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FOURIER ANALYSIS OF SOME PROBLEMS IN RADIOLOGY

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1. Introduction:

During the course of research into a problem on a certain dimension, we often encounter difficulties seeming to be unsolvable. Of the various techniques available in this case, the changing of the dimension is an effective one. This method consists in shifting a problem difficult of solve on dimension A to dimension B. The results may be expressed in terms of dimension B, or converted into dimension A. The present study proposes to apply Fourier analysis to the changing of dimension. Fourier analysis, the foundation of the applied science, plays an important part in the information theory. It was introduced secondarily into the computation of the information volume in the continuity system. This is due to the fact that the wide-ranged study of linear phenomenon is remarkably simplified by the application of Fourier analysis. The information theory traces its origin to the statistical study of the wave-form of noise made by Carson in 1922; it was developed to the present level of the theory by Hartley in 1928, and completed by Shannon in 1948. A Frenchman named Duffieux in Besancon, a small university town of France, published in 1946 a book entitled: "An Application of Fourier Analysis to Optical Science."

Up to then, the theory of image formation of the optical science had discussed the relationship between the object and its image in terms of the intensity distribution on the spatial co-ordinates. However, in his study, thé intensity distributions of the object and its image are expressed respectively in terms of their spatial frequency characteristics by means of Fourier analysis, and the image formation of the optical science is treated in the domain of the spatial frequency.

This suggests one of the analytical methods of the problem through changing the dimension as the author of this report stated at the outset. Spatial frequency characteristics of the intensity distribution of the light of objects into sine wave forms of various spatial frequencies. The spatial Modulation Transfer Function (MTF). It may, therefore, be said that the theory of the MTF, now in great vogue, was originated in France.

It is in 1954 that the information theory was first introduced in this country and the application of the MTF using the technique of Fourier analysis, to the study of optics, particularly to the efficiency of lenses started in 1956. Partly due to the greatly developed camera industry, the achievements made in this field rank among the first in the world, and the progress in industrial application of this theory, in particular, has outpaced all other nations. Introduction of the information theory to radiology of this country began in 1958 and that of Fourier analysis in 1963. Stimulated by the vigorous development of researches in the field of optical science, the progress of radiological studies in the period following the introduction of these was truly remarkable. The group of Japanese radiologists working in conjunction with the Research Institute of Radiation Image information now maintain close liaison with such reputable societies as Schober's in Europe and Rossmann's in the United States, and their findings are evaluated as the first rate.

The technique of Fourier analysis is introduced into the evaluation of the sharpness of radiation images in the form of MTF and into the evaluation of film graininess in the form of Wiener spectrum. The subject of this report is an analysis in the domain of spatial frequency, of the optimal magnification ratio of enlargement radiography and the dosimetry, which are the recurring topics of today's radiography and measurement in their relations to the MTF.

2. Modulation Transfer Function

To begin with, if

$$\hat{h}(\nu,\tau)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}h(x,y)\exp(-j2\pi(\nu x+\tau y))dxdy \quad \text{------ (1)}$$

then

$$h(x,y)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\hat{h}(\nu,\tau)\exp(j2\pi(\nu x+\tau y))d\nu d\tau \quad \text{------ (2)}$$

follows, only provided that

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}|h(x,y)|dxdy \quad , \quad \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}|\hat{h}(\nu,\tau)|d\nu d\tau \quad \text{------ (3)}$$

is absolutely integrable.

The $\wedge$ of $\hat{h}(\nu,\tau)$ as used in the foregoing indicates the Fourier transform of the $h(x,y)$.

In case the illumiantion of an object is incoherent, the MTF can be defined as the Fourier transform of the point spread function. The Fourier transform in this case may be expressed as follows:

$$\begin{aligned}\hat{h}(\nu,\tau)&=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}h(x,y)\exp(-j2\pi(\nu x+\tau y))dxdy\\ &= H_1(\nu,\tau)-jH_2(\nu,\tau)\\ &= |\hat{h}(\nu,\tau)|\exp(-j\delta(\nu,\tau))\end{aligned} \quad \text{------ (4)}$$

$$H_1(\nu,\tau)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}h(x,y)\cos(\nu x+\tau y)dxdy \quad \text{------ (5)}$$

$$H_2(\nu,\tau)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}h(x,y)\sin(\nu x+\tau y)dxdy \quad \text{------ (6)}$$

$$|\hat{h}(\nu,\tau)|=\sqrt{H_1^2(\nu,\tau)+H_2^2(\nu,\tau)} \quad \text{------ (7)}$$

$$\delta(\nu,\tau)=\tan^{-1}\frac{H_2(\nu,\tau)}{H_1(\nu,\tau)} \quad \text{------ (8)}$$

$h(x,y)$: Point spread function

ν, τ: Spatial frequencies in the direction of axis and axis

$\hat{h}(\nu,\tau)$: Modulation transfer function

$\delta(\nu,\tau)$: Phase

However, when both ν and τ equal to 0 $|\hat{h}(\nu,\tau)|$ and $\delta(\nu,\tau)$ are normalized to equal respectively to 1 and 0. Since $\hat{h}(\nu,\tau)$ is generally the complex function of the spatial frequency ν,τ, it is appropriate to present clearly its absolute value $|\hat{h}(\nu,\tau)|$ and the phase $\delta(\nu,\tau)$ in order to indicate it.

Assuming the intensity distribution of the light of the object at $O(x',y')$, $O(x',y')$ is an assemblage of points, and the points at x' and y' are distributed at x and y on the image plane as the point image of $h(x-x',y-y')$. Accordingly, the image $i(x,y)$ of the object is represented by the convolution integral of $O(x',y')$ and $h(x,y)$. That is to say,

$$i(x,y)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} O(x',y')\,h(x-x',y-y')\,dx'dy' \tag{9}$$

Even if the point spread function $h(x,y)$, which is the image forming characteristic of the optics system, is already known, it is difficult to obtain the image $i(x,y)$ from the $O(x',y')$ of a given object, and generally it is the numerical integral of Equation (9) mentioned above. This is due to the relationship between the object and the image being discussed in terms of the intensity distribution and this is the weakness inherent in the optical wave-form image formation theory. Transformed by means of Fourier analysis, Equation (9) is represented as follows:

$$\begin{aligned}\hat{i}(\nu,\tau) &= \int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} O(x',y')\,h(x-x',y-y')\exp(-j2\pi(\nu x+\tau y))\,dx'dx\,dy'dy \\ &= \hat{O}(\nu,\tau)\,\hat{h}(\nu,\tau)\end{aligned} \tag{10}$$

In other words, the spatial frequency characteristics $\hat{i}(\nu,\tau)$ of the image are represented by the simple product of the spatial frequency characteristics of the object, $\hat{O}(\nu,\tau)$ and those of the point image $\hat{h}(\nu,\tau)$. The $\hat{h}(\nu,\tau)$ is a function determined by the optical system, and when it is already known, the $\hat{i}(\nu,\tau)$ can be obtained from $\hat{O}(\nu,\tau)$ and vice versa. Now, assuming that the $\hat{i}(\nu,\tau)$ and $\hat{h}(\nu,\tau)$ are already known, in order to calculate $O(x,y)$ from $\hat{O}(\nu,\tau)$, inverse Fourier transform of $\hat{O}(\nu,\tau)$, that is to say

$$O(x,y)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\hat{O}(\nu,\tau)\exp(j2\pi(\nu x+\tau y))d\nu d\tau \qquad (11)$$

will be made. Thus the Fourier's theory of image formation is proved to be right.

