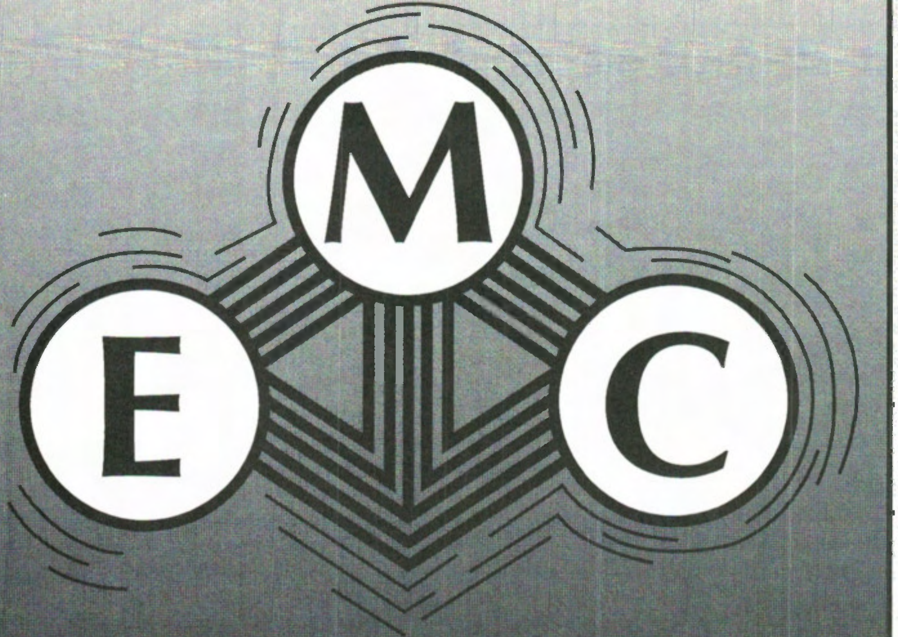

– an Extra Major Calamity?

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Part 1–Where We Are and How We Arrived There

EMC stands for 'electromagnetic compatibility', a mouthful which has a correspondingly complex official definition. What it boils down to, is that any piece of electrical or electronic equipment can potentially interfere with the operation of any other, but if they don't, then the two pieces are 'compatible'.

WHILE the interference problems are usually more evident if two pieces of equipment are close together, they could even be on opposite sides of the world. Consider, for example, trying to receive in Australia a short wave transmission from Britain on a frequency very close to that of a much higher-powered transmitter in France. To eliminate interference from the unwanted transmitter, you would need a receiver with good selectivity and good cross-modulation performance, because even a directional antenna would not be much help.

The Stone (or at least Crystal) Age

Interference problems between transmitters appeared even in the very early days of radio, because the simple receivers had poor selectivity and some types of transmitter, notably spark transmitters, produced signals of quite wide, and fairly uncontrolled, bandwidth. The situation became better and worse practically simultaneously, when triode valves were introduced in receivers. The valve provided the opportunity to obtain better selectivity through the use of more tuned circuits, less heavily damped by both signal source and load. However, the intentional or unintentional occurrence of RF positive feedback ('reaction' if it was intentional) both increased selectivity and made every receiver a potential, and all too often an actual, oscillator and transmitter.

Electrical Interference

Around 1930, the increasing use of radio for other purposes than broadcasting, and the increased use of electrical machines in industry and the home, led to the realisation that these machines could also cause serious interference with radio reception. Most of the trouble was due to sparking, and some of the early household equipment, such as food mixers and electric shavers, used motors or speed-control devices which generated very energetic sparks. This energy was barely constrained by tuned circuits, so it was radiated from the wiring over a very large bandwidth indeed (for those days), such as 10Hz to at least 30MHz, as measured on a vintage electric shaver before I threw it away. There was some attempt to reduce the spark energy, but this was designed simply to reduce the vaporization of the contacts, not to minimise interference.

First British Legislation

The intervention of the Second World War, bureaucratic inertia and very different political attitudes from todays, even in the post-war Labour government, delayed legal controls on electrical interference in this country until the 1949 Wireless Telegraphy Act. The preservation of this early 20th century name for radio communication is sufficient evidence of the bureaucratic inertia aspect. This Act, which was quite controversial at the time, sought only to protect AM broadcasting on long and medium waves, and it was only after several more years, and increasing public agitation, that a legal requirement was introduced to require cars to be fitted with suppressors to reduce interference with Band 1 television transmissions (41·5 to 68MHz).

