MEASUREMENT AND ANALYSIS OF HUMAN PERCEPTION THRESHOLD OF ELF ELECTRIC FIELD

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1. Introduction

Today, we are living in natural and artificial electromagnetic fields. With the rapid increase in the power of electric facilities and electric equipment in our environment, there has been a growing interest in the biological effects of ELF (Extremely Low Frequency, particularly DC, 50Hz and 60Hz) electric fields. Great importance has been placed on a safety assessment of high voltage transmission lines, and extensive studies have been conducted [1-3]. The World Health Organization (WHO) published a health criteria for the exposure to ELF electric fields [4]. However, many important points concerning the biological effects such as threshold and mechanism remain unknown.

Among several possible mechanisms, there is a mechanism in which ELF fields apparently interact with living systems to produce effects [2]. The mechanism is the stimulation of neural receptors at or near the surface of the skin. Humans and animals can sense the presence of a field with this mechanism. By dissecting individual neurons from the spinal columns of live cats, the response was measured from a tactile neural sensor in the animal's paw when it was exposed to strong electric fields [5,6]. The possibility that this sensation induces physiological or psychological effects in the exposed body can still not be denied. Thus, the threshold level of field perception has been considered as one of the most important factors in establishing a safety standard for field exposure [4].

The threshold values of field perception have been investigated and different values have been reported [7-9]. In these studies, the following facts have been found. The threshold was lower among men than women. It was lower on rainy days than fair days, and in summer than in winter. These results imply that the biological effects vary according to different conditions and thus, the safety standard must differ accordingly.

Considering the importance of this problem, we have developed the measurement techniques of the electric field exposed to biological bodies [10-12]. And we have reported that the main mechanism of human perception of electric field is due to the movement of hairs, and that the perception-threshold changes by the relative humidity[13]. This paper presents the measurement technique of the perception-threshold and experimental analysis on the cause of the threshold variation.

2. Measurement of Human Perception Threshold

2.1 Measurement System and Method

Fig.1 illustrates the measurement system schematically. An electric field was generated by applying a constant DC voltage (0 - ±10kV) between a pair of plane parallel electrodes (110mm square, 20mm distance). There was a circular hole of 30mm in diameter in the center of the lower electrode, and the electric field was able to be exposed on the outer surface of the human forearm. The environmental condition of a hair was controlled by keeping the arm in the container of a thermohygrostat for a certain period. Using a CCD camera and a VTR, the movement of the hair was recorded for a future analyses.

Using this system, a human perception-threshold of an electric field was measured. The threshold was determined to be the minimum field intensity with which the subject started perceiving the field. In the measurement, we tried not to give any audiovisual cues to the subject. The experimenter operated the power source and switches behind the wall in a different room. Further, the subject put on an eyemask and a headphone to control audiovisual interferences.

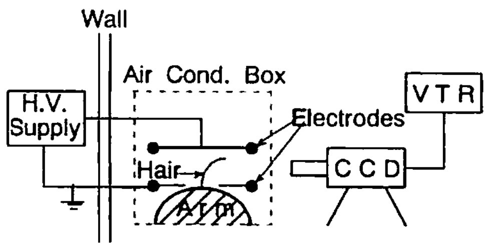

Fig.1 Measurement system.

2.2 Results of Measurement

Fig. 2 illustrates the averages and the standard deviations of the perception-thresholds of 15 male and 13 female subjects. As the relative humidity increased from 50% to 90%, the threshold decreases by almost 30%. This result directly verifies the fact that we cannot neglect the effect of a relative humidity to consider the biological effects of an electric field.

Above results suggested that there are a sex difference and an individual difference in the threshold values. To investigate the differences, the effects of a hair length and a hair

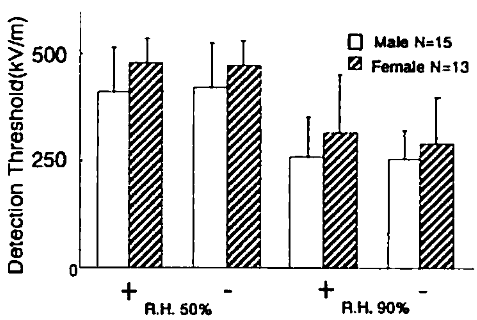

Fig.2 Measured results of detection threshold of electric field.

