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A TRIAL ON HIGHER ORDER MUTUAL CORRELATION FOR ACOUSTIC AND ELECTROMAGNETIC ENVIRONMENT AROUND VDT

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Nowadays, owing to the rapid and wide application of many type information technology equipments, we are always exposed to acoustic and electromagnetic waves. For evaluating step by step these complicated accumulative and multiplicative effects, it is first important to extract the correlation information among them as deeply and quantatively as possible. In this paper, some new trial of hierarchically evaluating mutual correlation between them is proposed based on the conditional probability density function form derived from a statistical type Hermite series expansion expression for the two-variate joint probability density function. The proposed method has been experimentally confirmed by applying it to the actual environment around VDT.

1. Introduction

At present, since many types of information technology equipments like personal computer and the portable radiophone are widely and rapidly spread, we are always exposed to acoustic noise and electromagnetic (abbr. EM) waves regardless to our intention. In such wave motion type environment, it is difficult and important to clarify not only the individual effect but also accumulative and multiplicative effect caused by acoustic and electromagnetic waves. Up to now, many researches reported in an individually separated field of acoustic and EM types. Especially if citing a basic example of EM environmental researches, its standard type of theoretical analysis has been greatly progressed by D. Middleton [1, 2]. However, for this complicated mutual correlation problem, not only concrete physical factors but also higher order type functional and/or psychological factors should be considered together. Although many factors, sometimes an organic effect [3] should be considered, in this paper, by focusing on the mutual correlation between acoustic and EM waves, as an early stage of study, some new trial on how to evaluate mathematically-statistically the higher order mutual correlation effect between them is first discussed in the real environment measurement. Then, for step by step grasping some whole compound image of individually separated factor, the probability distribution is employed as the first stage of study on accumulative description of fluctuation. However, since originally these fluctuate respectively in a non-Gaussian distribution form, it is difficult to find such mutual correlation effects minutely only by employing the usual standard type correlation analysis in terms of linear and/or nonlinear type regression functions. More concretely, a trial on stohastic evaluation method for finding this correlation information as minutely and hierarchically as possible is proposed. That is, the joint probability density function (abbr. p.d.f.) of two-variate fluctuation factors is first expressed in a statistical type Hermite series expansion form. By using this probability expression, a general expression of the conditional probability distribution, reflecting various types of mutual correlation information between two-variate fluctuation factors, is explicitly derived. This leads to an extended regression function reflecting hierarchically not only the lower order but also the higher order mutual correlation informations. Moreover, this can be used to estimate the probability distribution form of another fluctuating factor from the data of one factor. Finally, the effectiveness of the proposed method is partly confirmed experimentally too by applying it to the real compound environment measurement of acoustic and EM waves leaked from VDT under playing the game on a personal computer.

2. Mutual correlation analysis between acoustic and EM waves

For the evaluating of the total compound effect caused by the acoustic and EM waves, it is first necessary to grasp step by step the mutual correlation information between environmental factors as minutely and hierarchically as possible. Since originally these environmetal factors fluctuate in a non-Gaussian distribution form, it is difficult to find this correlation minutely only by employing the usual standard type correlation analysis in terms of linear and/or nonlinear type regression functions. So, first, let us derive a new general regression function between two random variables. Assuming that $P(x,y)$ and $P(x)$ denote the joint p.d.f. of x and y, and the p.d.f. of x, respectively, it is well known that the regression function of y with respect to x can be originally determined by the conditional p.d.f., $P(y|x)(= P(x,y)/P(x))$, of y conditioned by x. In order to get the hierarchical type of general expression for this conditional p.d.f., let us expand it into the orthonormal series expansion form [4]:

$$P(x,y) = P_0(x)P_0(y)\sum_{m=0}^{\infty}\sum_{n=0}^{\infty} A_{mn}\varphi_m^{(1)}(x)\varphi_n^{(2)}(y) \tag{2.1}$$

with

$$A_{mn} = \left\langle \varphi_m^{(1)}(x)\varphi_n^{(2)}(y) \right\rangle, \tag{2.2}$$

where $\langle\ \rangle$ denotes the expectation operation with respect to x and y, and $\varphi_m^{(1)}(x)$ and $\varphi_n^{(2)}(y)$ denote orthonormal functions with weight functions $P_0(x)$ and $P_0(y)$, respectively.

