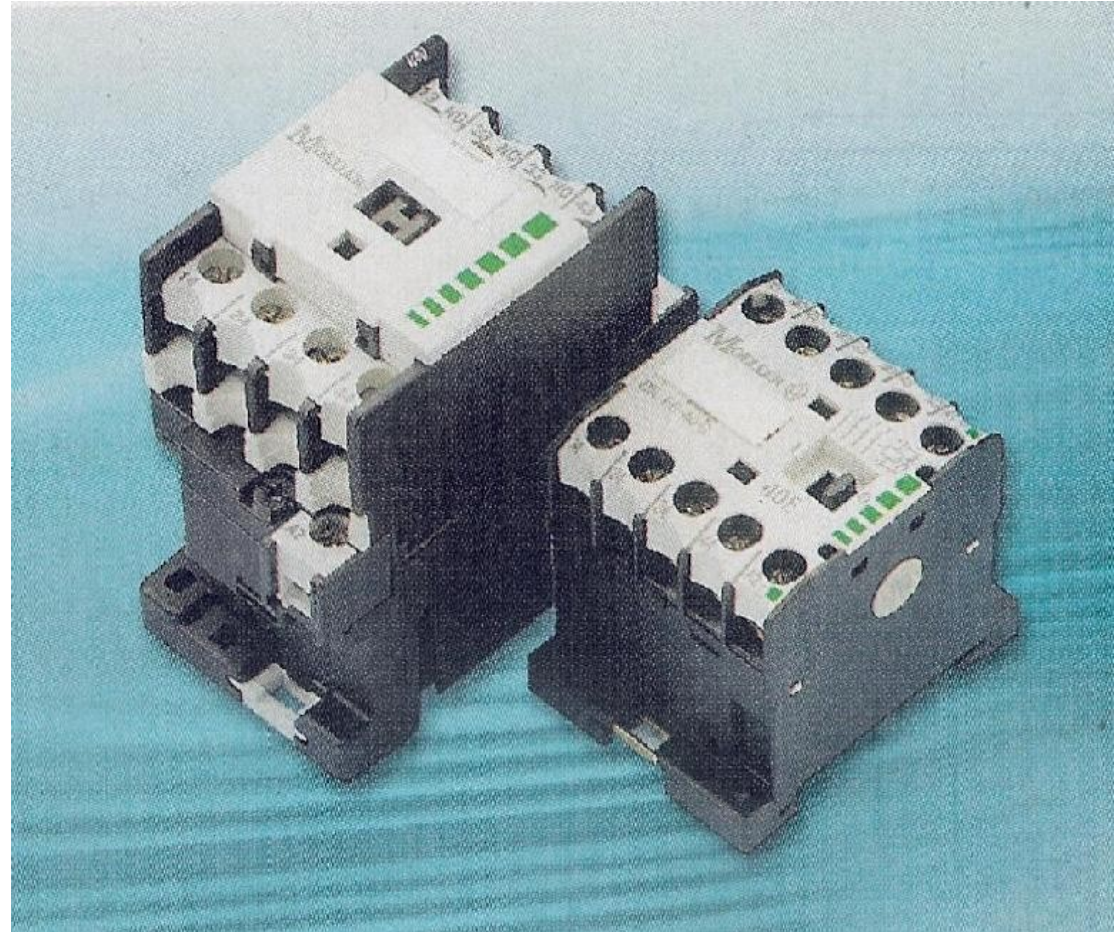
- **Permanent damage can be caused by overvoltages...**
 - ◆ surges, fast transients, ESD...
 - and also by overcurrents
- **Control terminals could be triggered at the wrong time...**
 - by interference with a microprocessor
 - causing malfunction, and/or actuation of protective devices, and/or damage



A module-type 'stack' from Eupec

EMI Victims: *Electromechanical devices*

- E.g. relays, contactors, solenoid valves, motors, etc...
 - which many designers seem to assume are totally immune to all types of EMI



Some 'contactor relays' from Moeller

EMI Victims: *Electromechanical devices* continued...

- **But dips and dropouts in the AC supply can cause relays, contactors and solenoids to ‘drop out’...**
 - individually – depending on type, age, and temperature...
 - ◆ and can stall motors...
 - and in some situations they may not return to original operation after the dip or dropout
- **Shock and vibration can make switch contacts ‘chatter’, causing sparking...**
 - causing RF noise that can interfere with electronics

