Who's Bugging my Phone Sales?

EN55024:1998[1] has telephone manufacturers vexed

Abstract

How many times have you heard that annoying rat-a-tat-tat produced in the earpiece of your telephone when you've put your mobile phone down too close to it? Well the European EMC immunity standard covering IT and TTE equipment was updated in 1998 to include acceptable performance criterion for just this type of Electromagnetic Interference. Compliance with the standard became mandatory on 1st July 2001 for product sales into the European union. The problem for TTE manufacturers is that complying with the standard is technically difficult and potentially costly whilst the market pressure on the price of the plain old telephone gives little if any margin to play with. Many manufacturers, expecting to make small tweaks to their products in order to comply, have been taken utterly by surprise having to virtually redesign from scratch. This paper analyses the requirements of the standard and attempts to answer two fundamental questions: just how realistic are the requirements and what techniques can be used to design compliant telephone products?

What is EN55024:1998?

European Norm (EN) 55024 is the European EMC standard for immunity of Information Technology and telephony products[1]. The immunity standard subjects products to conducted and radiated Amplitude Modulated (AM) Radio Frequency (RF) disturbances as well as Electro-Static Discharges (ESD) and other transients and surges. In 1998 the standard was updated with the addition of annex-A, which defines limits for demodulated interference (table A.1[1]).

Demodulated interference occurs when semiconductors within a product encounter AM radio signals. Each semiconductor junction demodulates the RF signal much like an old-fashioned crystal radio set. Therefore at radio frequencies the modern telephone is nothing more than a complex network of crystal radio sets. The resulting demodulation is heard as an irritating noise superimposed on the wanted speech signal. Annex-A gives the acceptable limit for this unwanted noise in various frequency bands.

Since 1 July 2001 manufacturers or distributors placing telephony products on the single European market must declare compliance with this standard and it's counterpart EN55022:1998[2], the European EMC standard for emissions.

Does Annex-A apply to my Product?

There is a good deal of interpretation required to determine whether all or part of annex-A applies to a given product. In the annex there are three defining clauses for Telephone Terminal Equipment (TTE) summarised below:

(i) All TTE shall be able to maintain an established call;

(ii) For TTE supporting telephony service, the noise signal limits also apply (table A.1, column 3);

(iii) For TTE having an acoustic interface, the acoustic sound pressure limits also apply (table A.1, column 4).

Table A.1 – Maximum acoustic demodulated levels at the telecommunications port and at the acoustic receiving device (measurement method 1)

Frequency band (MHz)	Type of immunity test	Noise signal (dBm)	Acoustic sound Pressure level (dB(spl))
0.15 to 30	Conducted	-50	55
30 to 40.66	Conducted	-30	75
40.66 to 40.7	Conducted	-50	55
40.7 to 80	Conducted	-30	75
80 to 1,000 (except at 900*)	Radiated	-30	75
900*	Radiated	-50	55

* This requirement is not applicable for countries where no digital mobile service operating at 900 MHz exist.

NOTE – These test are designed to ensure a minimum acceptable immunity to amplitude modulated radio frequency disturbances for devices having acoustic interfaces. The demodulated disturbance levels are higher than those that will be found acceptable in practice. The levels in the tests have been chosen for their practical test convenience, having regard for the maximum allowed background acoustic noise level of 40 dB(spl) and the test levels to be applied for functional testing. The amplitude demodulated disturbances will arise, almost invariably, from semi-conductor junctions behaving as inadvertent square law detectors. This means that for every 1 dB change in the level of the applied radio-frequency signal the demodulated level will change by 2dB. Therefore, if a radiated immunity test subjecting the EUT to a test field carrier level of 3 V/m produces a resultant demodulated acoustic 1 KHz disturbance output of 55 dB(spl) (a distinctly annoying acoustic level for most listeners with normal hearing, but conveniently above the allowed background noise level of 40 dB(spl)), the test ensures that an amplitude modulated disturbance field of 1 V/m (approximately 10 dB lower in field strength) applied to the same equipment in a real world situation can produce a demodulated acoustic disturbance level of approximately 35 dB(spl), which most people in a practical listening environment do not perceive as annoying.

