Interferences in ECG and elimination

General points

The signal voltages in ECG recording are known to be very small and are in the millivolt range, i.e. they have amplitudes of only a few thousands of a volt. The R wave is the curve segment with the greatest amplitude, i.e. approx. 0.5…4 mV depending on the lead. However, segments with considerably smaller voltages, sometimes within the range of 0.1…0.5 mV, are of higher diagnostic value.

If we consider the ratios to all noise fields, we can see that the ratio of the mains voltage (230 V) to the ECG wanted signals is 230 V / 0.1 mV = 2.3 million: 1. This figure is unimaginable. It would be like trying to find a thick hair measuring 0.1 mm in diameter in a car park of 230 square meters area. Only such parallels show what kind of demands are made on ECG equipment.

Fortunately, modern circuiting techniques enable these extremely low voltages to be relatively effortless processed. However, the human as the source of ECG voltages also acts as an antenna for the most different noise fields.

The target of this abstract is to describe the types of interferences which occur. Their origin will be described detailed and find enclosed some advices how to eliminate them.

Types of interferences

The interferences which occur may be distinguished into five categories:

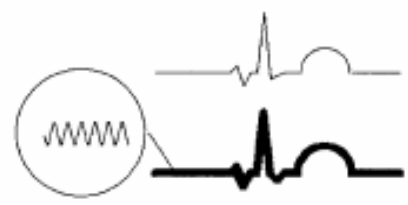
- AC interference caused by other types of interference
- AC interference due to earth circuit or incorrect earthing
- AC interference due to potential differences
- Shaking
- Zero line fluctuations (Base line shifts)

AC interference

AC interference is an interference which arises from superpositioning of the ECG signal with sinusoidal voltages with mains frequency. It may be recognized by its constant frequency of 50 Hz or 60 Hz depending on the individual country currency. Sometimes it can also be 16 2/3 Hz as this is the frequency used by trains.

This constant frequency is often only recognized when the ECG recorder has a high rate of paper speed (i.e.100 mm/s). In this case, a full wave is
approx. 2 mm at 50/60 Hz
approx. 6 mm at 16 2/3 Hz

„clean“ ECG



ECG superimposed with AC

AC interference caused by other types of interference

AC interference arises from interference of the mains frequency on the treated patients, on the electrodes and on the patient cable.

Electrode tubes and patient cables normally have such a good shielding that there are only small effects concerning this matter. Exceptions are unshielded electrode cables which in many cases act as an antenna by absorbing the interference.

Interferences occur due to electric fields which are generated from

- electric leads in the wall

- chokes in fluorescent lamps

- other close distance positioned units (e.g. diathermy units)

- large units either in the vicinity or even further away (X-ray, elevators).

A commercial lead finder obtainable in a DIY store can be very useful in localising leads behind plaster. If such a lead will be found i.e. inside the wall behind the patient table , it can already be sufficient to switch off all consumers at the end of the lead and thus minimises the current conduction of these generated fields. However, the course of the current conduction must be known exactly. Another possibility is the grounding of the patient table, the metal frame of the table being connected to the grounding pins of the ECG recorder by a sufficiently thick cable (≥ 4mm²). For a permanent solution the table should be contacted by firmly tightening the grounding cable. Other solutions such as crocodile clips or only even winding around a metal part (all already tried!) firstly do not guarantee sufficient contact of low impedance and secondly it is more than possible that cleaning staff or other persons will tear them off. A proper solution is the use of a ring terminal which is screwed to the screw on the table using a tooth lock washer.

If the grounding of the table does not generate success, mounting metal on the wall is often the only solution. This can be taken in form of metallized wallpaper or a fly screen. A good connection to the earthing pin of the ECG is necessary in both cases. Space permitting, simple moving of the equipment often leads to success.

Interferences generated by fluorescent lamps are of magnetic origin and are usually effective because The lamps are located close to the ECG equipment. Simply switching on and off the lamp can determine whether such a lamp causes interference. This problem may be remedied by replacing the choke with a shielded version or by using a totally different kind of lamp.

The effects of other units may also be determined by simply switching them off. In this cases simply moving the units to another place is very often the easiest method to solve these kind of problems.

If interference is generated by large electrical units, changing the ECG room is usually the simplest and cheapest solution. In principle, every room may be shielded from external fields but the costs are To be considered. Very problematic is, when the fields are generated by large motors or transformers, i.e. when magnetic fields are involved. In this case mu-metal has to be used which is highly expensive.