By using Eq. (2.1) and the definition of the above conditional p.d.f, we direcly obtain

$$P\left(y|\, x\right)=\frac{P_0(y)\sum\limits_{m=0}^{\infty}\sum\limits_{n=0}^{\infty}A_{mn}\varphi_m^{(1)}(x)\varphi_n^{(2)}(y)}{\sum\limits_{m=0}^{\infty}A_{m0}\varphi_m^{(1)}(x)}. \tag{2.3}$$

In the similar way, the conditional p.d.f. $P(x|y)$ of x conditioned by y can be obtained. Next, let us derive the regression function to grasp the average tendency between x and y based on the above expression of the conditional p.d.f.. In order to derive the regression function y^k $(k=1,2,\ldots)$ with respect to x, in advance, let us expand y^k by use of the above orthogonal function

$$y^k=\sum_{i=0}^{k}C_{ki}\varphi_i^{(2)}(y). \tag{2.4}$$

By calculating the conditional expectation $\langle y^k|x\rangle$, we can obtain explicitly the expression of the regression function

$$\left\langle y^k \mid x\right\rangle=\frac{\sum\limits_{m=0}^{\infty}\sum\limits_{n=0}^{k}C_{kn}A_{mn}\varphi_m^{(1)}(x)}{\sum\limits_{m=0}^{\infty}A_{mn}\varphi_m^{(1)}(x)}. \tag{2.5}$$

Especially, when Gaussian distribution forms are chosen as $P_0(x)$ and $P_0(y)$, the following expression for the case $k=1$ in Eq. (2.5) can be derived:

$$\langle y \mid x\rangle=\mu_y+\sigma_y\frac{\sum\limits_{m=0}^{\infty}A_{m1}H_m\left(\dfrac{x-\mu_x}{\sigma_x}\right)\Big/\sqrt{m!}}{\sum\limits_{m=0}^{\infty}A_{m0}H_m\left(\dfrac{x-\mu_x}{\sigma_x}\right)\Big/\sqrt{m!}}, \tag{2.6}$$

where $H_m(\,)$ denotes the m-th order Hermite polynomial [5]. In the similar way, we can derive the inverse regression function. Furthermore, by employing mutual correlation informations, not only the regression function but also the whole probability distribution form can be estimated. Upon integrating Eq. (2.3) with respect to x, it can be expressed as follows:

$$P_s(y)=P_0(y)\sum_{i=0}^{\infty}E_i\varphi_i^{(2)}(y) \tag{2.7}$$

with

$$E_i=\left\langle\sum\limits_{m=0}^{\infty}A_{mi}\varphi_m^{(1)}(x)\Big/\sum\limits_{m=0}^{\infty}A_{m0}\varphi_m^{(1)}(x)\right\rangle_x, \tag{2.8}$$

where $P_s(y)$ denotes the estimated p.d.f. of y and $\langle\,\rangle_x$ denotes an expectation operation with respect to x. When two Gaussian distribution forms are chosen as $P_0(x)$ and $P_0(y)$, these are concretely given as follows:

$$P_s(y)=\frac{1}{\sqrt{2\pi}\sigma_y}e^{-\frac{(y-\mu_y)^2}{\sigma_y^2}}\left\{1+\sum_{i=1}^{\infty}E_i\frac{H_i\left(\dfrac{y-\mu_y}{\sigma_y}\right)}{\sqrt{i!}}\right\} \tag{2.9}$$

with

$$E_i = \left\langle \frac{\sum\limits_{m=0}^{\infty} A_{mi} H_m \left(\dfrac{y-\mu_y}{\sigma_y} \right) \Big/ \sqrt{m!}}{\sum\limits_{m=0}^{\infty} A_{m0} H_m \left(\dfrac{y-\mu_y}{\sigma_y} \right) \Big/ \sqrt{m!}} \right\rangle . \tag{2.10}$$