Clearly annex-A is intended to apply to terminal equipment, therefore current practice is to exclude routing equipment such as PBX and PABX. If however a PBX has a dedicated management terminal with an acoustic interface then the terminal should be tested.

EN55024:1998 doesn't apply to cordless terminal equipment such as DECT and CT0, which have their own product specific standards.

This leaves basic telephones, headsets, speakerphones, voice recorders, digital telephones, fax machines, voice modems, etc. Clause (i) applies to all of these.

Demodulated Noise presented to the telephone port

Clause (ii) in the measurement method involves measuring the demodulated noise a product presents to the telecommunications port. This is the noise heard by the remote party from local radio interference. The clause applies only to devices supporting a telephony service, which EN55024:1998 defines this as:

> "A service providing users with the ability for real time two way speech conversation via a network"[1][3].

The phrase 'real time two way' speech immediately excludes voice recorders and voice modems unless these devices allow a user to make a regular telephone call, for example, as a fax machines does.

For plain old analogue telephones demodulated noise is simply measured in dBm across a 600Ω termination (simulating a Public Switched Telephone Network (PSTN) line). For digital telephones, such as ISDN terminals, a decoder is necessary for meaningful measurements to be made. However the term 'telecommunications port' is given a wider definition in EN55022:1998 (curiously the term is not defined at all in EN55024:1998!). In the 1998 revision the term's meaning was extended to include indirect connection to a public network via a multi-user network (such as an office LAN). Although this was the intent the actual definition has caused confusion and CISPR have proposed amending it as follows:

> "Telecommunications/Network Port: Ports for voice, data and signalling transfer which are intended to interconnect widely-dispersed systems via such means as direct connection to multi-user telecommunications network (e.g. public switched telecommunications networks, integrated services digital networks, xDSL, etc.), and similar networks. Ports generally intended for interconnection of components of an IT system under test (e.g. RS-232, parallel printer, Universal Serial Bus (USB), IEE Standard 1395, ("Fire Wire"), etc.) and used within its intended specifications, e.g. maximum length, are not considered to be telecommunications ports under this definition."

Whether this amendment will make it to the standard and when is currently under consideration by CISPR. Will it end the current confusion over the issue, who knows?

Additionally there is some confusion as to whether products exempt from clause (ii) still need to meet clause (iii). The purists argue that they do, but this author argues that the word 'also' in clauses (ii) & (iii) implies 'and'. Indeed there seems little point in testing the acoustic interface of a device that does not support a telephony service.

Demodulated Acoustic Sound Pressure Level (spl)

Clause (iii) in the measurement method involves measuring the demodulated acoustic noise a product presents to the local user due to local radio interference. The clause applies only to devices with an acoustic interface. The sound pressure level (spl) is measured in the presence of a modulated radio disturbance.

Products with multiple acoustic interfaces such as headset-handset-speaker phones present more interpretation problems. Clearly it is proper to test the spl at every acoustic interface but should telephone port demodulated noise also be tested in each mode? Currently this author doesn't do so, measuring demodulated noise in the default operating mode only (usually handset operation).

Annex-A doesn't specify a measurement method for hands-free phones (speakerphones) although these products do support a telephony service and do have an acoustic interface. This author uses the ITU-T recommended method[4].

Considering after-market headsets, which do support a telephony service and do have an acoustic interface. The difficulty, until very recently, for headset manufacturers has been obtaining an EN55024:1998 compliant telephone to test with.

Weaknesses in the Standard

In addition to the ambiguities already mentioned there are problems with the test method that make it very difficult to obtain consistent results from laboratory to laboratory. These problems are now discussed.

<u>Demodulation Mechanism</u>

As already mentioned every semiconductor junction within an electronic circuit demodulates RF. This includes every diode, transistor or integrated circuit. Circuits designed only to work at audio frequencies still demodulate RF disturbances often up to many gigahertz.