Voluntary Restraint and the German Dimension

During the 1960s and 70s, there was a gradual increase in both legal and voluntary control of potentially interfering emissions. One example of voluntary control was the agreement on limiting oscillator radiation from television and FM radio receivers, adopted by most major manufacturers in Europe to prevent interference between one receiver and another when the oscillator frequency fell within the reception band. However, during this time, the German government, prompted by the German Post Office, introduced very stringent controls on emissions from all kinds of electrical and electronic equipment, partly justified by the post-war restrictions on the number and power of their broadcast transmitters. These controls, incidentally, had the effect of defending the German electronics industry against foreign competition, but of course, that was regarded by the authorities as a regrettable necessity.

First Steps by the EEC

By the early 1970s, the politicians of the EEC (as it then was) realised that the different laws on radio interference in the members states represented a considerable technical barrier to trade, something the Treaty of Rome was supposed to get rid of. They therefore introduced two Directives, one on radio interference from household appliances, and one specifically on interference from fluorescent lamps. These Directives were based on CISPR 14 and CISPR 15, two international performance standards for emissions, produced by CISPR (Comité Internationale Spéciale des Perturbations Radioélectriques, a subsidiary body of the International Electrotechnical Commission, or IEC). Directives of this kind are not themselves laws, but the member states are required to bring them into force in terms of their own laws, so that, in theory, the laws are the same over the whole Community (take no bets on this!). The technical requirements of the standards were, with some changes, included in the Directives themselves, and this proved to be a BIG mistake, because all standards are frequently revised. This is not (contrary to legend) because the standards bodies want to keep selling new versions, but because electrical and electronic science and engineering are still evolving rapidly. It takes long enough to revise a standard, but when it comes to revising legislation, we are talking decades.

A 'New Approach'

Faced with this problem (which industry had been telling them about for some years), the EEC launched the concept of 'New Approach Directives', which would set requirements only in very general terms, and allow equipment manufacturers to rely on standards to prove that their equipment satisfied the detailed technical requirements. This cleared the way for a new and far more comprehensive Directive on radio interference, which has become known as 'the EMC Directive', even though it is not the only, and certainly not the first, Directive concerned with this subject. It was published in 1989, and was due to come into force on 1st January 1992. But, it was found essential to introduce a four year delay so that equipment manufacturers could redesign, or make new products, meeting the requirements of the Directive. So now it comes into force on 1st January 1996, although the industry in general (but not, of course, Maplin Electronics plc) is still far from ready. Computer manufacturers are pleading for another five years of development before they can cope with some of the requirements.

The CB Radio Problem

The rash of interference complaints which arose when CB radio equipment began to flood into Europe, led to another aspect of EMC being brought to wide notice. There had been problems of this nature before, right back to the restarting of television broadcasting after the Second World War, and some spectacular accidents, involving many fatalities, in the military field. The problem is that a piece of equipment may be overly-sensitive to a perfectly legitimate radio signal or electric, or magnetic field. This is known as susceptibility or 'lack of immunity'. In the early days of post-war television, many receivers were 'wide open' to legal amateur radio transmissions, which often fell in the IF band of the receiver. Although the Post Office (which was then in charge of such matters) would help if the problem was technically soluble, if it was not, the amateur was simply shut down, and told not to transmit on that band or bands.

The problem came up again with CB radio, especially the illegal AM variety, because many television receivers were overly sensitive around 27MHz, and they now have to meet requirements in this respect (standard BS905-2/EN55020). The result of these problems was that the 1989 Directive not only seeks to control emission of potentially interfering signals, but also requires attention to the achievement of an adequate degree of immunity.

European Standards

The standards which are intended to support the Directive are standards prepared or adopted by the European standards bodies CENELEC, ETSI and CEN. We need not be concerned with the latter two, because they deal with telecommunications and non-electrical matters (except automobile electronics), respectively. When CENELEC looked at the standards available to support the EMC Directive, it was concluded that none of them were satisfactory and all would have to be revised. This took (and is still taking!) an enormous amount of time, because it is easy to agree a standard if conforming to it is voluntary, but if you might go to jail if your product does not conform, you are likely to be much less willing to agree.

