

## Technical contribution

# INTERFERENCE SUPPRESSION FOR EEG RECORDING DURING OPEN HEART SURGERY

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## Introduction

During the last 10 years open heart surgery has become increasingly important in the treatment of coronary disease. To ensure that the patient is under optimal condition during surgery, various parameters such as blood and body temperatures, systolic, diastolic and venous pressures, EEG, ECG, pump flow and oxygen saturation are monitored. Due to the complex galvanic circuitry around the patient, interference may easily occur when small signals such as ECG and EEG are recorded. Moreover, it is necessary to protect the patient from damage by electrical currents.

For these reasons, it is necessary to isolate electrically the input circuits of both the signals mentioned above. It is well known that ECG and EEG signals may be greatly disturbed during diathermal coagulation. This situation often occurs, especially when coronary bypass surgery is performed. To obtain usable records of EEG signals and to perform automatic signal analysis, even in these circumstances, we developed a new measuring device.

## Description

The apparatus is mounted in two separate boxes. The first contains the RF filters, preamplifiers, photon couplers and an impedance-check circuit, the second houses rejection filters, bandpass filters (0.5–30 Hz), buffer amplifiers and the power supply. The preamplifier box is installed just beneath the operating table at the patient's head end and permits the recording of 4 EEG derivations. A cable 15 m long connects the preamplifiers with the filter box, which is placed in the monitoring room. Recording of the EEG signals takes place in the monitoring room with a Siemens-Eléma recorder. The recording sensitivity is generally fixed at  $50 \mu\text{V}$  for 1 cm deflection.

## Electronic circuits

A simplified diagram of the preamplifier is shown in Fig. 1. The first amplifier, A (Burr Brown, model 3621), is DC coupled with the electrode input terminals via an RF filter.

This RF filter suppresses the high frequency signals originating from the diathermy apparatus with an attenuation of approximately 80 dB in the frequency range of 100 kHz–5 MHz. The phase shift and attenuation of low frequencies, especially in the EEG range, have been kept to a minimum to prevent deterioration of the common mode rejection ratio of the instrumentation amplifier. Besides the filter requirements, input chokes are also present to limit the RF current through the patient leads.

To achieve greater safety for the patient, all input circuitry is powered by a DC-DC converter (E) and signal transfer is achieved by photon couplers (F). After high-pass filtering (cut-off frequency 0.32 Hz), the EEG signal is amplified to about 34 dB (B). In the 2nd stage the total gain of the preamplifier can be trimmed to 60 dB.

It was found that, presumably due to the special conditions and the relatively long durations of the surgical intervention, the DC offset voltage of the electrodes could vary considerably. Therefore, in order to keep the amplifier A1 within the normal working range, the gain was limited to 40 dB, on the basis of practical experience.

To check all 4 EEG channels during operation, a small DC current (I) can be applied to the offset output terminal of amplifier A. The resulting step function output signal corresponds with an EEG amplitude of  $50 \mu\text{V}$  at the amplifier input. The operator in the monitoring room can activate this check function by a simple press on a button.

At the front of the preamplifier box a rotating switch permits selection of the electrodes singly for impedance checking (not shown on schematic dia-