AC interference due to earth circuit or incorrect grounding

This occurs when the protective earth is forming a closed ring. An interference voltage similar to a transformer is included in this loop. This can be remedied by interrupting of this loop somewhere. Earth circuits may be avoided by connecting each unit **only once** with a central earthing socket (normally on the ECG recorder).

Often, little attention is paid to grounding. You cannot depend on any socket outlet, especially not in old buildings where the earthing (connecting the grounded connection to the N-lead) was, and is still common.

In the interests of the patients and personnel (and not least for liability reasons), installation should be carried out according to the appropriate IEC regulations. Groundings over heaters or water pipes may indeed bring an improvement in AC problems but they are definitely not a permanent and safe solution as such installations are mostly only connected in the cellar to the house grounding and corrosion at the various sites can worsen electrical conductivity slowly but surely.

AC interference due to potential differences

Electrical consumers often cause a reduction in voltage along the power line which is often enough to generate interference in the ECG. This can also easily be resolved by connecting all units belonging to the ECG measuring station to **one** wall outlet.

Shaking

At first glance, shaking often appears to be AC interference. However, it may easily be distinguished if observed at a high paper speed rate. The frequency in this case is not constant, the amplitude and frequency of every wave is different.

„clean“ ECG



„shaky“ ECG

Shaking is based on interference voltages from the patients themselves. For example, when the patient is “cold”, the musculature is contracting. This contraction is controlled by currents from the brain which are, however, also taken up by the ECG electrodes. Another reason can be nervousness; in this case, interference voltage is generated by tensing of the muscles.

The first problem mentioned can be successfully remedied by heating of the investigation room. Additionally psychological methods have to be practiced in case of nervousness of the patient.

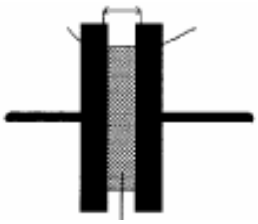
The patient surroundings can often help: An undisturbed view to a park, flowers or even just pictures on the walls are proven methods. The impression of an “investigational piece of machinery for patient processing” should be avoided in any case and at all costs. It has to been shown that even careful and invisible positioning of the different cables helps to avoid the impression that it has something to do with electricity (most people are afraid of electricity).

The creation of a quiet, familiar atmosphere by personnel is also very helpful. Explaining the treatment and investigation and indicating that the treatment is absolutely painless for the patient often induces the patient playing a cooperative part in the proceedings.

Zero line fluctuations (Base line shifts)

Zero line fluctuations are easily to be recognized by movement of the curve upwards or downwards.

Skin A Electrode



Contact medium

As is known from physics, the voltage at a capacitor changes when the distance between the boards changes. This is the most effect which induces zero line fluctuations. If the distance of the electrode button to the skin changes, a voltage of several tens of millivolts is generated. The capacitor has a voltage because two different materials which touch each other directly or via a dielectric form a voltaic cell, i.e. a battery. This is also the reason why good quality electrodes exclusively use silver-silver chloride (Ag-AgCl) as a contact medium. This material is very sensitive when touched, to sunrays, to chemical decomposition, etc. but it has an electrochemical voltage most similar to that of the skin. When this material is going to be used, the voltage generated between the skin and the electrode is minimal.

In principle, a constant DC voltage generated between the skin and the electrode is safe as it can be effortlessly compensated by the input amplifier of the ECG recorder. However, fluctuations in this DC voltage cannot be compensated as they are in the same frequency range as the ECG itself and all of these fluctuations are the stronger the higher the voltage.

D.C. voltage with constant distance	Fluctuation by distance change in %	Absolute Fluctuation
10 mV	10%	1 mV
50 mV	10%	5 mV

Thus use of good quality electrode material and secure fastening (hook up) of the electrode onto the skin is indispensable for stable zero-line leads.

Troubleshooting

As the types of interferences described above have a different effect on all electrodes, the following analysis table is useful. It shows the disturbed electrode in connection with the disturbed leads.

1. Analysis of the limb electrodes using the lead diagram according to Einthoven.

Lead I	Lead II	Lead III	Disturbed electrode
disturbed	disturbed	OK	right arm
disturbed	OK	disturbed	left arm
OK	disturbed	disturbed	left leg
greatly dist.	disturbed	disturbed	right arm and left arm
disturbed	greatly dist.	disturbed	right arm and left leg
disturbed	disturbed	greatly dist.	left arm and left leg
Identical interference in all three leads			right leg

2. Analysis of the precordial electrodes

Before the precordial electrodes are analysed, the limb electrodes have perfectly to operate as the leads according to Wilson refer to the limb electrodes.
Then analysis is simple: When lead VI is disturbed, there is an interference in electrode VI, etc.

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