The demodulation mechanism assumed by the standard is square-law power demodulation (figure 1).

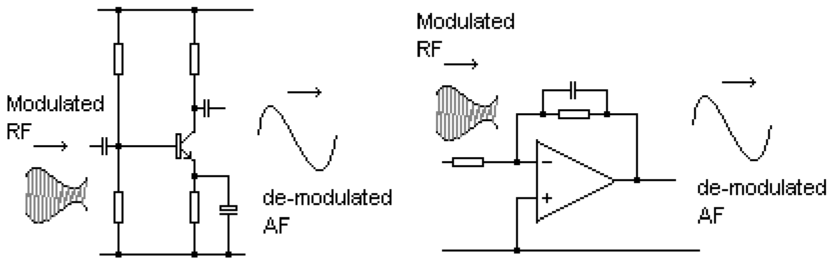

Figure 1 – Demodulation in Linear Circuitry

A square-law detector has the property that for every 10dB increase in modulated RF power there will be a 20dB increase in the demodulated noise power. Most PN junction demodulators only approximately deliver square-law demodulation at best, indeed very careful design is required to produce intentional square-law demodulators[5]. Furthermore semiconductor devices used for audio switching produce wildly different results in practice (figure 2).

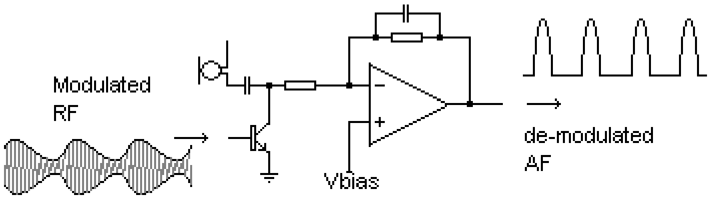

Figure 2 – Demodulation in Switching Circuitry

In the example above a transistor has been used as a microphone mute switch. There will be no demodulated noise due to the transistor until the peaks of the modulated RF energy in its base circuit are just sufficient to start to cause it to switch on. At this point demodulated noise occurs as shown and in the case of the simplified mic circuit (above) becomes greatly amplified. The demodulated noise power rises disproportionately quickly with extremely small increases in modulated RF power.

In a laboratory test situation small variations in field uniformity from chamber to chamber are inevitable giving often unrecognisably different results for the same sample.

Problems of repeatability worsens with cabling

Repeatability problems are increased for products with cables and all the products to which annex-A applies will have cables of some sort. Differing cable lengths and placement (often very slight variations) frequently yield markedly different results. Figure 3 shows sound pressure level measurements taken between 80 and 200 MHz for the same product in the same configuration in three different chambers at two leading UK test laboratories.