3. Modulation Transfer Function of Radiographical System

Generally speaking, factors causing blurs in radiographical system are as follows: in the case of direct radiography, they are the focus of the X-ray tube, the scattered radiations from the object, the intensifying screen, the film and the naked human eyes: in the case of indirect radiography, the fluorescent screen, the lense, and the mirror, and in the case of fluoroscopy, the fluorescent screen, the image amplifier and the television. In addition, the movements of the radiographical equipment or the object also cause blurs. As means for diminishing blurs, there are grids and a collimater. These blurs are indicated on the vertical axis by such different measures as the intensity of X-ray or lights. The unitary evaluation measure has been used in these systems and the uniformity of the measure facilitates the expression of individual blurs and the comparison of blurs within a given element, but it is difficult to synthesize as a whole. On the other hand when they are viewed in terms of spatial frequency, individual blurs can be indicated by a single measure and at the same time the synthesis of blurs caused by heterogeneous elements. In radiography, the spatial frequency characteristics of an object are perceived as the final image created through, as described above, blurs of many different spatial frequency characteristics. Accordingly, it is necessary for an effective radiographical system to have the blurs of different spatial frequency characteristics well balanced. One must bear in mind the fact that some of the elements of blurs have the non-linear image transmission system. For instance, in the case of films, the MTF should be calculated after the blackening rate was converted into effective exposure by means of such conversion characteristics as the characteristics curve.

Let us review the basic elements of radiographical system, that is, the source of rays, the object, and the receptor system. The distribution on the image plane of penetration rates of the rays through a plane object from the point source is set at $O(x_2, y_2)$ on the co-ordinate of the plane of the object, the point spread functions of the focus and the receptor system on the image plane are set at $f(x_1, y_1)$ and $i(x, y)$ on their respective co-ordinate. The intensity distribution $Z(x, y)$ of the final image on the image plane is represented by the following convolution integral.

$$Z(x,y)=\int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} O(x_2, y_2) f(x_1-x_2, y_1-y_2)\, i(x-x_1, y-y_1)\, dx_2\, dx_1\, dy_2\, dy_1 \qquad (12)$$

When the above is transformed according to Fourier analysis with regard to x and y, it becomes

$$\hat{Z}(\nu,\tau)= \hat{O}(\nu,\tau)\, \hat{f}(\nu,\tau)\, \hat{i}(\nu,\tau) \qquad (13)$$

Each of the spatial frequency characteristics of Equation (13) above is that registered on the image plane. If the distance between the focus and the plane object is designated as r_1, that between the plane object and the image plane as r_2, the magnification ratio m of the focus is r_2/r_1 and the enlargement of the object is $(r_1+r_2)/r_1$. In other words, when m is used, it becomes $m+1$. Accordingly, if the point spread functions of the actual dimensions on respective co-ordinate are designated as $f_0(x_1, y_1)$ and $O_0(x_2, y_2)$, the $\hat{f}(\nu,\tau)$ and $\hat{O}(\nu,\tau)$ of Equation (13), they are represented by the Foruier transform of

$$f(x_1, y_1)= f_0\left(\frac{x_1}{m}, \frac{y_1}{m}\right), \quad O(x_2, y_2)= O_0\left(\frac{x_2}{m+1}, \frac{y_2}{m+1}\right)$$

respectively. These relationships pose interesting questions to the enlargement radiography. This is the question of the optimal magnification ratio enlargement radiography. In order to simplify the calculation. Equation (13) is treated on a simple dimension and when considered on the spatial frequency axis of the image plane, it becomes as follows:

$$\hat{z}(\nu) = \hat{f}_0(m\nu)\,\hat{O}_0((m+1)\nu)\,\hat{i}(\nu) \qquad (14)$$

If $(m+1)\nu$ is equated to ν_0 and Equation (14) is viewed on the spatial frequency axis of the object plane, it becomes

$$\hat{z}_0(\nu_0) = \hat{f}_0\left(\frac{m}{m+1}\nu_0\right)\hat{O}_0(\nu_0)\,\hat{i}\left(\frac{\nu_0}{m+1}\right) \qquad (15)$$

As Equation (15) shows, if the enlargement magnification ratio is increased, the spatial frequency characteristics of the focus $\hat{f}_0(\frac{m}{m+1}\nu_0)$ moves down toward the low frequency side and the spatial frequency characteristics of the receptor system $\hat{i}(\frac{\nu_0}{m+1})$ moves up toward the high frequency side. This suggests that as the blur of the focus becomes larger, the object also becomes larger and the blur of the receptor system relatively smaller. On the basis of Equation (15), the existence of the optimal magnifecation ratio of the enlargement radiograph can be conjectured. In an experiment with a minimal focus of 50 and a fine intensifying screen, it was confirmed that the optimal enlargement magnification ratio lies in the vicinity of 4-fold.

The problem to be analyzed in radiographical system is the one of the optimal enlargement magnification ratio when scattered rays exist due to the plane object being in the phantom of a certain volume. Studies are made taking into consideration the Groedel effect on the spatial frequency characteristics of the scattered rays as the enlargement magnification ratio m increases. In practical enlargement radiography, the scattered rays emanating from the object gives a profound influence on the image quality. It seems, therefore, meaningless to discuss the optimal magnification ratio without referring to the scattered rays. Investigations were also made to compare the spatial frequency characteristics of the enlargement radiographical system containing scattered rays and those not containing them and to determine how the scattered rays in the hypersensitive intensifying screen and those in the high fine intensifying screen are affected by the Groedel's effect.

4. Modulation Transfer Function of Dosimetric System

The concept of MTF was first introduced into the radiography and produced many fruitful results. In the radiographical system, mainly the techniques of Fourier transform has been used and the evaluation of the image has been made on the basis of MTSs. This is because of the fact that the use of the MTF in the optical system has been developed as the best means for the rationalization of the radiographical system, the evaluation of the image quality and the improvement of image has facilitated the application of a similar idea to the radiographic image. MTF is an effective tool for expressing the characteristics as long as the conditions of the linear type and the constancy are adequately satisfied. Since many other systems can meet its mathematical conditions, the MTF should be applied not only to the system relating to the radiographical image but also to other systems. In this sense it is but a natural development that the question of image correction should be dealt with in the study of the MTF of the R.I. scanning system, the studies of the super-decomposition of the radiation spectorum and of the analysis of the γ-ray spectorum by electronic computers. This is an example of the dimension-shifting method as stated at the outset of this paper, that is, how to get an answer by transferring to dimension B the question difficult to solve on dimension A and by re-transferring the answer to the original dimension to get a final result.

The question of analysis in the dosimetric system boils down to that of correction of the dosimetry by spatial frequency characteristics. Despite the bulk of data gleaned by many scientists on the dosimetry, many problems remain yet to be solved. Of particular interest is the effect of the volume of the ionization chamber on the depth dosimetry. Analytical approaches have already been attempted to solve this problem, but the question of how to determine the real dose distribution, free from errors, is yet to be worked out.

Generally, the dosimetric system consists of a source, a collimator, a test object (phantom) and a dosimeter. These elements contribute to the blur of the image and they can be treated as a series of linear spatial fiequency filters. Ordinarily, the spatial frequency characteristics of the radiation dosimetric system are expressed as follows. A measurement plane is located at a fixed site within the phantom. Now, the depth intensity distribution on the measurement plane, which is formed by collimating the radiation emanating from a point source, is designated as $d(x_2, y_2)$ on the co-ordinates of the collimating plane, the point spread function of the extended source in the position of measurement plane in air and that of the ionization chamber in the depth radiation on the measurement plane are designated as $f(x_1, y_1)$ and $m(x, y)$ on their respective co-ordinates. The depth dose distribution $z(x, y)$ which is obtained by examining the field at the measurement plane with the ionization chamber is given by the following convolution integral:

$$z(x,y)=\int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} d(x_2,y_2)f(x_1-x_2,y_1-y_2)m(x-x_1,y-y_1)\,dx_2\,dx_1\,dy_2\,dy_1 \qquad (16)$$

The Fourier transform of Equation (16) is

$$\hat{z}(\nu,\tau)=\hat{d}(\nu,\tau)\hat{f}(\nu,\tau)\hat{m}(\nu,\tau) \qquad (17)$$

Accordingly, the spatial frequency characteristics of the ionization chamber in depth dosimetry is

$$\hat{m}(\nu,\tau)=\hat{z}(\nu,\tau)/\hat{d}(\nu,\tau)\hat{f}(\nu,\tau) \qquad (18)$$

Conversely, the real depth dose distribution $r(x, y)$ in the field is to be obtained by the following processes, i.e., if

$$\hat{d}(\nu,\tau)\hat{f}(\nu,\tau)=\hat{r}(\nu,\tau) \qquad (19)$$

then

$$\hat{r}(\nu,\tau)=\hat{z}(\nu,\tau)/\hat{m}(\nu,\tau) \qquad (20)$$

$$r(x,y)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\hat{r}(\nu,\tau)\exp(j2\pi(\nu x+\tau y))\,d\nu\,d\tau \qquad (21)$$

In this paper, assuming the spatial frequency characteristics of a 4mm diameter ionization chamber in dosimetry both in air and in depth at 2 and 3, computation will be made and the soundness of the assumption will be checked by comparing with the results obtained by some experiments with a lead slit. Furthermore, the dose distribution in air and in depth in the collimated field will be examined by scanning the ionization chamber, and the errors of blurring caused by chamber size will be corrected by means of Fourier analysis in order to obtain the real dose distribution. The above-mentioned experiments were performed using 190kVp X-rays and Co^{60} γ-rays respectively, and the results of these experiments were compared with the energy dependency of the chamber. With regard to the depth dosimetry, studies are made on the dose distribution not only on the $x-y$ plane but also on the plane in the direction of z axis, that is, the correction of the attenuation curve.