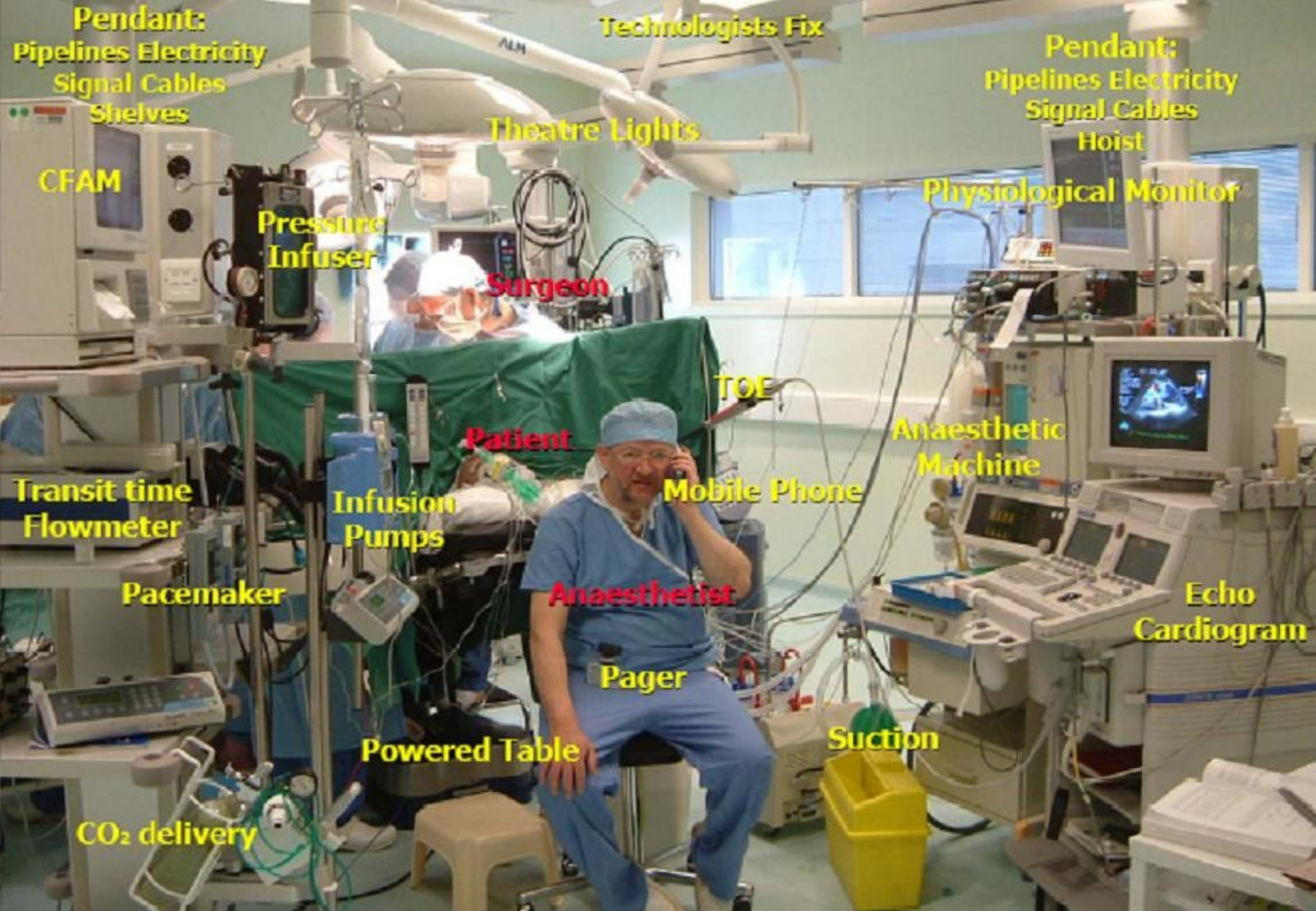
EMI Victims: *Electromechanical devices* continued...

- **Overvoltages due to lightning surges can make open contacts spark-over...**
 - which is the same as closing them momentarily...
 - ◆ applying power to circuits which should be off

- **And lightning surge currents can ‘weld’ contacts together, so that they won’t open...**
 - even when their mechanical armature has switched...
 - a problem for most switches, relays and contactors...
 - ◆ because they don’t use positively-guided or forced contacts, or feedback their contact position

The medical environment can offer many opportunities for EMI

- **As we can see from this photograph of an operating theatre in typical use...**
 - **provided by Dr David H T Scott (the guy on the phone),
Pask Certificate of Honour,
Consultant Cardiothoracic Anaesthetist
and Intensive Care Specialist
Department of Anaesthetics,
The Royal Infirmary of Edinburgh, EH16 4SA
Mobile 07788 415 489**
 - ◆ **who retains the copyright**



Pendant:
Pipelines Electricity
Signal Cables
Shelves

Technologists Fix

Pendant:
Pipelines Electricity
Signal Cables
Hoist

Theatre Lights

CFAM

Pressure
Infuser

Surgeon

Physiological Monitor

Patient

TOE

Anaesthetic
Machine

Transit time
Flowmeter

Infusion
Pumps

Mobile Phone

Pacemaker

Anaesthetist

Echo
Cardiogram

Pager

Powered Table

Suction

CO₂ delivery

Conclusion

- **The hospital environment contains many sources of EMI, and is constantly getting worse (e.g. RFID)...**
 - **and also contains a great deal of electronic equipment that is susceptible to EMI...**
 - ◆ **and getting more susceptible as electronic devices evolve, and as complexity increases**
- **So it is very important to control EMI...**
 - **to achieve and maintain productivity targets...**
 - **and for the safety of patients, visitors, and medical personnel**

Electromagnetic Interference (EMI)

What it is, and why we are concerned about it

the end



Eur Ing Keith Armstrong CEng FIET SMIEEE ACGI
phone & fax: +44 (0)1785 660 247
keith.armstrong@cherryclough.com

Some useful references

- ***Assessing an Electromagnetic Environment***
Keith Armstrong, from the “Publications and Downloads” page at www.cherryclough.com
 - ***Note:*** this document was written to help with EMC Directive compliance, not for safety purposes

- ***REO (UK) booklets on EMC***
available via the “Publications and Downloads” page at www.cherryclough.com
 - as well as describing how to perform tests to the IEC/EN basic EMC test methods, these booklets describe the various types of EM disturbances, where they might occur, their possible magnitudes, and what effects they might have on electrical and electronic equipment