Chapter 27 - Electromagnetic Compatibility

Electromagnetic compatibility (EMC) is the process of ensuring that equipment that radiates electromagnetic radiation, such as an amateur transmitter, does not **interfere** with equipment that may be sensitive to electromagnetic radiation, such as television and radio receivers.

There are two considerations when dealing with interference problems.

- The first is a **legal** and **social** one: who is responsible for solving the interference problem. (I say legal and social because sometimes a purely legal approach will generate quite undesirable social results).
- The second consideration is **technical**: what are the causes of interference, and how can it be eliminated.

EMC problems can be classified according to whether the device that is radiating the signal causing interference is an **intentional radiator** (that is, a device that is intended by virtue of its function to radiate, such as an amateur transmitter or a garage opening remote control) or an **unintentional radiator** (that is, a device that does not need to radiate in order to perform its intended function, such as a motor vehicle ignition system or an electric fence) and whether the device being interfered with is a receiver (that is, equipment designed to receive radio signals at some frequency) or is not a receiver (such as a CD player (HiFi) that is picking up breakthrough from nearby transmissions).

*[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.)]*

Unintentional Radiators

There are strict limits to the maximum permitted radiation from any system that does not have to radiate in order to operate correctly. If a system that does not include a radio transmitter of some kind is causing interference, then that is generally because the system is radiating more than permitted, and it should be repaired or replaced at the owner's expense.

For example, if you receive interference from a neighbour's electric fence, then that probably indicates that the electric fence is radiating more than is permitted, and the neighbour is responsible for having the defect rectified, and must turn the electric fence off until it complies with requirements. Of course convincing your neighbour of this may be difficult!

Interference to non-receiving equipment

The converse applies when the equipment being interfered with is not intended to receive radio signals. For example, suppose your neighbour reports that your radio transmissions are "breaking through" on their **HiFi stereo system** when they are listening to CDs. Because the stereo system when listening to CDs is not supposed to receive radio signals, the problem lies with the stereo, not with the radio transmitter.

Often the root cause is that the affected equipment was not designed for, and has not been tested in, environments with strong RF signals present. Unfortunately it is quite legal for such equipment to be sold, and it will work fine for 99% of the time, since in most locations it will encounter only weak electromagnetic radiation from distant transmitters. Then an amateur moves in next door, sets up equipment that is operating within the limits of their license, and all of a sudden the neighbour's CD player receives interference. It is quite natural for the neighbour to think that this is the amateur's fault, and that they must fix the problem or stop transmitting. However in actual fact, the fault lies with the manufacturer of the equipment for not designing it to withstand the levels of electromagnetic radiation that may result form a nearby amateur installation.

In this case, even though it is the neighbour's responsibility to solve the problem, it would be diplomatic for the amateur concerned to make his or her technical skills available to the neighbour to help diagnose the problem and suggest solutions. Apart from good neighbourliness, the same neighbour may have the opportunity to comment on your application to erect a tower, and is more likely to be kindly disposed to such a request if you have helped them to solve any problems that appear to have been caused by your transmissions in the past!

Intentional Radiators interfering with Receivers

The situation is slightly more complex if an intentional radiator (such as your amateur transmitter) interferes with a device that is intended to receive radio signals (such as your neighbour's television). In this case, the key question is the **nature of the interfering signal**.

If the interfering signal is in all respects a legal licensed transmission – that is, it is within an amateur band, does not **exceed the power permitted** for the band and license holder, and is a **clean signal** – then the problem is being caused by the receiving equipment being affected by an out of band signal, and it is the receiving equipment that is defective and must be repaired.

On the other hand if the transmitted signal in any way does not conform with the requirements of your license, then you should first correct the problem with the transmitted signal before suggesting to your neighbour that they have their TV fixed! <u>This is particularly important because if interference is reported to **ICASA** then their first course of action will probably be to inspect your transmitting equipment.</u> If it is found to be out of order in any way then you may be held responsible for the interference and, even if you are not, the transmitting equipment can be confiscated if it does not conform with your license requirements.

Once again, as a matter of <u>diplomacy</u>, it is a good idea to assist your neighbour if possible to solve the interference problem, even if you have determined that your transmitter is operating quite legally. As well as maintaining peace in the neighbourhood, this will help to maintain the good reputation of amateur radio. However if this is not possible – for example, if your neighbour refuses your assistance and insists that you just stop operating – then as long as you are certain that your equipment is operating legally, then you are entitled to continue to operate despite the interference to your neighbour's television or other equipment.