As regards Equations (16) up to (21), similar analysis in air dosimetry is made much easier and the same approach can be taken for the correction of the attenuation curve.

5. Conclusion

The study of the spatial frequency characteristics in the radiological domain is already in its maturity. This report dealt with the basic concepts of MTF and an introduction to a few problems of particular interest, such as the optimal magnification ratio of enlargement radiography and the correction in dosimetry. These analytical approaches are expected to make greater development and it will largely contribute to the progress of radiology.

COMPARISON OF A RADIOGRAPHIC ASSESSMENT OF X-RAY BEAM QUALITY WITH SPECTRAL MEASUREMENTS. G. M. Ardran, M.D., F.F.R., A. K. Burt, H. E. Crooks, M.S.R. and L. H. J. Peaple, B.Sc. (Health Physics and Medical Division, A.E.R.E. Harwell, U.K. and The Nuffield Institute for Medical Research, University of Oxford, 43 Woodstock Road, Oxford, England)

It has been increasingly recognised over the last 20 years that quantum noise is the ultimate limiting factor governing the formation of a radiographic image. It is this factor which prevents, without a dterioration in quality, very significant dose reduction below levels which can be currently reached using the faster film screen combinations or image intensification.

When making comparisons of different techniques and measurements of radiation output it is essential to know the quality of the X-ray beam or to be certain that one is using similar quality beams on different occasions. We have developed a radiographic method for measuring or comparing the quality of diagnostic X-ray beams: a comparison of the results with spectrometric measurements shows that one can determine the mean keV or kVp for similar voltage wave forms within about 1 kV. One can also determine the kVp at which the beams from different voltage wave forms are practically identical in quality. This enables one to balance the total filtrations used and provides a relatively simple means of determining beam quality under practical working conditions. The value and implication of this knowledge will be discussed.

S0216

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EVALUATION OF IMAGE QUALITY IN VARIOUS METHODS FOR THE RECORDING OF MOVEMENT PHENOMENA. (Dr. J. Feddema, Dr. A. Recourt, Mr. G. L. A. Monté, Philips' Health Centre, Eindhoven, the Netherlands).

In analyzing movement phenomena the following methods need consideration: serial full-scale roentgenography, serial intensifier fluorography, intensifier cinefluorography on 16 mm ir 35 mm film, video tape recording, video fluorography and video cine fluorography.

A physical assessment concerning the influence of exposure data (focus size, movement velocity, exposure time etc.) on the modulation transfer function and noise characteristics of the imaging system in its entirety, will be discussed.

S0217

SOME FACTORS AFFECTING IMAGE QUALITY IN ANGIOGRAPHY. K. Rossmann, Ph.D., A. G. Haus and G. D. Dobben, M.D. (Department of Radiology, The University of Chicago, 950 East 59th Street, Chicago, 111inois 60637)

The relative effect of several physical system parameters on angiographic image quality has been investigated. These factors in include screen and film speed and unsharpness, geometrical unsharpness and film changer operation. The optical system performance is spec specified in terms of the modulation transfer function.

The visual image quality of test object and clinical radiographs is compared with the measured modulation transfer function.

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S0218

INFORMATION TRANSFER IN X-RAY IMAGE INTENSIFIERS.

Wilfrid F. Niklas, Ph. D. and Nathan D. Levin (Varian/EMI, 601 California Avenue, Palo Alto, California)

X-ray image intensifiers of the vacuum tube type have found general acceptance in diagnostic equipment. One of the design rules for systems employing such devices is placing the quantum fluctuation noise limits into the X-ray energy converter at the input window of the tube. The primary design goal for the imaging sensor and the system is approaching the information perception as determined by the shot noise level in the incident X-ray beam. The spatial and temporal device noise contributions should be such that they limit the attainable performance at a higher level than set by quantum fluctuations.

Studies by Mr. Ter Pogossian and others have indicated that NaI and CsI show absorption characteristics for diagnostic X-ray energies superior to those displayed by the sulfide-type energy converters, commonly employed in X-ray image intensifiers.

The use of multi-crystaline CsI:Na energy converters in X-ray image intensifiers has been reduced to practice in our laboratories. The preparation of such scintillators will be discussed together with interface questions unique for their use in imaging photo-electric devices. Tube design and performance will be reported on with emphasis on information transfer characteristics determined with the help of CTF equipment especially developed for X-ray image intensifiers.

S0219

IMAGE IMPROVEMENT BY PROCESSING THE FOURIER SPECTRUM OF X-RAY PATTERNS. O. Schott (X-ray research department, Siemens AG, Wernerwerk für Medizinische Technik, Erlangen, Germany).

The image quality of an X-ray image depends on the properties of the X-ray pattern, particularly its fourier spectrum and on the properties of the transmission system that converts the X-ray pattern into visible light, i.e. chiefly on the MTF of the transmission channel. These relations are explained, and with the aid of examples of the fourier spectrum and the MTF the influence on the image quality is demonstrated. In particular it is shown how this spectrum changes when the MTF is modified in the electronic part of the transmission channel and certain spatial frequencies are enhanced or suppressed. In certain radiological tasks processing of the fourier spectrum by means of a suitable MTF leads to a more informative X-ray image and thus facilitates diagnosis.

S0220

SPATIAL FREQUENCY DISTRIBUTION OF CHARACTERISTICAL DETAILS AND NOISE IN X-RAY PICTURES. Prof. Dr. Herbert Schober (Director of the Institute for Medical Optics, 8 Munich 13, Barbarastr. 16, West-Germany.)

With a special X-ray computer which was produced by S. Boseck in the Institute for Medical Optics of the University of Munich the spatial frequency distribution of some characteristical X-ray pictures was quantitatively analyzed. The experimental results concern physiological and pathological examples, esp. bones, lungs (tuberculosis and silicasis), etc., but also quantum noise, granularity of the film, and of screen and amplifier systems. Some aspects, and also limits for an objective X-ray computer resulted by these experiments.

S0221

SIGNAL-TO-NOISE RATIOS AND SPATIAL SPECTRA OF RADIOLOGICAL IMAGES
--- DIGITAL-COMPUTED AND OPTICAL-SIMULATED ----

Eiichi Takenaka, M.D.,B.A. (Department of Radiology, Faculty of Medicine, University of Tokyo, Japan), and Kojiro Kinoshita, D. Sc. (Research Laboratories, Shiba Electric Co. Ltd., Japan).

Informations of X-ray imaging systems are decided by the spatial frequency characteristics and signal-to-noise ratios(S/N) of every component of the systems. We obtained the threshold S/Ns and the necessary spatial frequency bandwidths of the radiological images of the bone:

First, bone slides and random noise slides are projected upon the same screen. The latter correspond to stochastic distribution function of normal type and uniform one. The S/Ns are calculated using the illuminations on the screen, with each slide projecting respectively. The S/N-observability curves and the threshold S/Ns are obtained, and the results of uniform type are compared with those of normal type. The S/N-observability curves have good normality in both types. Generally the S/Ns in uniform type are 5-7 dB lower than those in normal type. The threshold S/N never to miss the observed images lies in the range of 12-13 dB in uniform type. Clinically subjective observability is in good proportion to the objective effective S/N value, which is corrected for area, length and periodicity.