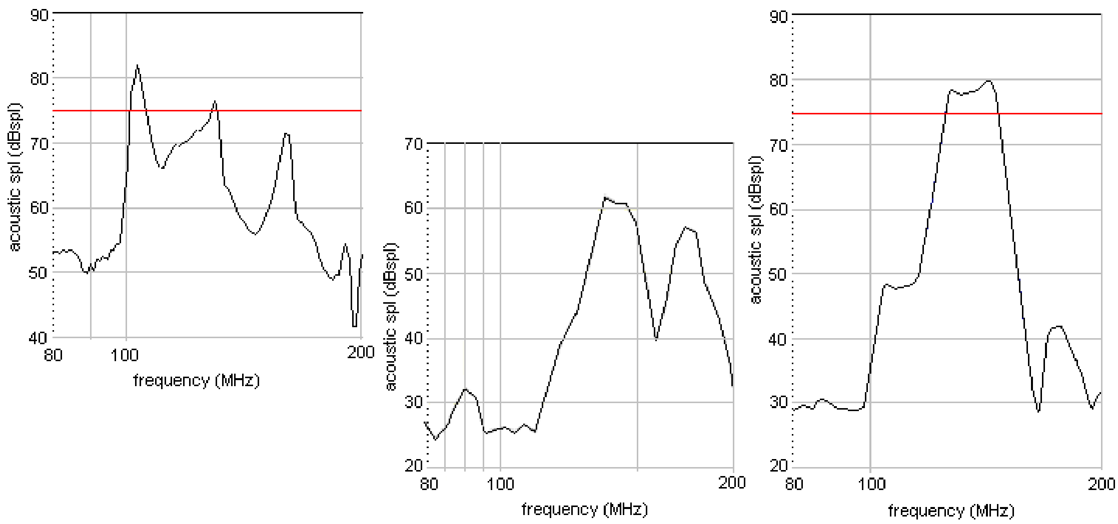

Figure 3 – Comparison of measurements for one product in three chambers

Poor correlation between conducted and radiated tests

CISPR have already recognised that there is a discrepancy between the conducted immunity test above 10 MHz and equivalent radiated immunity test. Their report concluded that: "both test results coincide with each other except a discrepancy approximately above 10 MHz" and "the applied voltage (Vemf) of the RF continuous conducted testing should have frequency dependence". Accordingly table A.1 has been amended in CISPR24 to relax the limit above 10MHz[6]. Whether this amendment will make it to the standard intact and when is not known.

Design tips for compliance

With all its weaknesses and ambiguities compliance with the standard for TTE sales into Europe is now mandatory. The first question most manufacturers with an existing TTE product ask is "can I just tweak it to pass"? Experience shows that the answer is a resounding no! Modifications to the layout of analogue Printed Circuit Boards (PCBs) within are invariably required.

It's not possible in a single article to describe all the techniques for EMC hardening a telephony product but a brief introduction to the most important factors is given here.

Segregation, Isolating Sensitive Circuitry

It is virtually impossible to EMC harden a sensitive analogue circuit, such as a telephone, without proper physical segregation of circuit blocks on a PCB. The sensitive circuitry must be confined to a single area termed the 'clean zone' well away from noise sources, especially cable entry points which carry RF disturbances in. The experienced designer will know roughly which circuit blocks are going to be sensitive, microphone circuits for example. Identifying susceptible circuitry by testing 'on the bench' is recommended for existing products prior to re-working the PCB[7].

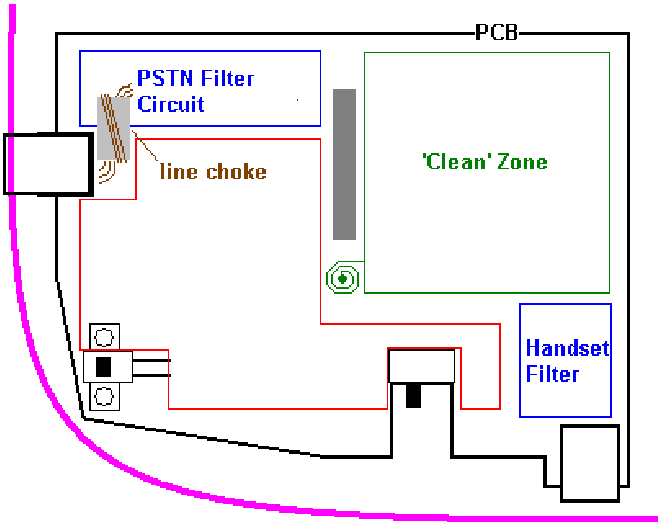

Figure 4 – Example of telephone circuit segregation

Other less susceptible circuitry should be placed in another area of the PCB away from the clean zone. For example the ringer circuit in a telephone, which will probably not be particularly sensitive. The positioning of filters to arrest cable induced RF is also important. They need to be as close as possible to the cable entry points. Designers should avoid using flying leads to bring signals onto the analogue PCB as they can be consistently routed away from sensitive circuitry.