The Export-market Question

The situation is complicated, because some EU countries see the EU as almost their sole export market, and will, therefore, settle for purely European standards, while others, including Britain, want to trade worldwide and do not want to have to make different versions of products for different countries. They thus want European EMC standards to be as close as possible to the international standards produced by IEC and CISPR, preferably identical. There is a further dimension introduced by some countries for what can only be politely described as philosophical reasons. This involves thinking of all the possible (and sometimes, it seems, extremely quasi-possible) EMC effects that could occur, and then insisting that all equipment meets requirements for these effects (usually called 'phenomena', which indicates the type of approach), whether there has ever been an actual reported case of such interference or not. For example, the mains supply voltage waveform is not usually precisely sinusoidal – it contains harmonic distortion. These harmonics can, it appears, cause problems to very large electric motors. OK – there is provision in the standards system so that motors can be tested for this effect, but some countries want *everything* potentially subject to similar testing, even though the result is virtually certain to be 'no effect'.

Scope of the Directive

The Directive applies to ALL manufactured electrical and electronic equipment offered for sale or used for the first time in the EU after 31st December 1995. Some equipment, of course, is not 'manufactured' – anything you make at home for your own use. Kits, however, are regarded as 'manufactured', and Maplin has to ensure that a sample made-up kit of each type meets the relevant requirements of the Directive. Again, some equipment is incapable of producing significant emissions or of being unduly lacking in immunity, such as a torch. A digital watch is sometimes quoted as another example, and emissions are indeed almost undetectable, but a badly-designed watch could well misbehave under the influence of an RF field.

Home-constructed Equipment

This does not mean that anything you make at home can freely interfere with anything else. There are two aspects to this. The Directive refers to the definition of 'radio amateur' in the ITU Radio Regulations. Home-constructed equipment for amateur radio use is definitely outside the Directive, presumably because the licence legislation can be used to control any cases of interference. However, much home-constructed equipment is not for 'amateur radio'; it may be a computer peripheral, a security system, or any one of the hundreds of applied electronics projects brought to you by this magazine. It was suggested to the British Department of Trade and Industry (DTI, which is the government department responsible for implementing the Directive in this country), that all home-constructed equipment should be treated in the same way, but this was not accepted. It *appears* (and it is virtually impossible to obtain clear rulings on such matters) that home-constructed equipment which causes interference, and is not for 'amateur radio' use, would be dealt with under the old Wireless Telegraphy Act legislation, part of which is not being repealed. However, the DTI does assure everyone that there are no plans to recruit 'EMC Police' to go around looking for minor violations of the rules, and, apart from pirate radio stations, whose owners and operators are considered to have had fair warning already, any violations that do come to notice will first be dealt with by 'advice', and only if the advice is ignored and the offence is repeated, will serious action (prosecution of offenders) be undertaken.

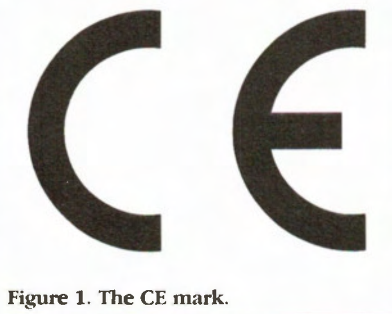


Figure 1. The CE mark.

Trading Standards and the CE Mark

Products made in large numbers and sold in shops will be investigated by Trading Standards officers. In order to show that a product is claimed by the manufacturer to meet all the EU Directives that apply to it, a special 'mark' has been devised, and it even has its own Directive, the 'CE Marking Directive'. The mark is shown in Figure 1, and in many cases, it will appear on the product itself, *but this is not compulsory*. It could be on the carton or in the instruction book, for example. The CE mark is NOT a product quality mark, unlike the BSI Kitemark, it is simply supposed to show that the product can legally be sold, and be transported across national borders, in the EU.

You may already have seen the CE mark on toys, because it is required by the Toys Directive to be shown. What has actually happened is that the mark has simply been added by some manufacturers in the Far East 'across the board' to everything they make. Indeed, the fact that a toy is produced by an unscrupulous manufacturer and is actually dangerous, makes it more likely that the manufacturer just adds the CE mark without doing anything to improve the toy. Much of industry warned that the CE mark scheme would not work, but the EU bureaucrats have to find out the hard way, thereby wasting millions of our taxes.