Secondly, the visual spatial cutoff frequencies of the optically defocused images are measured by means of the blurred Siemens' stars photographed on the reproduced pictures simultaneously. These cutoff frequencies are ranged in 0.3-2 dB lines/mm.
The threshold cutoff one of the 1% probability to miss the observed objects is about 2.5 lines/mm. The amplitudes corresponding to the spatial frequencies are ranged in 8-70% (average 45%).

S0222

Minute Focal Spots: Performance and Role in Roentgenology, by Eric N. C. Milne, John C. Klopping, Pekka Soila and Erich Voegeli; Harvard Medical School, Peter Bent Brigham Hospital, Boston, Mass. Electron beam focusing and new anode construction techniques have brought the load capacity of minute focal spots into the range of clinical usefulness. Many dynamic factors influence the functional size of a focal spot, including Kv, MaS, beam composition and object-to-anode orientation. We will present Kv-current-time curves and relate the modulation transfer function properties of the focal spot to the intensity distribution of the X-ray beam. Minute spots are being used increasingly for primary magnification. We will show that, even when functional focal spot size is determined accurately for each examination by nomograms linking Kv, MaS and object position, for geometric reasons the true size of any minute object still cannot be calculated from its magnified image. i.e., images produced by primary magnification cannot be used for morphometry (unless the focal spot is very small in relation to the object size.)

P0886

THE SELECTION OF INTENSIFYING SCREENS IN RADIOGRAPHIC EXAMINATION OF GASTROINTESTINAL REGION. Tatsuji Takizawa, Minoru Hiraki and Norio Miura (Dai Nippon Toryo Co., Ltd., 1060 Naruta, Odawara, Kanagawa, JAPAN)

A type of intensifying screens should be chosen by taking into account of movement of object, then a desirable radiograph could be obtained.

In radiography of the gastrointestinal region and the chest, the radiographic image is strongly affected by peristalsis and movement of border area of the left ventricle of the heart.

Therefore, the radiographic examination of these objects should be made with a short exposure time in order to decrease a blur of movement.

In general, the exposure time is determined by speed of intensifying screens and X-ray film, capacity of X-ray equipment and thickness of object.

In this report, a relationship in sharpness between the intensifying screens and the effect of movement is considered from theoretical calculation and experiment. In the theoretical calculation, modulation transfer functions (MTFs) of the intensifying screens and the effect of movement are treated approximately as exponential and sinc functions, respectively.
In the experiment, the over-all MTF of them are evaluated by taking radiographs of a rectangular lead-chart, where during the exposure, the lead-chart is moved with uniform velocities which are obtained from clinical data.

The experimental results coincide with the theoretical calculations.

P0887

Improved Information Transfer with X-ray Image Intensifiers containing Newly Developed X-Ray Screens.

By W. Kühl, N.V. Philips, Eindhoven, The Netherlands

In the past decade X-ray image intensifiers have greatly contributed to the progress in Röntgen diagnostic techniques.
Due to their larger effective quantum detection efficiency, as compared with fluorescent screens and full-size radiographs, they have enabled such widely used techniques as Röntgen-cinematography and - television. Until now their primary Röntgendetector consisted of a powdered screen the characteristics of which were comparable with those of conventional X-ray screens.
As they furthermore contain additional imaging components which necessarily contribute to the contrast degradation of the transferred image the gain in effective quantum detection efficinency was achievable only on account of reduced modulation transfer (resolution).
Due to the penetrating power of X-ray quanta through matter the requirements on X-ray screens, e.g. effectively absorbing X-ray quanta and maintaining image contrast, are contradictory. An optimum can be reached only if such a screen consists of constituents of high atomic numbers very densely packed which is impossible with conventional powdered screens. New developments in screen making techniques have lead to results that fulfil those requirements to a large extent. Together with improved electron-optics they allow of making X-ray image intensifiers which - while maintaining the quantum detection efficiency - have a modulation transfer close to that of full-size radiographs.

P0888

GEOMETRIC BLURRING AND RADIATION INTENSITY IN THE RADIOGRAPHIC EXPOSURE FIELD. Dr. E. Fenner, A. Elsas †, R. Friedel, H. Schnitger
(X-ray tube laboratory, Siemens AG, Wernerwerk für Medizinische Technik, Erlangen, Deutschland)

The focal spot size of X-ray tubes is measured in a defined beam direction (central ray). In accordance with the tube geometry, the dimensions and shape of the focal spot change in other beam directions. There is, therefore, geometric blurring in the X-ray image, which varies according to the beam direction.

As a measure of geometric blurring, a particular value of the modulation transfer is taken. The changes in the modulation transfer with variations of the tube geometry and the presence of X-ray scattered radiation and the influence of grids are determined and discussed.

The radiation intensity in the film plane is influenced by the scattered radiation produced in the object. If, during the measurement of the spatial distribution of the radiation intensity in the film plane, only the filter used for obtaining a particular quality of radiation is fitted onto the X-ray tube shield, then there is practically no influence of the scattered radiation from this filter on the distribution. This arrangement, however, is not in accordance with practice. The spatial distribution of radiation intensity in the film plane is, therefore, determined behind a water phantom near to the film with and without grid.

P0889

SIGNAL AND NOISE IN RADIOGRAPHIC IMAGED

Kazuo Sayanagi, Dr. Eng.
(Optics Division, Canon Camera Co., Inc., 30-2 Shimomaruko 3-chome, Ohta-ku, Tokyo)

Radiographic images are suffered by mottle (noise) structure originated from several different causes. Three types of noise i.e., additional, quantum and multiplicative noise, are specified in this paper according to their origins.

Transmission process of noise through radiographic system, and correlation between signal and noise for each classified noise type are considered to obtain clear understanding about real image structure. Some simulation experiments by computer and measurements have been done. Results will be shown to explain optimum optical transfer function (blur effect) of systems which include all different noises according to their configuration. Several systems such as fluoroscopy, radiography and X-ray television system are treated and compared.

Quantum noise takes main part when a system has a higher sensitivity, and an amount of information which can be transmitted through the system is given as a function of number of X-ray photons.

P0890

ELIMINATION OF STRIPES FROM LINEAR TOMOGRAMS BY PHOTOGRAPHIC AND ELECTRONIC METHODS. Paul Edholm M.D. (Radiodiagnostic department, Karolinska Sjukhuset, Stockholm 60, Sweden) and Lars Quiding M. E. E. (Research Laboratory of Medical Electronics, Chalmers University of Technology, Gothenburg, Sweden)

Linear tomography is simple, has high precision, and allows short exposure time. Many radiographic units can be adapted to linear tomography. However a major disadvantage is that the tomogram contains stripes caused by blurring of details outside of the tomographic layer. These stripes obscure the diagnostic information available. It is, however, possible to remove the stripes from the tomogram by photographic or electronic methods. The common principle can be described as a one-dimensional spatial filtering of the image.

From the tomogram a blurred contact copy is made by giving it a translatory motion in the direction of the stripes during the exposure. This causes the sharp details to disappear and the copy will only contain a negative of the stripes which are resistant to this kind of blurring. When combined with the tomogram the copy will eliminate the stripes so that the sharp details are seen without interference. Electronic methods may be used to simplify the procedure. With a photographic duplicate of the tomogram, and a modified unit for electronic subtraction the tomogram may be seen free from stripes on a TV-screen. If an ordinary TV-chain is combined with a high-pass filter no duplicate is needed. The tomogram is only placed with the stripes parallel to the TV-lines. If the high pass filter is of special construction a very good image-quality is achieved.

MODULATION TRANSFER FUNCTION OF SCATTERED RADIATION IN EVALUATING ITS EFFECT ON PHOTOGRAPHIC IMAGE QUALITY. Kunio Doi, D. Sc. (Kyokko Research Laboratories, Dai Nippon Toryo Co., Ltd., 14-1 Saiwaicho, Chigasaki, Kanagawa, Japan).