Ground planes

The 'clean zone' should be entirely covered with a solid copper ground plane. Avoid aperture cuts in the ground plane and use short ground stubs to connect surface mount components to the ground plane, especially RF filtering capacitors. Ground plane resonance effects (patch antenna) can be avoided at frequencies below 1 GHz by containing all the 'clean zone' circuitry in a square of 50 x 50 mm or less.

EMI Filtering

Two sorts of filters are usually required for compliance:

(i) Conducted RF filters (applied to cable ports only);
(ii) Radiated RF filters (applied to cable ports and elsewhere).

Conducted RF Filtering

Experience has shown that cable ports need a common mode filter on all incoming lines. For a two wire circuit a PCB mount choke can be used, for four or more conductors a common mode choke can be made by winding all conductors round a suitable ferrite toroid two or three turns.

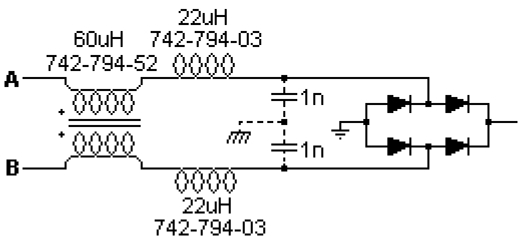

Figure 4 – Example of PSTN line filter circuit

Figure 4 shows a simple PSTN line cord filter circuit. The part numbers given are from Würth Elektronik[8], but any equivalent manufacture will do. The inductance of the choke and subsequent inductors is not as important. It is important that components have high impedance over the critical frequency range 1 to 80 MHz. The 1nF capacitors to chassis are only useful for products with an all metal chassis such as payphones. It is important, for safety performance, that these have a suitable voltage rating (at least 1.5 kV).

Radiated RF Filtering

All cable conductors should also have a radiated RF filter as should every track entering the 'clean zone'. The best filter is simply an in-line resistor of at least 10 kΩ as this presents an impedance mismatch at all RF frequencies and thereby reflects RF energy. Where high impedance is not possible use a 1 kΩ resistor and 100pF capacitor to ground. For very low impedance circuits a 150 nH inductor and 100pF capacitor.

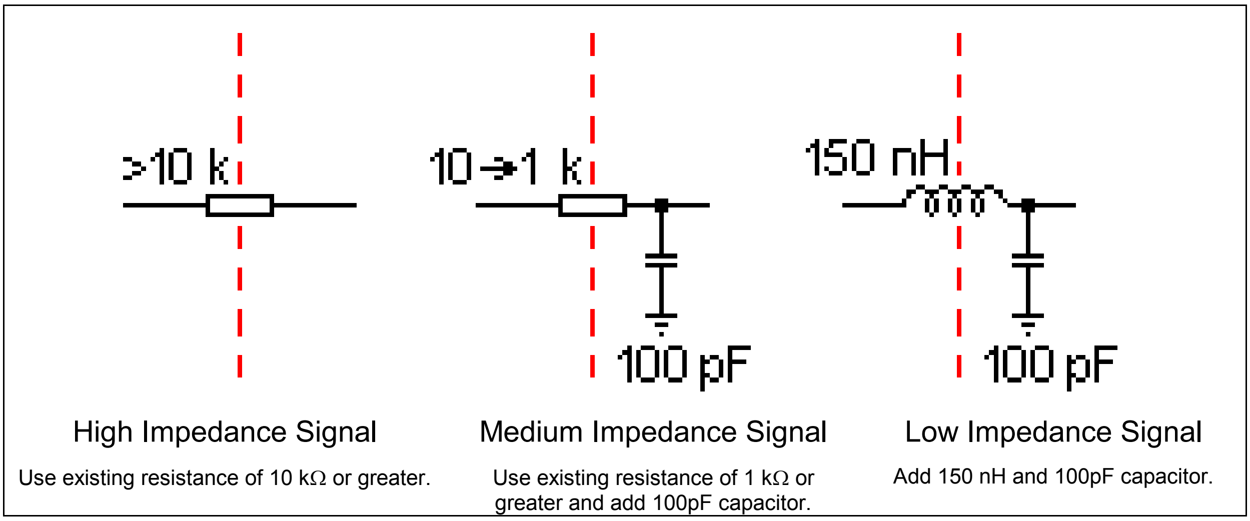

Figure 5 – Radiated RF filters

Filter Layout

It is best to place conducted filters on an area of the PCB without a ground plane to minimise stray coupling to the ground plane. Radiated filters need to be arranged so that the in-line resistor or inductor sits on the boundary of the ground plane and the shunt capacitor immediately inside the ground plane (figure 6).