EMC and Unfair Competition

The concept of the wide-ranging EMC Directive was 'sold' to some politicians with the aid of scare-stories about industrial robots running wild, driverless trains failing to stop and aircraft falling out of the sky. Now, it is certainly true that any or all of these things *could* happen, but it is hardly a justification for all that the Directive can imply. It bears down particularly hard on the smaller manufacturers, whose sales volume is not large. For them, the cost of testing sample products to make sure that they conform to the requirements of the relevant standards has to be spread over fewer unit sales, so that their products tend to become priced out of the market. Again, the manufacturer who skimps on testing, trusting that he will not be caught, can offer lower prices, at least for a while.

Double Whammy

In fact, the EU has dealt manufacturers a 'double-whammy', by extending the CE marking scheme to the Low Voltage Directive, which seeks to ensure that all electrical and electronic products are adequately safe in respect of electric shock, explosion due to discharge of stored electrical energy, fire and excessive temperature, ionising radiation (X-rays from cathode-ray tubes), laser radiation, chemical hazards from batteries and other components (such as RF transistors that contain toxic beryllium oxide) and mechanical hazards (tipping over, or injury from moving parts). The Low Voltage Directive (LVD) has been in force for several years, but from 1st January 1997, the attachment of the CE mark is a specific claim by the manufacturer, not simply that the product conforms to the EMC Directive requirements and is 'safe' in terms of the LVD, but that it *conforms to the requirements of the relevant European safety standard*, which could be a very different matter. Some Maplin products come within the scope of EN60950, which is basically aimed at computer equipment, but most should conform to EN60065, basically aimed at radio and television equipment. In the case of security systems, there is an as yet unresolved dispute: the European manufacturers have chosen to follow EN60950, but there is a body of opinion that says that EN60065 is more appropriate, especially for DIY systems.

EMC Phenomena

Out of the endless list of theoretical possibilities, we can select some emissions which are most likely to cause interference, and some disturbances which are likely to show up inadequate immunity. A large number of the emissions and disturbances are effects which come with the mains supply. There are two reasons for this: first, there is a Directive, and an associated standard, EN50160, controlling the quality of the mains supply, and the electricity supply industry is naturally keen to ensure that anything that this standard allows to be delivered with the 50Hz will not result in equipment misbehaving. The second reason is that (apart from in the military world) EMC problems other than radio interference were first made subject to a formal standards-based attack by the industrial electrical and electronic controls industry, which was in the process of producing the multi-part international standard IEC801, when it was 'hijacked' to be converted into part of the even more massive main IEC standard on EMC, IEC1000. This industry sector found that spurious signals on the mains supply were a major source of immunity problems, and another was electrostatic discharge, so these are very prominent in the list of phenomena.

Emission Phenomena

Figure 2 shows a diagram of emissions from equipment. Descriptions of the various types of electromagnetic emissions follow:

Radiated RF energy: according to the basis of the Directive, this should be subject to limits over the whole frequency range from 9kHz to 400GHz, but in practice, only the range 30MHz to 1GHz is controlled for most types of equipment. This is partly due to the difficulty of making repeatable measurements outside this frequency range.

Conducted RF energy: the problems with measuring radiated energy at lower frequencies are dealt with by measuring conducted emissions on the cables connected to the equipment, since these are the main source of lower-frequency emissions in the range 150kHz to 30MHz. The most important cable is the mains lead, because once the RF energy gets into the wiring in the building, it can and does go anywhere, notably next door, so that nice Dr. Jekyll at No. 6 very soon becomes nasty Mr. Hyde! For most equipment, too, the mains lead is the longest lead connected to it.

There are two sorts of radiated and conducted RF: *continuous* and *discontinuous*. Continuous disturbances are generated by devices such as clocked logic, phase-controlled dimmers, and anything that continually produces fast-edged waveforms. Discontinuous interference is produced in more-or-less isolated bursts, by switches, thermostats and programmable timers, for example. Different methods have to be used to measure the two kinds of disturbance.