Some works on the scattered radiation are reviewed relating to photographic image quality, and the modulation transfer function (MTF) is introduced to evaluate its effect on photographic image quality. The MTF of the scattered radiation is newly defined as a ratio of the Fourier spectra of input and output images, where its value of the MTF being unity at zero spatial frequency and equivalent to the content of the direct X-rays at non-zero spatial frequency. The MTF is, therefore, simply related to the several factors which have been used in radiography to evaluate the scattered radiations.

The relationships among the MTF and several distribution functions, for example, the edge traces are derived in general. These distribution curves are calculated in the case where the line spread function is given by an exponential approximation, which is verified by experiments in the case of water phantoms.

Two comparisons between theories and experiments give good agreements concerning the field size dependency of the scattering factor and the MTF.

P0892

COMPUTER SIMULATION OF RADIOGRAPH (IMAGE REPRODUCTION).

M. Takano (Section of physics and Technics, Fuji Photo Film Research Laboratories, Ashigara, Minamiashigara, Kanagawaken, Japan)

Image quality of radiograph depends on characteristics of X-ray tube, subjects, intensifying screen, photographic film and exposure condition. Among these factors there are spatial frequency response, granularity, quantum efficiency and H & D curve. No attempt have been so far made to describe radiographic imaging system as a whole on the basis of separate stages. In these studies, two dimensional radiographic image was simulated by a computer calculation considering these characteristics of each stage, determined experimentally, and the result was compared with existing radiographic image.

Response function of X-ray tube, X-ray distribution after passing the subject, quantum efficiency and response function of intensifying screen, and H & D curve and response function of photographic film were determined. Statistical distribution of X-ray quanta, and granularity of intensifying screen and photographic film were also determined, and then, radiographic image was constructed by simulation.

Agreement in a degree of 60~70% was obtained by comparison of the result with existing image. To achieve more accurate approximation, radiographic imaging system must be treated as a non-linear one, because of neighborhood effect in photographic development and multiple light reflection in the "Kassette".

P0893

COMPUTER SIMULATION OF RADIOGRAPH (INFLUENCE OF SCATTERED X-RAY)

I. Hatanaka (Section of Physics and Technics, Fuji Photo Film Research Laboratories, Ashigara, Minamiashigara, Kanagawaken, Japan)

The contrast of photographic image is lowered by scattered X-ray from the subject and other surrounding materials. These influence is studied by computer simulation using Monte Carlo Method.

Electron-pair creation, compton effect and photoelectric effect are taken account.

PO{

MODULATION TRANSFER FUNCTIONS IN DOSIMETRY. Suguru Uchida, D.E., Kaoru Morikawa, B.E. (Department of Radiology, College of Medical Technology, Osaka University, No. 1-1, Machikaneyama-Cho, Toyonaka City, Osaka, Japan)

The blur in the measurement system is analyzed by bringing into the dosimetric system the concept of Modulation Transfer Function (MTF) which has recently been introduced into the radiographic system with fruitful results in the analysis of images. In this study, the dosimetry, in air and in depth, of 190 kVp X-rays and Co^{60} γ-ray is treated respectively.

First, the values of calculations and experiments of MTF of an ionization chamber are obtained. Then, the MTFs of the dose distribution of the collimated utilizing radiation measured by the ionization chamber horizontally and vertically are obtained. After some treatments are given to these MTFs in the spatial frequency domain, the real dose distribution in the horizontal plane and in the vertical plane of the utilizing radiation is evaluated by inverse Fourier transforms.

The results of experiments obtained are discussed in the light of the assumptions for calculations. Thus by the method of Fourier analysis, it has become possible to know the real dose distribution by correcting the errors of blurring caused by the chamber size, although this has long been regarded as difficult. Therefore, the application of Fourier analysis is tried not only to obtain the expression of MTF of the ionization chamber, but, to go a step farther, to also measure the real dose distribution.

P0895

COMPUTER*AIDED OPTIMIZATION OF RADIOGRAPHIC DATA. Dr. H. Gajewski,

H. Kühn (X-ray research department, Siemens AG, Wernerwerk für Medizinische Techink, Erlangen, Germany).

The quality of radiographs is determined by a large number of factors from which many are interdependent. The general approach to optimization problems in radiography by means of the modulation transfer function (MTF) is time-consuming because of these nemerous variables, if the total course of the MTF is taken as a basis. With the aid of an electronic computer the modulation transfer factors K_ν as a function of several radiographic factors can be ascertained more rapidly for the diagnostically important spatial frequencies ν (detail sizes), and as a result, the radiographic conditions are optimized with greater ease. In this manner the influence of attenuation properties and the kinetic speed of the object, the geometric conditions of the examination unit, the focal spot size, the tube potential, the transfer properties of the screen-film system and of the X-ray generator output is investigated for specific objectives. From these studies conclusions are drawn as to the various examination procedures and the dimensioning of the technical aids.

P0896

MODULATION TRANSFER FUNCTION AND SENSITIVITY OF ENLARGEMENT RADIOGRAPHY. Kunio Doi, D.Sc., Takao Toryu, D.Sc., (Kyokko Research Laboratories, Dai Nippon Toryo Co., Ltd., 14-1 Saiwaicho, Chigasaki, Kanagawa, JAPAN) and Kazuo Sayanagi, D.Sc., (Canon Camera Co., Inc., 3-30-2 Shimomaruko, Ohtaku, Tokyo, JAPAN)

Optimum magnification in enlargement radiography has been decided mainly by several radiographic experiences concerning some test charts and or practical objects. This paper discusses the modulation transfer function (MTF) of the whole enlargement radiographic system. The over-all MTF is mainly composed of the MTFs of the focal spot of X-ray tube and the screen-film system. When these two elements are described on the object plane by spatial frequency domain, the MTF of the focal spot of X-ray tube decreases but the MTF of the screen-film system increases in accordance with the magnification increases.

These changes of the MTFs in opposite directions may have a possibility of obtaining the maximum over-all MTF multiplied with two elements. The magnification which gives this maximum MTF is the optimum magnification in this enlargement radiographic system.

The MTF of the focal spot of X-ray tube is approximated by a Gaussian distribution, and the MTF of the screen-film system is approximated by a Gaussian distribution or an exponential function. The over-all MTF is then calculated by using these approximated destributions as a function of the magnification.

The Gaussian-Gaussian approximation has a sharp optimum magnification, but the Gaussian-exponential approximation has an optimum magnification which depends on the spatial frequency.

P0897

MODULATION TRANSFER FUNCTION IN RADIOISOTOPE SCANNING SYSTEMS

Eiichi Takenaka, M.D., B.A.(Department of Radiology, Faculty of Medicine, University of Tokyo, Japan).

There are few papers on Fourier analysis of a radioisotope (RI) scanning system as a RI image transmission system. We measured the MTF in its system with the -131 paper and RI liquid Siemens' star, which condirms our theoretical calculations.

Let $h(x',y',z')$ be the observed image, $F(x+\xi, y+\eta, z+\zeta)$ be the RI distribution, $f(\theta,\varphi)$ be the directionality of the collimator (it gathers -rays in proportion to the angle (θ,φ), then the average RI image through the tissue can be convoluted as follows:

$$h(x',y',z')=\frac{1}{r}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\underbrace{F(x+\xi,\ y+\eta,\ z+\zeta)}_{①}f\underbrace{(\theta,\varphi)}_{②}\underbrace{\exp(-ar)}_{④}\frac{d\xi d\eta d\zeta}{\underbrace{(r+z_0 \sec\theta)^2}_{⑤}}$$

$\varphi=\tan^{-1}(\eta/\xi)$, $\theta=\cos^{-1}(\zeta/\sqrt{\xi^2+\eta^2+\zeta^2})$,where r is the distance from the point in the patient to the collimator's focal plane, z is the distance from the focal plane to the scinllator, and is the absorption coefficient of the tissue. (1) Now let $f(\theta)=\cos^2\theta$ and $f(x)=\{1+a\cos(\pi\ell/L)\}/2$ in one-dimension, then its MTF is shown as $\exp(-\pi\ell/L)$. (2) Moreover, taking account of the term ⑤, then its MTF is a $(\pi\ell/L)(1+L/\pi\ell)\exp(-\pi\ell/L)$. (3) If the term of ④ and the M MTF as $\exp(-\pi\ell/L)$, then its MTF is $\exp(w+d)[1-\exp(w+a)\Delta d\}]/\Delta d(w+a)$, where $w-2\pi f\ell$ and $w=1/21$.