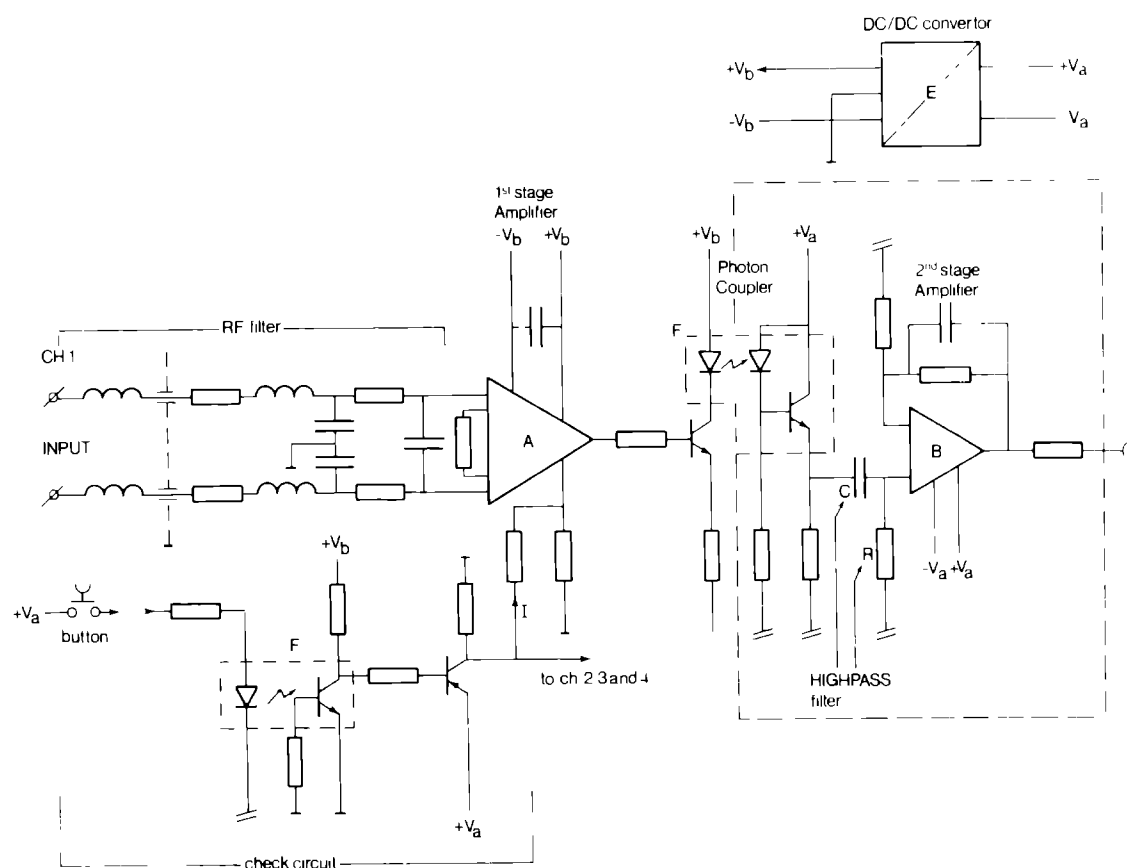


Fig 1 Simplified diagram of the preamplifier consisting of RF filter, 1st and 2nd amplifier stages, photon coupler and check circuit. For detailed description see text

gram) By means of a simple 14 Hz sine wave generator, a  $10\ \mu\text{A}$  current is fed into the selected electrode.

The resulting 14 Hz signal amplitude between the selected electrode and a common reference electrode (usually fixed on the shoulder of the patient) is amplified, rectified and smoothed. A level detector (Texas Instruments, type SN16889) indicates which impedance level is measured. A die-cast aluminium box, galvanically connected to the patient circuit, contains the preamplifier circuit. The output circuit, however, is provided with a shield inside the preamplifier box in order to suppress its sensitivity to amplitude-modulated RF signals.

A small box containing the power blocks and the print boards for filtering the EEG signals is fixed to the wall of the monitoring room. Each print board contains a low-pass filter (30 Hz, with 12 dB/octave slope), a high-pass filter (0.5 Hz with 6 dB/octave slope) and a notch filter to reject mains interference at 50 Hz.

The EEG signals are further amplified for paper recording and for signal analysis (Pronk et al 1978).

## Results

Due to the complexity of the electrical circuits surrounding the patient on the operating table, it was almost impossible to carry out dummy experiments. Furthermore, the disturbance in EEG signals may be dependent on the specific make of electrosurgical equipment, the method of operation, the energy level applied and the area of operation. Therefore, we carried out some experimental EEG recordings during similar types of operation in the same operation theatre.

For practical reasons, we could not compare the results obtained with our special device with those obtained with a standard EEG during one operation. Therefore, each record shown is from a different