Magnetic field: mains transformers, for example, emit magnetic fields with the main component at 50Hz, often with strong harmonics at 150 and 250Hz. This can be a serious problem with rack-mounted equipment and stacked Hi-Fi, particularly since cassette-deck heads are specifically designed to pick up magnetic fields. Electricity (kilowatt-hour) meters are particularly 'good' emitters.

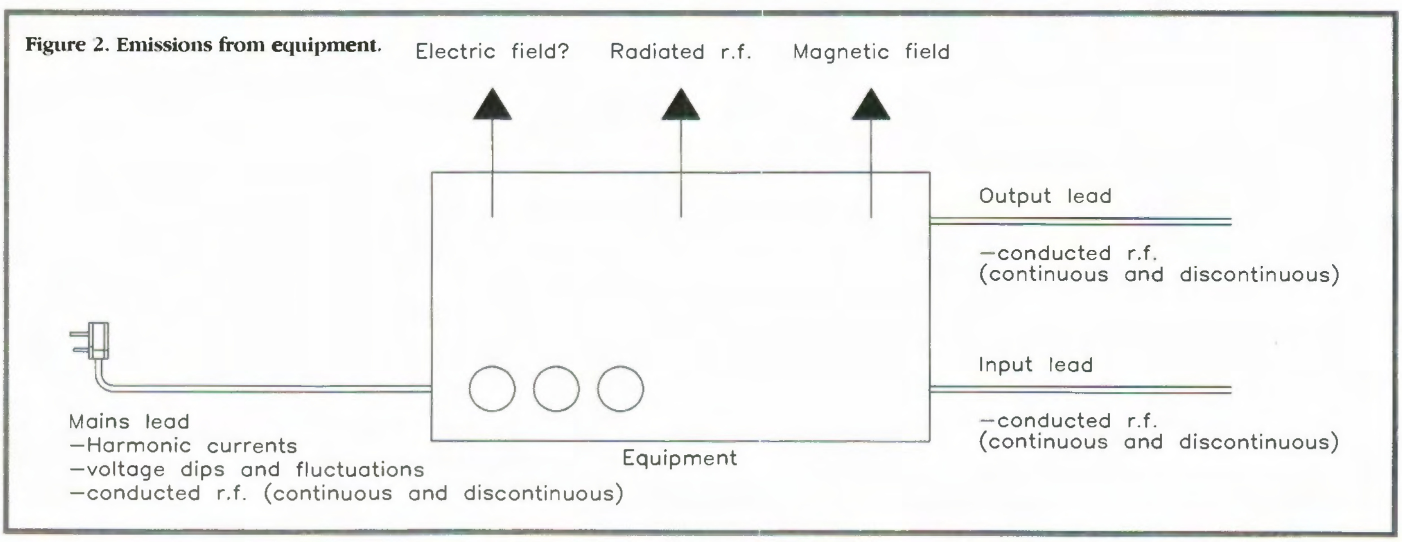
Electric field: there are not many sources of significant electric fields, apart from high-voltage power lines and electric fencing.

Mains harmonic currents: it may seem strange at first to refer to currents at harmonics of the mains frequency as emissions, but they are. While motors and other devices can produce such harmonic currents, the most significant for *Electronics* readers is the DC power supply. Irrespective of whether it is a 'linear' supply, with a mains transformer, or a switch-mode supply with a rectifier connected directly to the mains, if it includes a reservoir capacitor, it draws current from the mains supply in the form of a narrow pulse nearly centred on the peak of the voltage waveform (see Figure 3). There was a full analysis of this in my series on power supply design (*Electronics* Issues 48 to 50), but for now, we just note that any short current pulse can be broken down into a current at the fundamental frequency plus a series of currents at harmonic frequencies – integral multiples of the fundamental frequency. For most purposes, it is not the harmonic currents themselves that matter, but the flattening of the peaks of the mains voltage waveform. In fact, one power supply which causes peak flattening makes life difficult for other power supplies, because their output voltages (or the input voltage to the regulator circuit if the power supply is regulated) depend on the peak voltage of the mains supply, and this is exactly what is being squashed down.

An extreme case of mains harmonic current disturbance concerns half-wave rectification directly from the mains supply, which was very common in radio and television receivers between 30 and 40 years ago. This technique results in strong zero-order harmonic currents, or plain old DC, which is very effective in saturating the core of the sub-station transformer. Apart from getting very hot, the transformers used to produce very loud buzzing noises, and more than one actually exploded. Direct half-wave rectification is, therefore, now banned except in a few special cases.