Shared Bands

One exception to this is that some amateur bands are shared between different users, with one of the users being declared the "primary" user and the other as "secondary" users. For example, amateur radio has been allocated the 2 GHz band (2.3 – 2.45 GHz) on a secondary basis; the primary use is industrial, scientific and medical.

Simply put, secondary users may not cause interference to primary users (and must stop operating if this is the only way to prevent interference), while they must accept interference from primary users. **So if you live next door to a hospital and receive interference from medical equipment that is intentionally radiating in the 2 GHz band, then there is nothing you can do about it.**

Of course all amateur bands are shared with other amateurs, and it is important that we take steps to avoid interfering with our fellow amateurs. This should include **operating courtesy** and ensuring that your transmitter is radiating a **clean signal.**

Causes of Interference
There are three possible causes of interference.

1. The transmitter may be radiating on a frequency that it should not be radiating on.

2. The receiver might be receiving signals that it should not be.

The transmitter and receiver may both be working correctly, but something else is **translating** [mixing/converting] the transmitted signal to the frequency of the receiver. For example, corrosion can cause metal to operate like a rectifier, re-radiating **harmonics** of signals transmitted from a nearby transmitter.

Since the latter is quite uncommon and usually requires specialised equipment and significant expertise to resolve, we will only look at the first two possibilities. **[Not strictly so, but reasonable.]**

[LINK:
http://en.wikipedia.org/wiki/Electromagnetic_compatibility

There are four basic coupling mechanisms: conductive, capacitive, magnetic or inductive, and radiative. Any coupling path can be broken down into one or more of these coupling mechanisms working together. For example the lower path in the diagram involves inductive, conductive and capacitive modes.

Conductive coupling
Conductive coupling occurs when the coupling path between the source and the receptor is formed by direct contact with a conducting body, for example a transmission line, wire, cable, PCB trace or metal enclosure.

Conducted noise is also characterised by the way it appears on different conductors:

- Common-mode or common-impedance coupling: noise appears in phase (in the same direction) on two conductors.
- Differential-mode coupling: noise appears out of phase (in opposite directions) on two conductors.

Inductive coupling
Inductive coupling occurs where the source and receiver are separated by a short distance (typically less than a wavelength). Strictly, "Inductive coupling" can be of two kinds, electrical induction and magnetic induction. It is common to refer to electrical induction as capacitive coupling, and to magnetic induction as inductive coupling.

Capacitive coupling
Capacitive coupling occurs when a varying electrical field exists between two adjacent conductors typically less than a wavelength apart, inducing a change in voltage across the gap.

Magnetic coupling
Inductive coupling or magnetic coupling (MC) occurs when a varying magnetic field exists between two parallel conductors typically less than a wavelength apart, inducing a change in voltage along the receiving conductor.

Radiative coupling
Radiative coupling or electromagnetic coupling occurs when source and victim are separated by a large distance, typically more than a wavelength. Source and victim act as radio antennas: the source emits or radiates an electromagnetic wave which propagates across the open space in between and is picked up or received by the victim.]

Transmitter Defects
The most common problems in transmitters are **frequency instability**, **harmonic radiation**, **spurious oscillations**, and **"wide" signals [over deviation / over modulation]**.

Frequency instability is usually the result of LC (inductor/capacitor) oscillators that have not been adequately compensated for temperature variations or protected against mechanical shock. It is most likely to impact on other amateurs, unless the instability is sufficient to take the transmitter out of the amateur band and cause interference to other services. Fixing frequency instability usually requires design modifications or improved construction methods (for example, more solid construction that is less sensitive to mechanical knocks). It is quite uncommon with modern crystal-controlled radios, although it may occur if a PLL frequency synthesizer gets unlocked from the reference frequency.

Another type of frequency instability is **chirp**, which occurs when the oscillator frequency is affected by the loading of subsequent stages or by fluctuations in the power supply voltage when a CW transmitter is keyed. It can be prevented by using a high-impedance **buffer amplifier** after the oscillator; and by **regulating the oscillator voltage supply**.

Harmonic radiation occurs on multiples of the transmitter output frequency. For example, a transmitter operating at 144 MHz may interfere with a television receiver operating at 720 MHz (720 = 144 * 5). It can be caused by overdriving an amplifier stage (for example by having the microphone gain or CW drive level set too high) or by inadequate attenuation of harmonics by the transmitter's output low-pass filter.