3. Application to acoustic and EM wave environment leaked from VDT

By expecting faintly that this method may be a help for some explanation of the VDT syndrome as the first stage of quantative, we have applied the proposed method to the environment under the exposure of the acoustic noise and EM wave leaked from VDT under playing the game on a personal computer. We have experimented in an anechoic room. In the experiment, the sound pressure level and the rms-value of the electric field have been sampled at every 10 seconds and 500 sets of data have been obtained. Then, we have employed a HI-3603 VDT/VLF Radiation Survey Meter (Holaday Industries, Inc.) for the measurement of the electric field strength. Though quite different from this method, one of authors, M. Ohta had previously reported another type of evaluation methods [6, 7], especially in an EM field, its experimental setup is almost the same as the present study. By applying Eq. (2.6) and the reverse expression to the first 400 sets of data, we have obtained the regression curves of the sound pressure level to electric field strength and then the electric field strength to sound pressure level. These theoretical curves have been compared to experimental conditional expectations. The results are shown in Figs. 1 and 2. These theoretical regression curves in each figure have been calculated by truncating the series form in the denominator up to the 8-th order polynomial and taking the first expansion term, from the first term to the 2nd term, from the

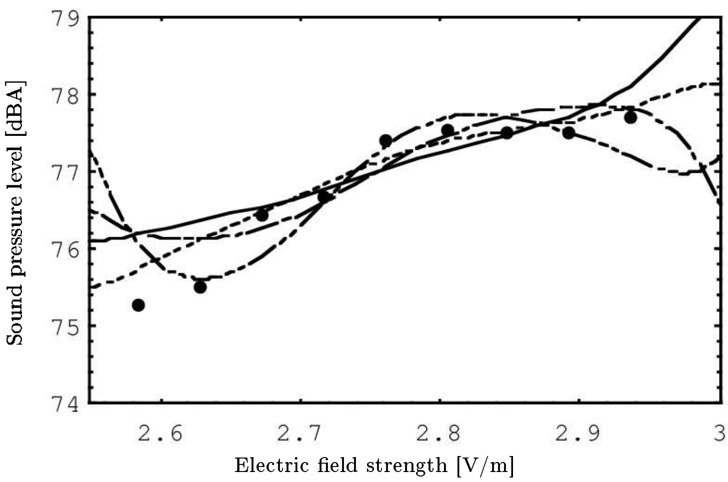

Fig. 1. A comparison between theoretical regression function of sound pressure level to electric field strength [1 st approximation (———), 2 nd approximation (— — —), 3 rd approximation (— - —), 4 th approximation (— - - —)] and experimental conditional expectations (•).

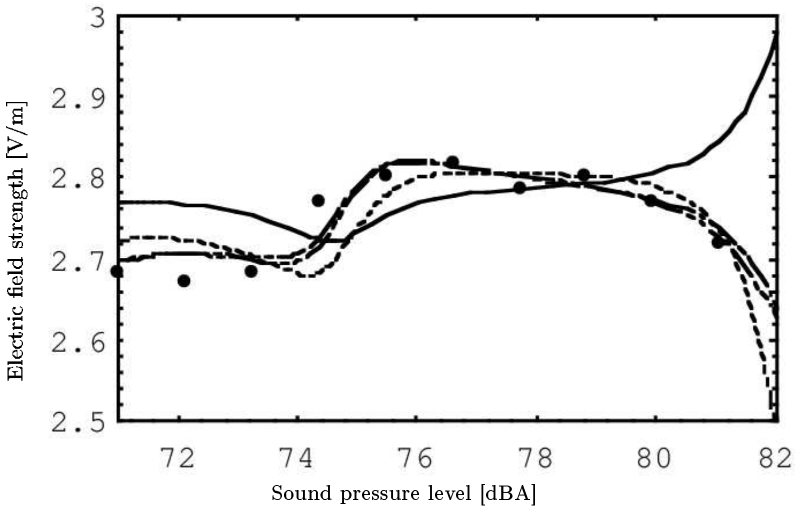

Fig. 2. A comparison between theoretical regression function of electric field strength to sound pressure level [1 st approximation (———), 2 nd approximation (— — —), 3 rd approximation (— – —), 4 th approximation (— – – —)] and experimental conditional expectations (•).