Mains voltage dips and fluctuations: while the source impedance of the mains supply is very low, as you find out if you short-circuit it, the value is not zero. This is why the current pulses drawn by rectifiers flatten the peaks of the voltage waveform. So, if the current drawn by a piece of equipment varies a good deal, over periods from about 30ms to 1s, the resulting variations in the supply voltage make the lights flicker, and this can be very annoying. Such problems mostly occur with domestic appliances such as washing machines, that have powerful heaters and motors that switch on and off automatically. Photocopiers can also produce this effect, and it is suggested that disco lights, too, are not innocent.

Figure 2. Emissions from equipment.



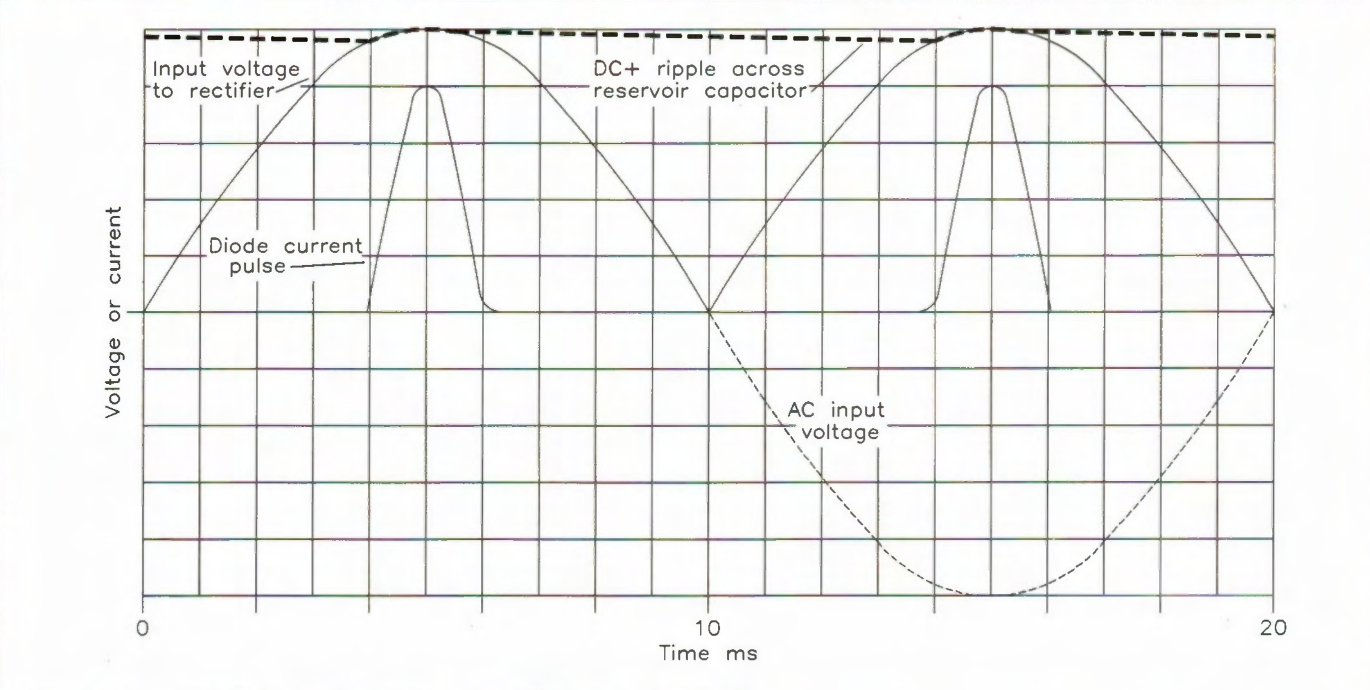


Figure 3. Voltage and diode current waveforms in a full-wave rectifier circuit.

