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MEASUREMENT OF THE FETAL MAGNETOCARDIOGRAM IN TAMPERE MAGNETICALLY SHIELDED ROOM

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Introduction

Fetal magnetocardiography (FMCG) is a non-invasive method for detecting the electrical status of the fetal heart. The FMCG was first observed by Kariniemi et al /1/, who used the FMCG for quantification of the fetal heart rate variability. The regularity of the heart rate is an indicator of proper oxygen supply to the fetus. Detection of the weak fetal electrocardiogram (FECG) is sometimes impossible because it is disturbed by the stronger ECG of the mother. The insulating effect of the abundant vernix caseosa may also cause the FECG to weaken or even disappear during some period of gestation /2/. In FMCG the disturbing effect of the maternal heart activity is usually negligible. We have measured the FMCG of a fetus of 37 weeks' gestation in Tampere magnetically shielded room.

Instrumentation

A gradiometer type superconducting magnetometer was used for FMCG recording. Figure 1 illustrates the principle of the measurement. The SQUID and the detector coil were immersed in liquid helium inside the dewar. The dewar was placed above the mother's abdomen close to the fetal heart without any contact with the mother. The detector coil was an asymmetric first-order gradiometer. Its lower pick-up coil was 28 mm and the upper coil 48 mm in diameter. The baseline was 160 mm. The gradiometer was balanced in three orthogonal directions

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with thin superconducting plates by using a slowly varying homogeneous magnetic field. The achieved balance was of the order of 10^{-5}. A commercial rf SQUID electronics part was used. The noise level of the system was as low as 50 $fT_{rms}/\sqrt{Hz}$ including the externally coupled magnetic noise. The bandwidth was 1-100 Hz. A digital notch-filter was used for attenuating the line frequency component and its harmonics. The measurements were carried out in magnetically shielded room /3/.

Results

A typical real time FMCG recording is presented in Figure 2. The QRS complex of the FMCG is biphasic and about 3 pT in height. The fetus was lying head downwards and right side anteriorly. The ECG of the mother was measured simultaneously. When comparing these two recordings we can see that the effect of the maternal magnetic signal is negligible in FMCG. A relatively high lower cut-off frequency of 1 Hz was used for attenuating the low frequency noise caused by mother's breathing and movement of the fetus. The signal-to-noise ratio was not good enough for real time measurement of the P- and T-waves.

Discussion

According to the lead field theory /4/ the FMCG seems to be very useful method for fetal heart activity investigation because the volume conductor formed by the abdomen is relatively homogeneous and the insulating layers which exist are spherical symmetric to the fetus. The magnetic field decreases much more strongly as a function of the distance between the source and the detector than the electric potential. This effect together with the use of gradiometer makes it possible to measure the FMCG without mother's signal. Recording

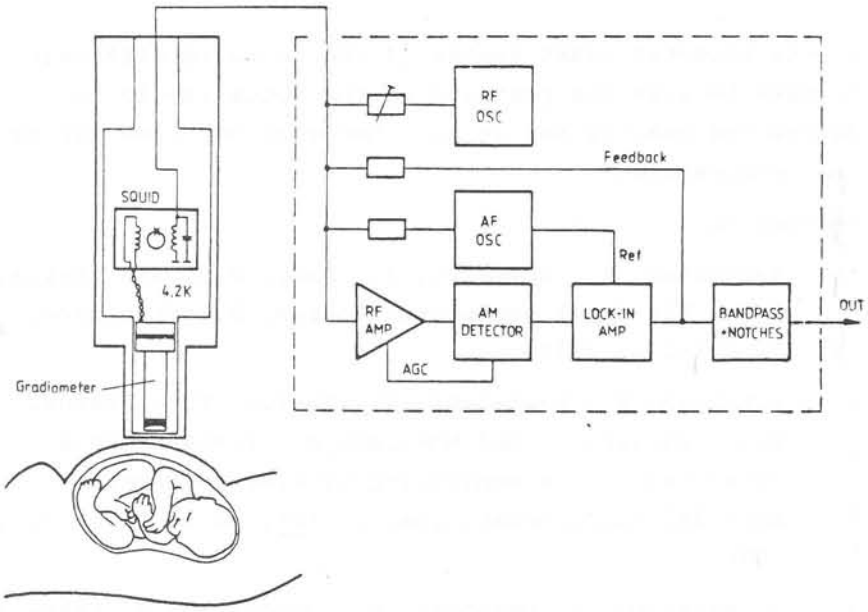

Figure 1. The recording of the FMCG with a superconducting gradiometer. The detector was placed as close to the fetus as possible with no contact to the mother.

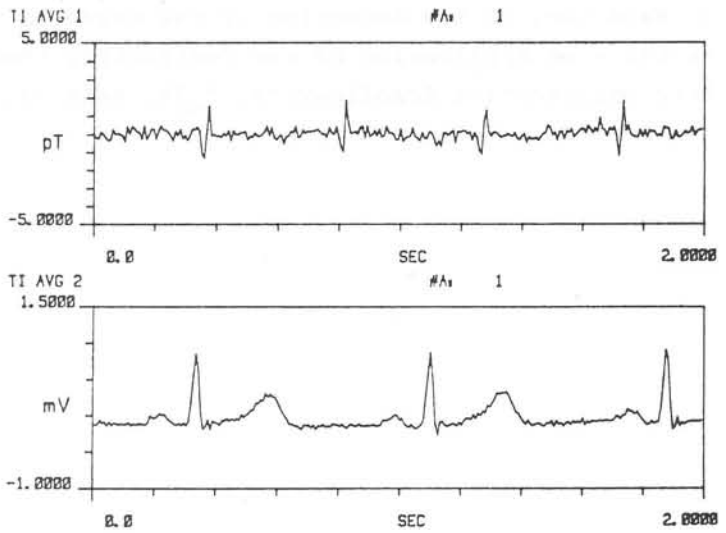

Figure 2. Measured fetal magnetocardiogram (upper trace) and simultaneously measured mother's ECG (lower trace).

of the magnetic heart vector of the fetus is difficult to make because the position of the fetus should be determined exactly and it may change at any time during the measurement.

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