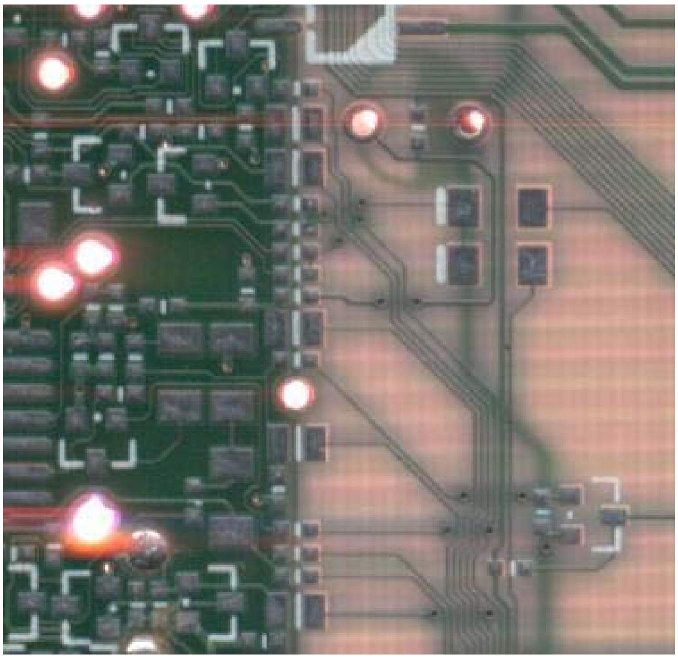

Figure 6 – Radiated RF filter layout example

Example: In-line inductors (0805) and resistors (0603) can clearly be seen placed on the boundary of the clean zone ground plane in this example.

Component Limitations

Filter components should be chosen with a suitable RF performance. This author recommends 0603 format 100 pF capacitors and 150 nH 0805 chip inductors (example: Coilcraft part no. 0805CS-151X_BC) as both parts have Self Resonant Frequencies (SRFs) at approximately 1 GHz (the upper limit specified by EN55024:1998).

Physically large electrolytic capacitors should not be used within the ‘clean zone’ as these become significant antenna at high frequencies.

Analogue Switches

Designers should avoid using discrete transistors as analogue switches and use instead FET based switches such as the 4066 as these devices have a much better noise margin.

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References:

1 - EN55024:1998 "Information technology equipment – immunity characteristics – limits and methods of measurement" ESO:CENELEC, based on CISPR24:1997. DOW 1 July 2001.

2 - EN55022:1998 "Information technology equipment – radio disturbance characteristics – limits and methods of measurement" ESO:CENELEC, based on CISPR22:1997. DOW 1 August 2001 (now postponed).

3 - ITU-T recommendation I.241.1

4 - ITU-T recommendation P.45 (also BS 6789 part 2)

5 - The Art of Electronics (2cd ed), Section 13.13, P.Horowitz and W.Hill, Cambridge University Press 1989, ISBN: 0-521-37095-7.

6 - CISPR24 Amendment 1, Information Technology Equipment, Immunity Characteristics, Limits and Methods of Measurement, 18 July 2001, IEC.

7 - Improving the RF Immunity of Sensitive Analogue Electronics, T.P.Jarvis BSc CEng MIEE & I.R.Marriott BEng. UK EMC Journal nos 9. Published by Nutwood UK Limited Feb 97.

8 - Inductors and EMC Components, Würth Elektronik catalogue 1999.