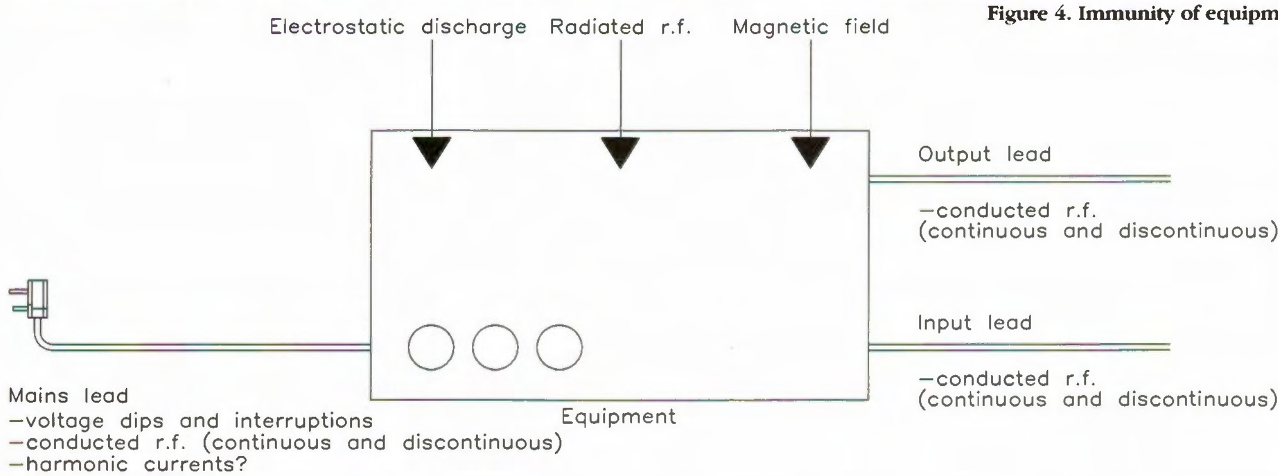


Figure 4. Immunity of equipment.

A problem here, is that the relevant standard, EN61000-3-3, is ambiguously written, and it has proved necessary to try to obtain clarifications on some points. This has happened because it is difficult to find people willing, or whose employers are willing for them, to edit the standards thoroughly before publication.

Immunity Phenomena

There are obvious parallels between what is emitted and what is received, but there are also differences (see Figure 4).

Radiated RF energy: effects could be simply annoying, such as television interference, or very dangerous, such as failure of an electronically-controlled braking system. A major factor is that there may be nothing visible to suggest that a problem may occur, unlike the case of conducted RF considered next, where it may be obvious that a cable is too close to a source of RF.

Conducted RF energy: this is particularly a problem with audio and video equipment, especially if the incoming RF is amplitude-modulated, because the transistors in the affected equipment rectify the AM signal and the modulation appears within the audio or video band, as noise or another intelligible signal. CW or FM signals are usually much less troublesome. Since the carrier amplitude is substantially constant, the effect of rectification is to produce a DC bias shift, which may have no significant effect unless it is quite large.

Poser-phones are a particular nuisance in this respect, because they can be used very close to cables or other equipment, and some types use a carrier system that is 100% square-wave modulated at 200Hz. Apart from conventional RF sources, there are wide-band disturbances on the mains supply, some of which result from switching operations on the high- and medium-voltage grid networks. As indicated above, the electricity supply industry is very keen to ensure that such disturbances do not cause equipment to malfunction.

Magnetic field: all sorts of equipment contains parts, even just loops of wire, in which external magnetic fields can induce disturbance voltages. Obviously, equipment that uses magnetic effects, such as cassette recorders and disc drives, can be particularly vulnerable.

Electric field and electrostatic discharge: external electric fields can induce currents in conductors, but as mentioned above, strong electric fields are rare, except where electrostatic discharge is a real threat. There are two types: *air discharge*, which probably acts mainly through its accompanying electric field, and *contact discharge*, which can not only produce very high voltage across points which should only experience very low voltages, but can also produce quite enormous currents – 30A or more. In addition, the transient voltages and currents contain spectral components up to at least 1GHz.

Mains harmonics: As mentioned above, these are a problem only in certain special cases.

Mains voltage dips and interruptions: dips may occur due to load switching, as well as effects in the supply authority's equipment, while interruptions usually occur through damage to cable or overhead wiring. These effects are usually most troublesome for data processing equipment and automatic machinery, which may lose data or operating sequence.

The Story Continues . . .

Next time, we will look at some sources of emissions and some circuits which may have poor immunity.