High Frequency Detection in Audio Installations (EMC)

Preface

Radio Hams know this phenomenon very well: sometimes their transmissions are audible in neighbouring audio installations and even disturb TV images. Mostly the *cables* connected to the audio equipment is the cause: they *behave as antennas* and generate such a large HF (high frequency) signal at the terminals of LF (low frequency) audio devices that they don't work properly any more: Detection (=transformation from HF to LF) occurs in the delicate audio circuits and becomes audible in the loudspeakers.
This is a clear case: neighbours come to the door and complain. But, what happens if the distance between the antenna of the transmitter and the audio installation is too large to create this direct audible effect? Could it be that the quality of the (high end) audio will be affected? What about all other short wave broadcastings with much larger transmitters than those of radio hams? There are thousands of them! Are our audio systems 'electro magnetic compatible' (EMC) enough?
With this writing the phenomenon is explained and remedies are offered.

The dipole antenna

In figure 1 a dipole antenna has been drawn. This antenna is most effective at frequencies for which the wave length (λ) is twice the length of the antenna. The antenna however will also function quite well at other frequencies. An example:
For transmitting on the 20-meter ham band (14.0 - 14.35 MHz) the wave length is about 21 meter. The erected antenna will be about 10 m long, two times 5 m. With such antennas the HF voltage is high at the tips and the HF current is maximum in the middle. The antenna should in general be placed as high as possible for the best results.
The neighbour of the ham has an audio equipment with for instance two loudspeaker boxes which are connected to the amplifier with two cables of..... 5 meters long! These cables just lay down on the floor but they make a well tuned dipole antenna, and during transmissions of the ham a substantial HF current will flow from one loudspeaker terminal of the amplifier to another. Not to mention the other connections as mains and interlinks to other equipment. The amplifier will not be able to cope with the situation.

Speaker cables and Interlinks

There are so many opinions on speaker cables and interlinks and folks have written so much about the subject in magazines and on Internet that I am in doubt to say something about it. It has become an almost religious subject! People hear differences between cables and interlinks, and there **are** differences! Once I read from a sound engineer who preferred cable-A during the day and cable-B in the night. I believe him, no doubt about this!
The question is: what is the source of this phenomenon. I am a scientist and I am not convinced by the commercial bla bla from people who try to sell me carbon cables, oxygen-free copper cables, silver cables and so on for much money.... In my opinion the differences stem from the *different antennas* the cables make up. If it would be possible to make our equipment really EMC, that is, to keep HF-signals out of our audio equipment by degrading the antenna-action of cables, the problem has been solved.
I am lucky to be a radio ham *and* an audio bug: after I suppressed my audio equipment from my ham transmissions [so that my wife could listen to broadcastings while I made QSO's] the audio became more stable and better! I investigated the subject conscientious and found out that the old ham trick of degrading the antenna-action for near fields with ferrite also counts for subtle far field influences. To say it sharp: if the cables no longer act as antennas, *the type of cable becomes irrelevant!* Cheep well screened cables for interlinks and a not too thin two-core cable for the speakers will satisfy henceforth.

Common mode and differential mode

Our cables and interlinks behave for LF different from HF. In a speaker cable the LF-current flows intermittent to the speaker in one core and returns to the amplifier in the other. There is no LF-voltage between the earth connection at the amplifier and the earth connection at the speaker side. The same counts for a screened interlink: there is no LF-voltage between the earth connection of the plug at one side and the one at the other side. If so, the installation suffers from hum by loop currents. LF voltages are *between* the two cores of the cable. These voltages are so called *differential mode*.
Keep in mind that the wavelength (λ) of 20 kHz is 15 km, so every cable in our home is short compared with the wavelength of audio signals.

Our cables and interlinks behave totally different for HF. The capacitance between cores in a cable is for HF a low reactance and the length of our cables is in the order of the wave lengths of electro magnetic fields around us. There are many of them from radio hams, broadcast stations, radiotelephones, GSM's, wireless telephones and don't forget the so called 'man made noise' from mains switches and the radiation of digital equipment (personal computers). All together forms a mush of HF-signals (between wave lengths of a hundred meter to some centimetres) which could very well influence our decent audio equipment.
HF-attacked audio cables behave *common mode*. There is no HF-voltage between the cores in the cable but the cables behave like a single conductor. It seems strange, but the HF-voltage between for instance the speakers (the tips of the dipole) and the amplifier (in the middle of the dipole) could be several volts so that between the two speaker connections at the amplifier flows an HF (common mode) current. If the construction of the amplifier is inadequate, this HF-current flows through the printed circuit boards inside and do their harm: any semiconductor junction will behave as an HF-detector and influence the low level LF-signals.

Remedies

The question is: how to degrade the common mode HF-currents without influencing the differential mode LF-currents.
If we make a coil of a multi-core cable, the differential mode signals (between the cores in the cable) are not affected by the inductance of the coil. However the inductance of the cable in common mode will be the inductance of the coil as if the coil had been reeled of a single conductor. This means that we could **affect the antenna-action without influencing the desired LF signals!** Moreover, if we could make a coil of such a bad HF-quality that the antenna-action of the cable in question has been disturbed, the problem will be solved.
Many years ago Dr J.J. Goedbloed[1] found out how to construct such a coil. The *best solution* in our case is to wind 5 to 7 windings through two 32 mm ferroxcube toroids (see picture 1): the purple toroid is of 4C6 ferroxcube (Philips) and the green one is of 3E3 ferroxcube (Philips). The 4C6-material (μ_r = 100) is applicable up to 30 MHz and the 3E3-material (μ_r = 1000) only up to some hundred kHz. This combination kills nearly all HF-current: they are dissipated in the 3E3-toroid.
The *second best solution* is to wind the cable around a feroxcube antenna rod from an old lf/mf-radio. Often one of the plugs of our cable should be removed before winding it through the two toroids. Often this counts for interlinks. To avoid this, the cable could be wound around an antenna rod (picture 2).

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[1] Jasper Goedbloed, Electromagnetic Compatibility, Prentice Hall 1992, ISBN 0-13-249293-8, 381 pages.
Jasper Goedbloed is someone who has contributed immensely to both the understanding and the practice of EMC from his position in the EMC group of Philips Research Labs in Eindhoven.

The best position

Where should the above described construction be positioned in the cable? In general: as close to the amplifier as possible. Sometimes tuners and (CD-) players are also sensitive to HF. An additional EMC-coil in the mains cord will help.

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