The formul in (2) and (3) show that absorption and depth of tissue worsen its MTF. (4) Taking account of the attenuation of distance besides (3), then its MTF is given as more complicated, byt the same form as in (3). (5) Our response curve obtained from the effective length from thecollimator's focal plane to the plane of RI distribu distribution (as same as if we could obtain it with the plane source) contains so-called area efficiency of collimator and narrows the gap between collimator and detailperceptibility better than the Tsuyascar or isoresponse curve.

P0898

IMPROVEMENT OF X-RAY TELEVISION FLUOROSCOPIC IMAGE AND FLUOROGRAPHIC IMAGE THROUGH EMPLOYING VARIABLE FIELD IMAGE INTENSIFIER AND X-RAY ENLARGEMENT TECHNIQUE. Sadao Tanabe, Ph.D. and Motohisa Tsuda (Radiation Apparatus Division, Shimadzu Seisakusho Ltd., Nakagyo-ku, Kyoto, Japan)

The quality of fluoroscopic image on X-ray television, expressed with modulation transfer functions, is compared among the following four cases, namely,

1) the object is in contact with the input surface of image intensifier,

2) X-ray enlargement technique is introduced,

3) electron optical enlargement technique is introduced, using variable field image intensifier tube, and

4) both electron optical enlargement and X-ray enlargement are introduced.

The quality of fluorographic image with 70 mm spot camera is compared also among the above-cited four cases. The result shows that the image quality of the 70 mm spot fluorography is almost comparable with that of direct spot radiography with intensifying s screen.

For the respective system, line spread functions are measured using a narrow slit made of lead, and the functions are transformed into modulation transfer functions.

Modulation transfer functions are also obtained directly through using rectangular wave form chart made of lead foil in which the spacial frequency is continuously changed.

Comparing these modulation transfer functions, the image qualities of various systems are estimated. And also, necessary X-ray dose rate or dosage and the costs for examination are compared.

P0938

第12回国際放射線医学会議のシンポジウム "Some Problems of Radiological Image Quality" について要約

東大医学部放射線医学教室
竹 中 栄 一

chairman の一人 Morgan はX線像質に関する問題は放射線物理の最も重要な研究の一分野であり、放射線診断学の基礎であり、被曝線量の減少は radiation hazard の点より望まれるが、線量と画質の相関が重要であること、MTF(modulation transfer function)や S/N (signal-to-noise ratio) による画質の評価が必要なることを強調した。

1. Moseley はX線診断に最適最良の像を与えるようにX線系を設計すべきであり、最終像の記録、視覚系、認識系まで含めて解析すべきことを言い、入力としてのX線像(アルミ試験体)のスペクトルについてノイズスペクトル(Wiener's spectra)との関与を重視した。
2. Bouwer は electro-optical XTV 系について
画質の評価を information content, S/N, MTE の点から行ない、isocon を使用した XTV の優秀さをこれを用いて撮影した臨床例のX線映画で示した。Feddema の発表、Schott の発表と夫々比肩する優れたものである。
3. G. M. Ardran は、X線像輝度増倍系のみならず、フィルム・スクリーン系でもX線の量子雑音が画質に関係することを示し、X線ビームの線質は線量測定やX線像の像質の比較に重要であると述べ、診断領域のX線線質を KVp や半価層で表わすより平均 KV で表わすことをすゝめ、フィルム撮影で濃度を比較することで、簡単に正確にX線像質を測定しうる装置(銅 penetrameter) を作製し、1KV 迄で測定できることを示した。
4. Feddema は種々の記録装置による運動体の画質評価について MTF と S/N を用いて比較した。記録は連続撮影(直接、間接、ビデオテープ)、X線映画(螢光増倍管によるもの、キネレコーディングによるもの)を取扱い、S/N としてはX線系のネックたる量子雑音で決定されるとして $N/\sqrt{N}\cdot k$ (N:X線量子数で曝射時間とX線曝射条件で定まる) で比較している。そしてX線系及び最終像の比較は MTF、S/N を別個に扱うべきでなく結合してなさるべきことをすゝめている。
5. Rossmann は血管撮影像の画質は増感紙、幾何学的不鮮鋭度、フィルム交換装置が関係することを述べ、基礎的実験としてアルミニウム円柱試験体(単1ないし並列) のスペクトルを実測および計算しかつ血管撮影で増感紙を使用したときスペクトルの低下を調べ、高感増感紙になるほど、入力たる血管X線像の差が少くなることを示し、低感度増感紙と高感度フィルム組合わせの意義を MTF により認めた。(併し被写体のスペクトルとしては短い長さの一定太さの

血管をしか取扱っていない。）

6. Niklas はナトリウム活性セシウム CsI(Na) を真空蒸着した入力層を有する螢光増倍管の開発を報告した。一般に CsI(Na) を使用したときは解像力がおちるが、これは3本／mm，X線 photon-to-photon 変換効率が優れており、周辺光量低下なく、像の歪の補正もすぐれているという、技術的考慮は入力面の螢光面について活性剤の添加、蒸着方法、厚さと粒子の大きさ negative vignetting について払われ、螢光増倍管としては入力ガラス窓、静電レンズ系、出力窓、第二螢光面に精緻な検討を加えている。

7. Schott はX線像が完全に伝達されているかどうかを見るには、入力たるX線像の空間周波数スペクトルが既知でなければならない。そしてX線TV系の MTF を変化させて被写体の特定周波数を向上させたり、低下させたりして、有利に診断できるかを実験した。診断に必須な情報とそれに固有の特定周波数との関係が分れば良いことを述べた。この関係は放射線医がきめるべきことであり、その点には言及してない。

8. Schober も被写体のスペクトルの重要性を強調し、Fraunhofer 回折（二次元スペクトル $F(n_x, n_y)$ や任意方向の強度分布のフーリエ変換で $F(n_x, o)$ を求め両者を比較した。かつ得られたスペクトルで①そのX線像に特徴的なものであるか ②そのスペクトルが診断に有利であるかが問題であると述べ、硅肺症、結核、骨疾患で低周波数にピークがあるが、周波数解析の診断的意義には悲観的であり、被写体のスペクトルは 'mass survey' のスクリーニング用に役立つだろうということと、診断目的によりX線系を選択するのに役立つと言っている。

9. 竹中はX線系の解析には系の S/N と最波数特性が必要であることを述べ、骨X線像につき S/N の識別閾値と視覚的遮断空間周波数を求めた。正規分布型雑音で18dB位であり、1％診断確率では後者は約3本／mmなることを示し、被写体は視覚的遮断空間周波数の近傍にその被写体固有の空間周波数が有ることを示した。これは被写体の定量的診断を示唆する。

ICRE の Honorary Secretary J. F. Rayan
からの手紙について

東大医放　竹　中　栄　一

昨秋の第１２回 ICR のとき、ICR の committee を新設することについて色々討論があり、最近の情報理論やコンピューターの発展を考えに入れて従来から ICRU、ICRP などの委員会の他に放射線医学の情報理論の委員会 ICRI(?)を作ろうとしたが、従来から米国で造影剤の副作用を調査研究しているグループと computer を中心とするものの３つが必要となり、ICRIE を作ることになったが、種々の事情で ICRE 委員会を作り、次の４つの subcommittee がおかれることになったということである。(４４年１２月日医放関東部会・足立 忠教授) ① education　② contrastmaterial の障害
③ conputer　④ Information

そして日本側連絡委員として教育について、足立 忠(医歯大)・塚本憲甫(癌センター)、造影剤の副作用について鈴木宗治(医歯大)、computer について梅垣洋一郎(癌センター)かつ足立 忠教授が日本側の全体の代表として ICR 理事会で選ばれたとの事です。

