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150th Birthday of Nikola Tesla (1856-1943) Inventor of Mobile Robot Teleoperation

MEASURING DATA EXTRACTING FROM PBS DETECTOR SIGNAL IN THE NIR MOISTURE METER

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Abstract: *The reflectance at two, absorbing and not absorbing wavelengths in the near infrared (NIR) region from several wheat grain samples with different moisture content detected by the precise gravimetric instrument, has been measured. The periodical measuring signal given by the photoconductive PbS detector and amplified with a band pass analogue preamplifier consists of both, beneficial and unfit information. The input radiation was assigned by the mechanical chopper with adequate optical filters and directed to the sample by the mirror system. The frequency analysis of both, the input and amplified output has been conducted by using the Fast Fourier transformation (FFT). The applied approach with all calculation and measurement results are presented in this paper.*

Key words: *photoconductive detector, moisture, NIR, FFT*

1. INTRODUCTION

The optoelectronic measurement system of the moisture meter with one beam which is described and analysed in some authors' previous papers is based on the cooled PbS photoconductive detector, the preamplifier and the mechanical chopper. The applied measuring principle consists of determining the reflected part with respect to the total radiation at two different wavelengths in the near infrared (NIR) region [1]. This was achieved by means of one beam with two pairs of narrow band pass NIR filters, the 1800nm wavelength which does not absorb water, in contrast to the 1940 nm wavelength which absorbs water. Both of them are embedded in the rotational wheel. The mechanical chopper has a double function. First, the NIR radiation at reference wavelengths, which water not absorbs, and narrow band at 1940nm, the so called absorbing for water, is extracted from the totally produced radiation by means of a halogen bulb whereas the lens system directs the incident radiation to the sample. Second, these two domains are mechanically modulated by the exactly chosen frequency [4]. The mentioned moisture measuring system consists of a radiation source, a mechanical chopper with two pairs of optical filters, the photoconductive PbS detector and analogue preamplifier as shown in Fig.1. The chopped radiation from the source is directed by a mirror system to the wheat grain sample. Furthermore, the reflected radiation from the sample is collected and directed by the concave mirror to the photoconductive PbS detector. The continual signal of the detector is AC coupled with the analogue preamplifier and acquired on the output by the PC card. However, the moisture meter is accomplished by one beam [2], the signal modulated by the mechanical chopper is not sinusoidal and it consists of information about radiation values reflected from the sample at both, reference and the absorbing wavelengths. Besides, a large amount of noises as well as some useful information occur in this signal. Henceforth, the measuring data at these two wavelengths have to be extracted from the acquired signal before a subsequent processing is done.

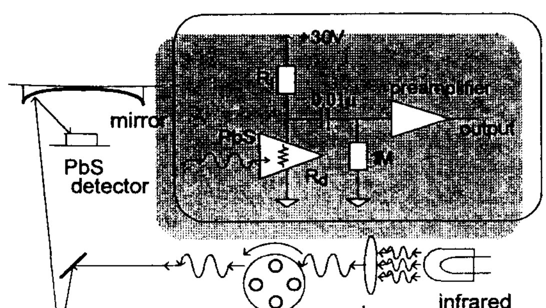

Fig. 1 NIR moisture measuring system

2. NIR SIGNAL MODULATION

The radiation consists of the NIR at 1800nm and 1940nm from the source shown in Fig. 1 which is directed by the achromatic lens to the mechanical chopper. Fig. 2 shows the sight on the wheel surface during its rotation by the angular velocity ω, which cuts the circular shape of the incident beam at the same time. Two pairs of the NIR optical filters are located in the four wheel windows which transmittance characteristics are shown into patterns apart.

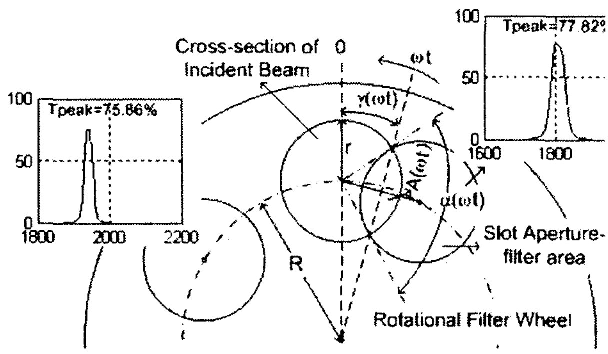

Fig. 2 View on the filter wheel

The energy density of the radiation which penetrates into the sample at 1800nm and 1940nm vary owing to different transmittance coefficients of the remote filters, T_{peak}=77.82% and T_{peak}=75.86% respectively. But, the energy density of the input beam around the corresponding wavelength is particularly constant.