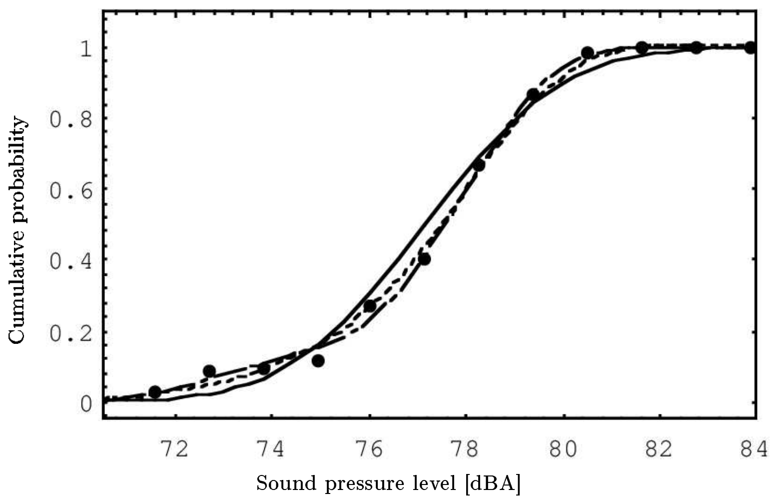

Fig. 3. A comparison between the theoretically estimated cumulative probability distribution curves of sound pressure level based on the electric field strength fluctuation [1 st approximation (———), 4 nd approximation (— — —), 7 rd approximation (— – —)] and experimentally sampled values (•).

first term to the 3rd term and from the first term to the 4th term in the series form of the numerator for the 2nd term of the righthand side in Eq. (2.6) and furthermore the reverse regression function type expression. They are called the 1st approximation, the 2nd approximation, the 4th approximation. Next, by applying Eqs. (2.9) and (2.10) to the first 400 sets of data, we have estimated the probability distribution of the sound pressure level based on the electric field strength fluctuation and that of the electric field strength based on the sound pressure level fluctuation. Then, we have employed lower and higher order mutual correlation information A_{mn}. Only one of our results is shown in Fig. 3. The theoretically estimated cumulative probability distributions have been calculated by replacing the series of the righthand side in Eq. (2.9) with no term, from the first term to the 3rd term and from the first term to the 6th term; they are called the 1st approximation, the 4th approximation and the 7th approximation. Then, E_i has been calculated by truncating the series of the denominator up to the 8-th polynomial and the series of numerator up to the 6-th polynomial in Eq. (2.10).

4. Conclusion

First, theoretically, some new trial has been proposed especially based on the conditional probability density function form derived from a statistical type Hermite series expansion expression for the two-variate joint probability density function. The proposed theoretical method has been confirmed experimentally too by applying it to the actual environment on the acoustic and EM wave environment leaked from VDT. In the experiment, although each environmental factor has fluctuated in a non-Gaussian distribution form and the linear correlation quantity has been rather small, especially by employing many of higher order mutual correlations according to the proposed method, the whole probability distribution could be explicitly estimated. That is, it has been obviously shown that the proposed method is fairly useful for the quantative evaluation of the mutual correlation for the environment evaluation under exposure to acoustic and EM waves.

Appendix I. Practical implication surrounding our rearch result

Since this paper remains at an early stage of study, it is very difficult to give explicitly some physical and/or biological implications corresponding hierarchically to each of the higher order mutual correlation quantities. It is well-known that the electromagnetic and sound waves are usually measured in a frequency domain under the standardized measuring situation in a reverberation room, anechoic room and radiofrequency anechoic chamber. Surely, these standard methods in a frequency domain are useful especially for the purpose of analyzing the mechanism of individual phenomena (from the bottom-up way viewpoint), but they seem to be insufficient for evaluating (from the top-down way viewpoint) total images on the compound or mutual relationship among electromagnetic and sound waves in the actual complicated living circumstances (e.g. thunder, electrostatic discharge, earthquakes, some kind of energy in the eastern mind-body theory, microwave hearing, magnetophoshene and so on). Not to say, such studies on mutual relationship among electromagnetic and sound waves (including a study on only electromagnetic environment itself) leaked from an electronic equipment in the actual working environment become more important year by year, according to the increase of various type of information and communication systems such as personal computers and portable radio transmitters. For instance, concerning their individual and/or compound effects on a living body, it is well-known that there are many unsolved questions on VDT symptoms for study. To cite several concrete examples, our brain nerve seems to be mostly influenced around the frequency of 15 – 20 Hz at electromagnetic and sound waves. This is recognized even in an amplitude modulation of the high frequency domain as well. Also, the generating order, the interval and the each time duration of flashes and noises along a time axis produce some problems for the relationships to physiological processes. Otherwise, there are more other similar problems, such as a predominant effect of sight (Heaing seems to be dragged to sight having higher warning ability), a promotion effect among different kind of senses, participation to VDT symptom groups (e.g. complain of general malaise) as well as multiplication effect with stress, relationships between daily rhythm of human life and the effects to a pineal body by electromagnetic field (light), some changes of brain waves by stimulus of electromagnetic (light) waves, and so on. For these modern problems, mutual compound correlation and/or accumulation effects seem unable to be originally denied.