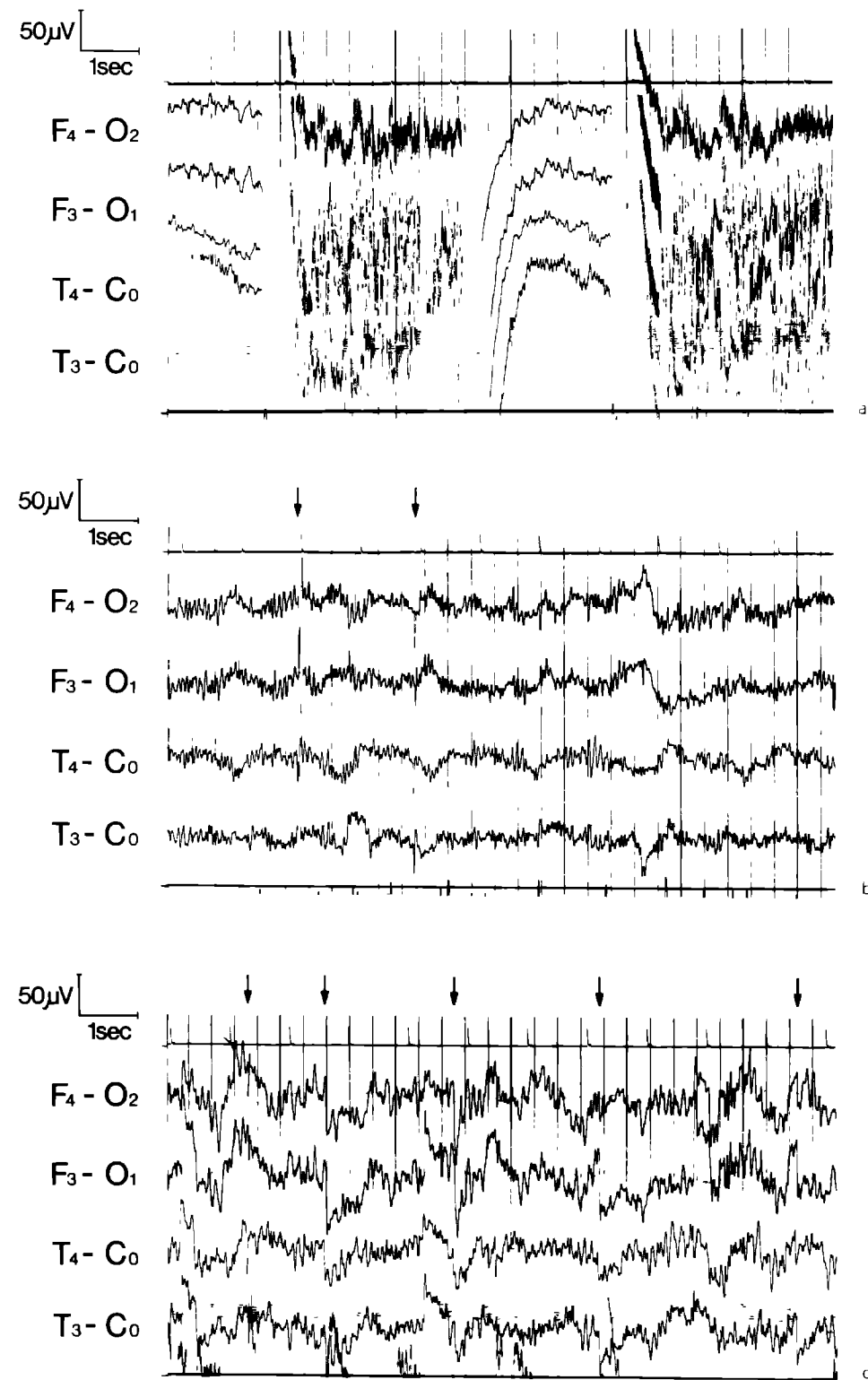


Fig 2 a: 4 derivations recorded during electrocauterization with a standard Siemens-Elema EEG machine. b. 4 derivations recorded with the experimental preamplifier as described in this article, the arrows indicate moments of switching the electrocautery on and off c: as b, under unfavourable circumstances.

patient. Fig. 2a shows derivations  $F_4-O_2$ ,  $F_3-O_1$ ,  $T_4-C_0$  and  $T_3-C_0$  recorded with a standard Siemens-Eléma EEG recorder. All input amplifiers are overloaded for some seconds when diathermy is switched on and switched off, while the EEG is completely disturbed by interference signals during the active period of diathermy. Fig. 2b and 2c present results obtained with the system described. In Fig. 2b, the diathermy responses indicated by arrows in the record have relatively small amplitudes and durations of less than 100 msec. So diathermal energy hardly disturbed the EEG recording in this situation.

Less favourable circumstances, as shown in Fig. 2c, may also occur. A low frequency interference component occurred due to intermittent diathermy. However, the authors believe that, by making some minor modifications, this type of interference could also be sufficiently suppressed. The results obtained so far during 30 open heart operations show that the signal disturbances due to RF interference are generally of the same quality as presented in Fig. 2b and 2c.

Therefore, it seems that this method of filtering has greatly contributed to reliable performance of automatic processing of EEG signals during open heart surgery.

### Summary

A device for recording the EEG during open heart surgery is described. It differs from most standard equipment in two ways. First, the input circuit is completely floating from earth and will withstand

500 V DC. Second, radiofrequency (RF) shielding and filtering permits continuous recording of the EEG during electro-surgery in the operating room. The almost undisturbed recording permits on-line continuous EEG monitoring by means of quantitative signal analysis methods.

### Résumé

*Dispositif supprimant les parasites lors d'enregistrements EEG en chirurgie à coeur ouvert*

Un dispositif est décrit, qui permet l'enregistrement EEG en chirurgie à coeur ouvert. Il se distingue de la plupart des équipements standards à 2 égards (1) le circuit d'entrée est complètement flottant par rapport à la masse, et peut supporter 500 V DC, (2) un blindage contre les fréquences radio et un filtrage permettent l'enregistrement continu de l'EEG en salle d'opération même pendant l'usage du bistouri électrique. L'obtention d'un tracé pratiquement normal permet un contrôle EEG continu et l'analyse quantitative du signal.

### Reference

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