2.1. Input signal evaluation

Some respective units are noted by adequate symbols in Fig.2. Provided that the incident energy of the input beam is constant and the chopper output is proportional to the sector indicated by $A(\omega t)$, the following expressions result from Fig.2:

$$A(\omega t) = r^2 \alpha(\omega t) \quad (1)$$

$$\alpha(\omega t) = 2a\cos\left(\frac{R\sin\gamma(\omega t)}{r}\right). \quad (2)$$

The rotational wheel changes γ angle twice as slow as ωt from $\pi/8$ to 0 corresponding to A changes from 0 to maximum, therefore

$$\gamma = \frac{\pi}{8} - \frac{\omega t}{2}, \text{ and} \quad (3)$$

$$A(\omega t) = 2r^2 a\cos\left(\frac{R}{r}\sin\left(\frac{\pi}{8} - \omega t\right)\right) \quad \text{for } \omega t = 0 \div \frac{\pi}{4}. \quad (4)$$

Because the energy density of the radiation is constant and two pairs of the optical filters have different transmittance characteristics when compared with each other, the incident radiation which has the same sample curves as a signal is shown in Fig. 3.

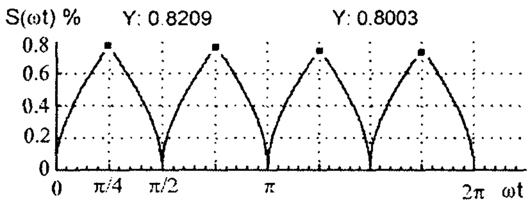

Fig. 3.Curve of the radiation penetrating into the sample

2.2. Fourier series of the reflected radiation

The curves of the reflected radiation from the sample depend on the moisture content and its other features. Linear changing of the reflected energy is assumed by using the reflected coefficient ε_r. The Fourier series of the reflected coefficient,

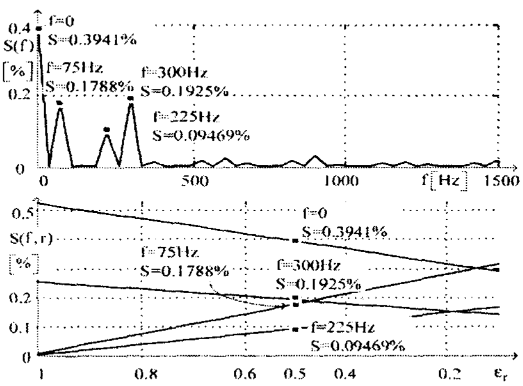

Fig. 4. Fourier series versus different reflection

which were obtained by FFT as well as how some harmonics change with ε_r are shown in Fig. 4. Proportional changing of one part of the reflected signal at 1940 nm [1] only, is being assumed and high band pass of the analog preamplifier circuit. DC (f=0) signal does not pass along the preamplifier which is also shown.

3. EXAMPLES AND EXPERIMENTAL RESULTS

Some of the output signals from the preamplifier are measured by the gravimetric instrument [5] at the constant temperature of the photodetector and ambient 22^{0}C [3] for the same wheat grain sample with various but known moisture content from 13.36% to 20.96%. One of the time responses and some harmonics compared to the moisture content characteristics which are calculated using the FFT of time curves at the rotary speed of the chopper 4500min^{-1} (75Hz) are shown in Fig. 5. The discrete values which are given by the FFT are marked by dots whereas the appropriate characteristics are indicated by lines.

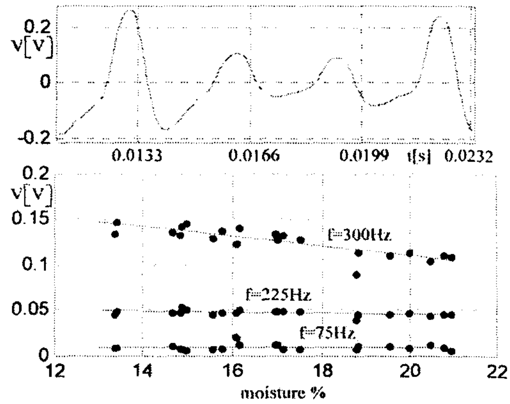

Fig. 5. Time response a) and frequency response b)

4. CONCLUSIONS

The NIR moisture meter measuring system is analysed by the discrete Fourier transformation at different but known moisture contents of the same wheat grain and the constant detector temperature. The detector temperature is measured by the embedded thermistor. The high order frequency components exist in the output signal of the analog preamplifier due to the applied frame of the optical filter windows. The frequency content of the output signal can be changed by the appropriate frame or/and size of the holes chosen in the filter wheel and by the parameter analog preamplifier circuit changing. But, the signals of the reference and absorbing beams are unmistakably measurable in the applied configuration. Linear dependency of several harmonics to the moisture of wheat grain changing was noticed at the process of conducting the analyses, although additional researches have to be carried out in order make a more accurate conclusion. Many problems can be anticipated when the signal of the absorbed beam is small. Noises influence the calculation of the harmonic content, and higher harmonics are distinct if compared to the 3rd or 4th, for example.

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