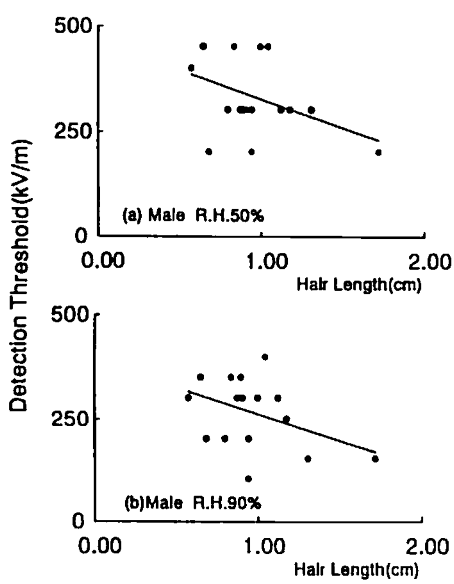

Fig.3 Dependence of detection threshold on hair length.
(a) R.H. 50% (b) R.H. 90%

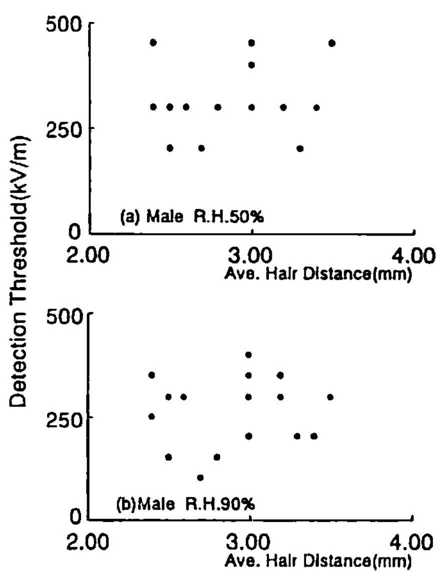

Fig.4 Dependence of detection threahold on hair density.
(a) R.H. 50% (b) R.H. 90%

density to the threshold value were analyzed. Figs. 3 and 4 show the dependence of the threshold on the hair length and the hair density, respectively. As can be seen in Fig.3, a weak negative correlation was found between the hair length and the threshold value. This suggested that the subject with longer body hair was more sensitive to the electric field. This seemed to be the cause of the less threshold of the male subjects than the female subjects which was seen in Fig. 2. In Fig. 4, we could not see any clear dependence. As to the hair density, further study is required to reach any conclusion.

3. Dependence of Detection Threshold on Body Hair Conditions

3.1 Method

To clarify the cause of the variability of detection threshold, the dependence of the threshold on the body hair conditions was further investigated. The following measurements of the detection threshold were conducted to differentiate the effects of the ambient humidity, the sex difference of subjects, the hair length and the hair density.

Fig.5(a) illustrates experimental conditions. The case I is a natural hair condition without any processing added on the hair. The hair lengths of subjects were 15-17mm and the distances between the hair(inversely corresponds to the hair density) were 2.8-3.1mm. The case II is the case in which the hair was cut in a half length. The case III is the case in which half of the hair was extracted to make the distance twice as large. In the case IV, the both processing(cut and extraction) were applied on the hair.

3.2 Results of Measurement

The results of the measurement were summarized in Fig.5(b). This figure shows the perception thresholds of 20 male and 10 female subjects in different hair conditions. The uncertain tops of the bar graph indicate that no subject perceived the field even with the maximum field strength possible with our experimental system.

In this figure, we can see distinct change of threshold due to the change in the relative humidity from 50% to 90%. We have previously reported that the dielectric constant of the body hair increased with the ambient relative humidity, and that the electric force applied on the hair increased accordingly. These facts well explain the threshold change found in this experiment.

Although it was not as distinct as the humidity, the relatively less thresholds were observed with the longer and the more hair. As to the sex difference, it was difficult to find any statistically significant difference. However, it seems that the female threshold became relatively lower than the male threshold in the case of short hair(case IV). We consider that the intrinsic sensitivity of female subject might appear when the difference of body hair became small.

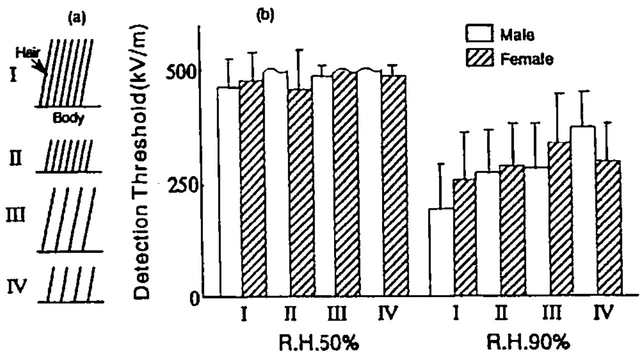

Fig.5 Dependence of threshold on different conditions:
(a) Conditions of body hair.
(b) Results of measurement.

4. Conclusions

For the study of the biological effects of an electric field, the human perception-threshold was investigated. It was found that the threshold depended on the physical conditions of the body hair such as the relative humidity of ambient air and hair length. Among the examined conditions, the dependence on the relative humidity was most distinct. The threshold becomes about 30% low when the relative humidity changes from 50% to 90%. The sex difference and the individual difference of the perception-threshold can be ascribed to the difference in the length of the body hair.

The results obtained in this study suggested the following point. That is, to establish the safety standard for field exposure, the two factors have to be taken into account. They are the relative humidity around the human body hair, and the physical condition of the hair such as the length of the hair.

In addition, the results obtained in this study will provide the important information for further researches. Particularly, it is expected that these results will shed a new light on the controversy about the reproducibility of the reported biological effects of an ELF electric field.

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