If the problem is caused by overdriving the transmitter, then the solution is to reduce the drive level by adjusting the microphone gain or CW drive correctly. However if the problem persists even when the transmitter is not being overdriven , then the best solution is to add an additional **low-pass filter** between the transmitter and the aerial. Low-pass filters for the HF bands (up to 30 MHz) are available at reasonable cost and provide substantial attenuation at higher frequencies, typically 50 dB or better at 50 MHz.

[Another solution sometimes recommended is to use an aerial tuning (matching) unit (ATU) even when it is not required to match the aerial, as the ATU may attenuate out of band signals. We think this was probably better advice in the days when most ATU's used a pi configuration and also acted as low-pass filters. Today many ATU's use a T configuration, and would act as a high-pass filter, making their value for reducing harmonic radiation questionable. In any case, since this is not what the ATU is intended for, there is no guarantee that it will be effective, so my advice would be to use a purpose-built low-pass filter instead.]

Spurious oscillations may either be **self-oscillation**, at or near the intended frequency of operation of an amplifier or mixer, or **parasitic oscillations**, which usually occur at VHF or UHF frequencies. **Self-oscillation** is caused by unintended feedback from the output of an amplifier or mixer that includes tuned circuits to its input, causing oscillation at the resonant frequency of the tuned circuit. It can be suppressed either by reducing the coupling (for example by shortening component leads) or by introducing **negative feedback** to reduce the loop gain and prevent oscillation.

Parasitics are VHF or UHF oscillations that occur due to unwanted "hidden" resonances in oscillators and amplifiers – for example, between RF chokes and decoupling capacitors, or due to the inductance of capacitors and/or leads at high frequencies. They can be eliminated by using low-Q (lossy) RF chokes, which are less likely to cause oscillations, or by using ferrite beads to add sufficient inductance to component leads or wires to dampen out unwanted VHF or UHF oscillations. **[Also use of lossy capacitors in decoupling. e.g. Tantalum capacitors.]**

"Wide" signals are signals which are due to intermodulation distortion where the bandwidth exceeds the maximum required. The cause is usually that some amplifier stage is being overdriven, and while this may result form a design defect it is more often caused by an incorrectly adjusted microphone gain control or CW drive level. On most modern transmitters the ALC (automatic level control) voltage can be monitored on the S meter during transmit.

The microphone gain or CW drive level should always be adjusted so the voltage remains within the acceptable ALC levels at all times. These levels are usually marked on the meter.

[Another cause of wide signals is amateurs intentionally “opening up” the audio paths on their transmitters to allow the broadcast of wideband audio signals that exceed the 3 kHz bandwidth required for communications quality in the pursuit of “fidelity” but at the cost of causing interference to other operators.]

A CW transmitter may generate **key clicks** if the carrier is switched on or off too rapidly when keying. The carrier should be turned on or off gently over a period of about 5 milliseconds to avoid generating key clicks. Unfortunately even some very well regarded modern transceivers like the FT1000 MP have a problem with key clicks and may need to be modified to reduce clicks to acceptable levels.

Mains hum [or switching pulses] may be heard on transmitted signals if the power supply is inadequately filtered. The addition of a voltage regulator or additional smoothing capacitors should solve the problem.

If a transmitter is using an aerial like a long wire that is driven against earth, then it is important to have a good RF earth system that is independent of the mains earth. The mains earth wire usually travels in close proximity to the other mains wires for some distance before being physically earthed, so RF signals in the mains earth are likely to be inductively coupled to the live and neutral wires and may travel through them to neighbouring buildings, causing interference, especially to mains-operated equipment. The mains earth also often has high impedance at RF frequencies, so an independent earth system is necessary to remove RF voltages from equipment and aerial feed-lines. Of course even if you cannot provide a good RF earth, a mains ground is still required to prevent the case from having a potentially lethal voltage in the case of a fault.

Receiver Defects

The most common defect in radio and television receivers that results in interference from amateur transmissions is **receiver overload**. This is when signals stronger that the receiver was designed to handle are present at the receiver input, and inter-modulation distortion in the first mixer causes spurious products that interfere with reception.

One common cause of this is inexpensive RF masthead amplifiers that are sometimes used to improve television reception in marginal areas. While amplifiers with decent signal-handling capabilities are available, they are generally more expensive, and the inexpensive ones that are widely available are very prone to overloading.

A solution to receiver overload is to add additional filtering before the receiver that removes the strong out of band signals that are overloading the receiver. What type of filter is required will depend on what frequency transmissions are causing interference. If transmissions in the HF bands are causing the problem, then a high-pass filter between the TV aerial and the TV might solve the problem, since the TV transmissions are on higher frequencies in the VHF and UHF region, so these frequencies can be passed while blocking HF frequencies.