ところで、昨年１２月 RII 研究会の和文白書を日医放誌に掲載して戴けるよう、足立 忠教授へお願いに行ったとき、別掲の Finland の Rekka Soila 教授(ヘルシンキ大)(我々の会のインフォーマルミーティングにも出席していた)から岐阜大 石口修三教授に日本の放射線学会への Suggestion を送って来ている手紙が足立教授に提出されており、その中に RII 研究会のことが書いてあることを知らされ、そのコピーを戴いたので会員諸君にお知らせします。なおそのとき上述の ICRE に足立教授から連絡事項があるので白書の英文があったらいっしょに送るからということで、英文コピーを提出しました。それに対する返事がこの Honorary Secretary (general secretary か?) J. F. Rayan からの手紙です、そして足立教授から RII 研究会が ICRE と積極的にコンタクト出来るように、かつ必要な調査研究で寄与できることがあれば RII としても喜んで協力したい旨をさらに伝えて戴き、ご尽力して下さるようにお願いしたような次第です。これに対する返答は会長及び常任委員会にて早急に返事する予定です。

(註) 手紙の掲載は足立教授の許可を得たことを感謝します。

(竹　中　栄　一)

Department of Radiology,
Royal Prince Alfred Hospital,
Camperdown. N. S. W. 2050.

11th February, 1970.

Professor T. Adachi,
C/- Tokyo Medical and Dental University
School of Medicine,
Yushima,
Bankyo-ku,
TOKYO. JAPAN.

Dear Professor Adachi,

Thank you very much for your copy of the White Paper of the Japanese Society of Radiation Images Information on Studies of Radiological Images. I would be very interested in publishing this paper if it has not been previously published in English. Alternatively, would it be possible to have the honour of publishing a paper which is more up-to-date, from members of the Society.

As Secretary of the I. C. R. E., naturally I am sure that the Japanese Commission would come into the activities of the two committees, that of Radiological Information, and that of computers. I shall send copies of this letter to the Chairmen of these two committees so that they can get in touch with Professor R. Takahashi, Professor of Radiology at the Nagoya University School of Medicine, Showaku, Nagoya. No doubt the Secretaries of these committees will get in touch with Professor Takahashi to form a close working connection with him.

Yours sincerely,

J. F. Ryan,
Honorary Editor.

第12回 ICR における放射線診断学の物理的方面の発表について

～主としてレスポンス関数、画質について～

東大医学部放射線科　竹 中 栄 一

今回の ICR におけるX線診断の物理的方面の発表について述べる前に、テーマの category の事について一言する。
従来の ICR と比べて異なる点は画質についての Symposium とレスポンス関数、Modulation transfer function(MTF) に関する proffered paper が多い事であり、Radiology の physical aspects として dosimetry と並んでとり上げられた点である。勿論、computer in Radiology, RI imaging, XTV, X-cine の発表の中にもいくつかルーチンの扱い方として取入れられている。X線像系を1つの情報伝達系と考えて、その系の構成要素と最終のディスプレー像との関係を合理的に解析することは、我国でも外国でもほゞ同時に1960年代から行なわれ始めた。X線像の記録像質については、螢光増倍管を用いたX線映画やX線テレビが開発されてから、特にその取扱いが MTF の点や Quantum noise の点で問題になって来ている。従って近年の ICR では、螢光増倍管を用いた X-cine, X-TV 像の評価、改善に関する発表が多い。(第11ICR, 第12ICR)。
螢光増倍管やテレビでは周波数特性の解析は従来から行なわれていたが、X線像系全体を通しての解析は殆んどなかった。併し 第11ICR ではそのような解析として情報理論を応用しようとする2、3のアプローチがあり、第12ICR では MTF を取扱った発表もいくつかあり、symposium では「情報理論とサイバネティックスの応用」を取扱っているが、論理診断を主として扱っていた。(Lusted, Lodwick ら)

今回の ICR の発表では画質の問題点、MTF の応用面も明瞭になって来た。即ち symposium proffered paper での内容から、次の点が問題とされていた。

① The base of image diagnostic radiology
② The radiological image quality (狭 義)
③ Components of X-ray imaging systems
④ Spatial frequency spectra of objects
⑤ Improvement of radiological images
⑥ Image reproduction and screen-film combination
⑦ Radioisotope imaging systems and dosimetry など

1. X線像診断という大きい点から見るとX線系の解析から進んでX線像について視覚、認識などの生理的、心理的な解析が重要な問題となってくる。コントラス識別閾値、大きさの識別閾値、

Signal-to-noise ratio (S/N) の識別閾値など(chairman Morgan の序言、S-Moseley, S-Takenaka) がとり扱われている。光学(応用物理)で外国では早くから取上げられているが極めて単純化された像(円形とか短形)についてのみであり、複雑なX線像については S-Takenaka の S/N 測定は始めてである。しかし臨床的解析には非常な困難がある。 Prof. Moseley は radiation physics は image diagnostic physics でないと言ったが味わうべき言である。 physical aspect として X-ray beam quality について S-Ardran は線質測定のみならずX線像の比較に重要なことを述べ正確に平均KVで1KV迄簡単に測定する方法を発表している。

2. X線像の評価は signal-to-noise ratio(S/N) と MTF の点で評価されるべきであり、それらは系の空間周波数特性(MTF) と S/N できめられる。そしてまた系の構成要素の最も悪い要素の S/N と MTF で主として左右される。各種X線写真、映画像、テレビ像などの記録像について P-Knhl S-Feddema が報告している。 S-Ardran は映画の画質から quantum noise の画質への影響を再確認し(Morgan & Sturm と同様な功績がある) beamquality の正確な評価迄研究している。S-Sayanagi は数個の系の S/N を比較している。(誌上) Takenaka は S/N 識別閾値が対象により異なり、従来の値よりX線像では高いことを示した。

しかし S/N の合理的な取扱い方法はまだ確立してない。

3. X線系の個々の要素の相互の影響の解析については MTF の最も有益な点である。従来の X-TV系、X-cine 系では螢光増倍管の直前の quantum sink と、その MTF で最終像を殆んど左右していて、前者はある程度止むを得ないが、後者については従来の MTF=0~0.1 の遮断空間周波10~12~15~18本/cm と比べ、今回の ICR で S-Bouwers P-Atem P-Kuhl, S-Schott らが最新の螢光増倍管で30本~40本/cm のものを示し、非常に奇麗な X-cine 線を示した。また S-Niklas は CsI(Na) シンチレーターを真空蒸着した例えば高解像力3本/mm、高効率 X-ray-to-photon の高性能螢光増倍管について発表している。これに現在のものの2倍の解像力を有するので、臨床上格段に診断能が高まると思える。焦点について P-Vogeli P-Fenner は焦点の大きさ(KV, MuS 線質を含み)、X線入射方向についての MTF を論じている。散乱線について P-Doi フーリエスペクトルの入力、出力の比と考え、直流成分と同一と考えて計算と実験を比較して一致することを確めた。 P-Hatanakaはモンテカルロ法で、水ファントームで或電圧の入射X線光子の透過散乱分布を計算した。

4. X線系の伝達特性を考えるとき、入力として入る被写体の強度分布またはフーリエスペクトルはどうかということを知るのが最も大事である。この発表は従来極めて少ない S-Rossmann は試験体と血管撮影像でそのスペクトルを計算した。強度分布のフーリエ変換法で S-Takenaka, S-Schober, S-Schott が、肺、骨、小腸などについて発表した。

とくに Schober は硅肺症と肺疾患について違いを述べているが診断的意義に疑問をもち Mass Survey に役立つことをのべている。P-Takenaka は肺疾患、正常肺のスペクトル変化を捕え、かつ、診断に有利な特異的な周波分布が存在することを optical simulation で遮断空間周波数として求めて示した。X線像系において伝達されるべき被写体の情報は最も大切で熟知されるべきものである。

