MEASUREMENTS OF ELECTROMAGNETIC ACTIVITIES OF THE HUMAN BODY IN THE FREQUENCY REGION 1 kHz - 2 GHz.

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Measurements of electromagnetic fields from the human body have been made extensively in the infrared region and at very low frequencies (around 1 Hz, EEG,ECG,EMG). Recently microwave radiation has been measured using microwave radiometers. The results indicate that the human body is only emitting thermal radiation except at very low frequencies (below 10^4 Hz).

The purpose of our experiments was to cover the frequency region 10^3 - $2 \cdot 10^9$ Hz where very few reliable investigations seem to have been made.

To investigate the emission of electromagnetic waves in this wide frequency range we designed a number of tunable radiometers. The general principle of these was a comparison of the noise power obtained from an antenna connected to some part of the human body with the noise power from a reference impedance. At frequencies above 10^8 Hz the antenna consisted of a loop about 1 cm in diameter connected to a coaxial cable. The loop was placed in close contact with some part of the human body. At frequencies below 10^8 Hz the antenna was a pair of EEG or ECG electrodes.

Our results show that the human body acts as a purely thermal radiator down to about 10^4 Hz. Below 10^4 Hz the high frequency components of EMG and similar signal rise above the thermal level. Many different positions on the body were tried as the head, the chest and the arms. For all positions the radiation temperature was equal to the body temperature at frequencies above 10^4 Hz.

Measurements of electromagnetic activities of the human body in the frequency region 1 kHz - 2 GHz.

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Electromagnetic fields known to be generated by the human body have mainly two sources. One is the random thermal motion of the charged particles of the body, which generate weak electromagnetic fields over the entire frequency spectrum. This phenomenom is called thermal radiation or thermal noise and the emitted power is given by Planck's law. The other source is the more orderly motion of charged particles, mainly ions, in nerves and muscles, connected with the communication system of the body. These signals are slowly varying and can be measured above thermal noise only at low frequencies $1\text{-}10^4$ Hz. Measurements of electromagnetic fields created by the human body have been made extensively in the infrared region and at frequencies around 1 Hz (EEG, ECG, EMG).
Recently several investigations of radiation in the microwave region have also been published (1). The only deviations from thermal radiation have been found in the frequency region below a few kHz.

The aim of our experiments has been to investigate the frequency region 10^3 Hz - $2 \cdot 10^9$ Hz where almost no reliable investigations seem to have been made. For this purpose we designed a number of tunable radiometers operating in this frequency band. The noise from a human was coupled to the radiometer by an antenna which at frequencies above 10^8 Hz consisted of a loop about 1 cm in diameter connected to a coaxial cable. The loop was placed in close contact with some part of the human body. At frequencies below 10^8 Hz the antenna was a pair of EEG or ECG electrodes.

A summary of the results of a large number of measurements made during the years 1973-1976 is shown in Fig.1. The solid curve is obtained at most locations of the body when muscles are contracted. The dashed curve gives the low frequency fields when a muscle close to the electrodes is relaxed. Most of the measurements were made on the authors themselves, but some measurements have been made on colleagues in our laboratory. Some of the measurements were made at night when the subject was asleep. The curve is based both on highly accurate measurements of radiation temperature at a large number of frequencies and on swept measurements where the entire frequency band was swept continuously with sensitive low noise receivers to look for deviations from thermal radiation.

As seen from the curve the human body seems to be a purely thermal radiator at frequencies above 10^4 Hz.

Many different positions on the body were tried as the head, the chest and the arms. For all positions the radiation temperature was equal to the body temperature at frequencies above 10^4 Hz.

Below frequencies of the order 10^4 Hz the electromagnetic emission of the body raises above the thermal level. This is caused by the same electromagnetic phenomena that are observed in EEG, EMG and ECG.

The detailed behaviour of the curve in the low frequency region depends on the type of electrodes used on the location of the electrodes and also on the state of the human body. The highest noise magnitude is obtained for coaxial needle electrodes inserted inte some muscle. The magnitude on electrodes placed on the lower

part of the arm increases when a muscle is contracted. The general behaviour of the spectra agrees with that obtained by earlier investigations in the low frequency region. (2)

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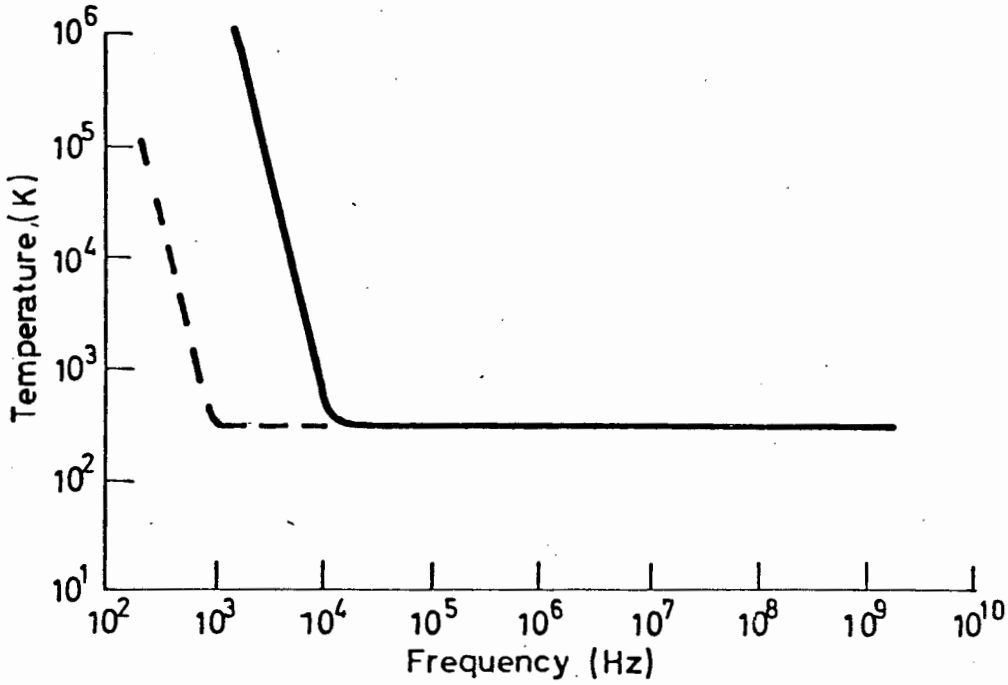
2. See e.g. I.Gath and E.V.Stålberg, "Techniques for improving the selectivity of electromyographic recordings", IEEE Trans. Biomed. Eng, vol BME-23 pp.467-472, Nov. 1976.


Temperature (K)
10^6
10^5
10^4
10^3
10^2
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^{10}
Frequency (Hz)

Figur 1.