If amateur VHF transmissions are interfering with UHF television reception then a high-pass filter with a cut-off frequency of 470 MHz <u>might solve the problem</u>. However if VHF transmissions are interfering with VHF television reception, then a band-stop filter for the particular interfering amateur transmission band might be required. These band-stop filters are also called “traps”. A quarter-wavelength transmission-line “stub” connected across the feed-line and open at the far end, may also serve as a trap. It presents low impedance at the frequency on which it is exactly a quarter wavelength, effectively shorting the two conductors in the feed-line together at that frequency, while presenting a high impedance at most other frequencies.

However note that if the problem is being caused by overloading a masthead RF amplifier, then no amount of filtering of the signal between the amplifier and the television will help, as in-band spurious products may already have been generated by the amplifier. In this case, replacing the amplifier with one that is more resistant to overload (or removing it altogether if reception conditions permit) may be the only option.

Interference to receivers may also result from **image signals**, also known as **second-channel interference**, if the image frequency of a receiver coincides with the frequency on which a strong amateur signal is present and the receiver has insufficient image rejection.

Common-Mode Chokes [Push-Push chokes]
Interference usually "gets into" the equipment being interfered with through the wires attached to it – these include aerials, speaker leads, interconnections between audio components, and mains power leads. In **common–mode interference**, the signal is transmitted in phase by both the conductors in the connection – for example by <u>both the live and neutral wires</u> in the mains, or both conductors in the speaker cable, or both the <u>inner conductor and the earth in a coax cable</u>.

Common-mode interference can be effectively eliminated by a common-mode choke, also known as a "braid breaker". (Although it does not involve physically breaking the braid in a coax cable, it effectively blocks the flow of common-mode signals that travel along the braid as well as in the inner conductor, which is where the name comes from).

This consists of winding several turns of the cable – which could be a mains lead, a speaker cable, or a coax cable – around a suitable core to form an inductor. Ferrite toroidal cores are the best, and are available for the purpose from local suppliers. The idea is that common-mode currents will generate a magnetic field in the core, and so the choke will act as an inductor to common-mode signals. If the inductor has sufficiently high impedance at the frequency causing the interference, then this signal can be rejected.

However **differential signals** – that is, signals where currents flow in opposite directions in the two conductors, for example the signal from the aerial in a TV aerial lead – will not generate a magnetic field since the fields generated by the two currents flowing in opposite directions cancel out; and so the common-mode choke does not act as an inductor for differential signals, which pass through unaffected.

Common-mode chokes can be used both with receiving equipment, such as television receivers, and with non-receiving equipment such as audio amplifiers that are suffering interference from strong radio signals.

Summary
EMC should be looked at from two perspectives: the legal (who is responsible for solving the problem) and the technical (how to solve the problem). If the interfering signal is being generated by equipment that does not need to transmit in order to function, then it is this unintentional radiator that is usually at fault since there are strict limits as to how much electromagnetic energy can be radiated by unintentional radiators. If the equipment being affected is not intended to receive radio signals of some kind, then it is the affected equipment that is at fault. If a signal from an intentional radiator is affecting equipment that is designed to receive radio signals, then the key question is whether the transmitter is operating within the frequency and power limits specified by its license. If the transmitter is not radiating legally, then this must be fixed. However if the transmitter is operating correctly and within license requirements, then the problem is being caused by the affected equipment responding to an out of band signal, and ultimately it is up to the owner of the affected equipment to have the problem repaired at his or her expense.

However it is advisable for an amateur whose transmissions are causing interference to assist as much as possible in diagnosing the cause of the problem and suggesting solutions. This is both to maintain a good relation with neighbours and to maintain the good image of amateur radio.

The most common transmitter problems are **frequency instability**, **harmonic radiation**, **"wide" signals** and **key clicks**.

- Frequency instability requires due attention in design and construction to temperature compensation, mechanical rigidity and suitable buffering of oscillators to avoid chirp.

- Harmonic radiation can be attenuated by a suitable low-pass filter.
- Wide signals are usually caused by setting the microphone gain level too high.
- Key clicks are the result of turning the carrier on or off too rapidly.

Receiver problems can be caused by **common-mode** or **differential signals**.
Common-mode signals can be attenuated by a suitable **common-mode choke** (also called a "braid breaker").

Differential-mode signals require the use of suitable high-pass or band-stop filters between the aerial and the receiver.

Mast-head TV amplifiers are often subject to overloading; if this occurs then the amplifier may need to be removed or replaced with one that is less subject to overloading.