In these studies, it is generally pointed out that the first important topic is to find some new measurement and evaluation methods even in a quantitative approximation. In general, in the actual phenomena affected in a complex manner by the natural, social and human factors, it is necessary to abstract various type latent correlation information of not only the ordinary lower orders, but also of higher orders in order to quantitatively investigate and evaluate the mutual relationship among them. In this paper, a stochastic methodology to grasp the mutual relationship among sound and electromagnetic waves leaked from a VDT in an actual working environment is discussed, especially through a system model from an extended regression analysis reflecting not only the linear but also the nonlinear correlation information of higher order. More specifically, in order to identify each regression parameter of the system model, we have proposed an evaluation method which is capable of giving some methodological suggestion to the measurement technology of compound and/or accumulation effects in the electromagnetic environment.

Appendix II. Inevitability of introducing higher order mutual correlation quantities

The necessity of invitabitably introducing several of mutual corrrealtion quantities of higher order seems to be itemized as follows:

1. As seen in Fig. 1, 2 and 3, it is obvious that our experimental results can be theoretically understood by taking some higher order mutual correlation quantities into consideration in order(though the fluctuation of electric field strength is statistically independent of that of the sound pressure level roughly on the average especially in Fig. 2, and it seems natural apparently only from a direct viewpoint of physics supported by the lower order statistics).

2. For example, as in the well-known study on a distorted periodical wave (deviated from a pure sinusoidal wave), the degree of distortion is hierarchically reflected in many higher harmonics and is measured sometimes in a scale of distortion factor as an existence style (behaviour or pattern) of physical quantity differing from the direct

connection to physical existence itself on an energy scale (like an effective value). In the similar way, in the study on one stochastic variate of non Gaussianly fluctuating wave too, many higher order statistics like skewness, kurtosis and so on seem to correspond to the scale on an existence style (behaviour or probability distribution form) of physical quantity, differing from the lower order statistics like mean and variance directly connected to the scale of physical existence itself. Accordingly, in the study on more than 2 stochastic variates (necessary to the special study on mutual correlation among them), it is inevitable to introduce step by step the idea of higher order mutual correlation as a scale of mutual relationship, especially among remote level apart from respective mean values, in addition to the well-known idea of the 1st order(linear) correlation (directly connected the mutual relationship mainly in the neighborhood of the mean value).

3. Especially, in the extremum statistics with more than 2 random variates, if we want to study hierarchically step by step based on the bottom-up way viewpoint (from the lower order to the higher order statistics) beyond only an apparently descriptive style study, it seems inevitable to introduce such an idea of higher order mutual correlation, even if it is not well-known.

4. Only from an opperational viewpoint as seen in the well-known signal processing techniques like AR, MA, ARMA and ARIMA models, the above higher order statistics is usually latently and artificially reflected only in the error style. But, since the human being is not only a biological but also high-ranking valuable existence (connected with truth, good and beauty) beyond only a physical existence, in our living nature and human, it is sure that many of the meaningful error, accident, exception, great genius, secret essense etc. certainly exist (sometimes partly related to the above higher order mutual correlation quantities?) and should not be excluded artificially in our eagerness to hurry up our artificial realization (only from workman's opperational standpoint forgetting our original quality of humanity).

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