5. X線像の MTF を用いて被写体の画像を見やすくすること、特定周波数領域の振幅を上げることが、断層撮影について P-Edholm が行ない(optical と electronical に) XTV 像について S-Schott が任意画面、任意部位について使っている。像処理の問題として将来ますます応用が期待される。このとき、ある特定被写体の特定部位の診断に必要なスペクトルが何かということが、臨床的にきめられていなければならない。

6. Image reproduction として、焦点、被写体、増感紙などの MTF を設定して computer を用いて simulation によりX線像を形成したり(P-Takano)、screen-film 結合への MTF によるその組合わせ選別(P-Takizawa) 増感紙、焦点の MTF を設定して最適組合わせを求める方法が P-Doi, P-Sayanagi により理論的に求められた。また P-Uchida は isodose distribution curves 描記のときの分布の補正を ionization chamber の大きさと速度による MTF により修正してより正確な分布を求めた。

Table 1

1. Diagnostic radiology(Morgan, Moseley)
   - Physical aspect -----
   - Physiologic and psychologic aspect

2. Radiological image quality(final image quality, component)
   - MTF(Frequency characteristics)-----Feddema, Kuhl
   - Signal-to-noise ratio-----Takenaka, Sayanagi, Feddema
     (quantum noise)
   - Spatial frequency spectra-----

3. Components of X-ray imaging systems
   - Improved Image Intensifier-----Niklas, Bouwers, Kuhl
   - Focus---------------------------Vogeli, Fenner,
   - Scattered radiation------------Doi, Hatanaka,
   - Test object--------------------Fenner, Ardran
     (X-ray beam quality)

4. Spatial frequency spectra
   - Test object-----Rossmann
   - Human body------Takenaka(Lung, Bone), Scober(bone, lung)
     Schott(bone lung), Rossmann(vessel)

5. Improvement of radiologic images
   - Tomogram-----Edholm(optical and electronical)
   - X-TV---------Schott

6.
   - Image reproduction----------Takano, Hatanaka,
   - Screen film combination-----Doi, Takizawa, Rossmann
   - Dosimetry-------------------Uchida.

第4回国際放射線技術学会議印象記

津　田　元　久

第4回国際放射線技術学会議の全日程を通じて出席する機会を得たので、全体的な印象や講演内容について報告してみたい。

会議は昭和44年10月2日から4日にわたって、内外のX線技師約3000人を集めて東京パレスホテルで開催され、盛会であった。

欧米諸外国の技師はほとんど女性であり、日本を含めたアジア諸国の技師がほとんど男性であるのに比べて対照的であった。

日本の者の演題は、技師の業務区分が明確であるためか、純技術的なものが多かったのに対して、外国から寄せられた演題は放射線科チームとしての業務内容を紹介したものが多く、純技術的な問題を扱ったものが少なかった。推察するところでは技師固有の業務が確立されていないのではなかろうか。

会議の内容は特別講演2題、シンポジウム9題、口述発表18題および展示発表51題であった。このうち RII 研究会に関連ある演題について、あらましを紹介しよう。

会議初日には RII 研究会会長の高橋教授の「放射線撮影および治療における回転技術」と題する特別講演があった。会員のみなさんには、なじみ深い演題なので説明するまでもなかろう。

おなじく初日の最後の講演は内田教授の口述発表「放射線領域におけるいくつかの問題のフーリエ解析」であった。フーリエ解析の手法が放射線技術の分野で広く利用されている現状の解説は、内外の参加者に大きな感銘を与えたものと思われる。

第2日にはいって、長崎大学の高雄義人氏の口述発表「血管造影の映画撮影ならびにビデオパルスX線テレビ映像法」が行なわれた。パルスX線法によって、像の識別性が向上することが映画で示された。

第3日に行なわれたミズリー大学の Lodwick 教授の特別講演“The computor: A solution to a dilemma of radiologic health care„は今回の国際会議中の圧巻であり、スケールの大きさ、野心的な試みに圧倒された。

電子計算器を適用する研究の範囲は、①放射線科を新設するときの建物・装置・人員の計画、②放射線科の業務運用をもっとも能率よく行なう方法の検討、③放射線科におけるデータ（X線写真を含む）の記憶と検索、④医師が放射線科の各種データ（X線写真を含む）から診断を行なう時の論理を体系化して計算器に記憶させ、自動診断に利用すること、⑤放射線像を処理して改良し、所望の情報を抽出することなどにわたっている。

研究の目的は放射線科の省力化にあり、研究全般の現状を紹介したあと Lodwick 教授は、画像から疾患を認識・識別するようなシステムによる診断の自動化を今後2年以内に実現させるこ

とを公約した。ミズリーの今後の研究成果に注目したい。

会議の最終プログラムは展示発表演題であったが、その中に本会会員である大阪大学の遠藤俊夫氏の「X線映画画像の鮮鋭度評価」が MTF を用いて行なわれていた。

総括的にみて、国内の演者による発表の内容が、国外から寄せられた演題よりも内容がすぐれており、日本のX線技師の水準が諸外国のX線技師のそれより高いことを物語っているように感じられた。

インフォーマルミーテング

10月9日(木)霞ケ関ビル東海大学同窓会ホール一室を借りて、わが RII 研究会のメンバー21名と欧米の特にシカゴミーティングのメンバー14名、合計35名が一堂に会した。(別表)この日は午前中スケジュール通りのミーティングがあり、午後になって自由時間となったのでその暇をみつけて、竹中先生が諸外国のメンバーに8月頃から連絡をとり、その甲斐あって多数の外人の出席を得た次第で本研究会にとってよろこびとする処である。

ミーティングは午後2時から始まり午後5時閉会するまで、色々の問題について話し合われた。まず佐々木が会長に代わって挨拶し、それぞれ自己紹介した。次に私共の研究会の内容について竹中佐柳らによって書かれた白書を中心に説明した。これに対し Rossman 教授はシカゴグループの活動の真の目的は私共の研究会のように研究を中心にやっているのではなく、ある一つの目標を決めて、その規格統一的な面から放射線防護を目的とする一種の技術的な標準化、その規格の規定方法について論じ合うもので、相互の競争の具とするものでないなどの説明があった。

Dr. Schober は5年前の京都に於ける I. C. O. の学会で写真、レンズなどについて Prof Ingelstam などと討論があり、本会からも佐柳氏、土井氏が参加されたことの報告があった。この後一つのテーマが取り上げられた。それは “Testobject„ についてであった。この問題の要点はこれを何を計る目的で作成するかにあると、Mr. Schott は発言し、彼は Techhical Service man のために作られているのが現状であると述べた。Dr. Kuhl は、これが Radiologist でも使用できるように簡単にした。又 Prof Morgan はその geometry について spacial 及び temporal sesolutim についてはどうかなど、これらについても計り得るようにしたいと発言した。

Dr. Ardran は I. I, T. V の他に用いることができないかなどと発言した。Dr. Zieler, Dr. Oesterkamp などからも発言があった。Dr. Holm は Conversion factor について発言し、それが日本で如何に用いられているか。恒岡氏はほぼそれに従って測定していると解答した。その他に1〜2のテーマについても Discuss されたが、時間もせまり再会を約し、又情報の交換を約して散会した。

出　席　者

金森仁志（京都工芸大）
内田　勝（宮崎大）
坂内秀郎（電々公舎）
高野栄一（キャノン）
滝沢正臣（信州大）
O. Schott（ドイツ）
平城　実（大日本塗）
土井邦雄（〃）
森矢達人（勧銀）
井上多門（東芝）
恒岡阜二（〃）
長谷川　伸（電通大）
白水俊次（東芝）
尾沢光久（日大芸放）
K. Rossmaun（USA）
Thure Holm（Sweden）
R. H Morgan（USA）
Feddema（Holland）
Recourt（Holland）
Oosterkamp（〃）
kühl（〃）
Luiten（〃）
S Schmidt（Germany）
本保善一郎（長崎大）
P. Soila（Finland）
西岡敏雄（日大）
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鳥生敏郎（〃）
P. Edholm（Sweden）
E. Ziehler（Germany）
E. Fenner（〃）
坂田俊文（東海大）
橋本光二（横浜市）
竹中栄一（東大放）
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