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LOCK-IN AMPLIFIER IN NIR REFLECTANCE MEASUREMENT SYSTEM

Ćorluka,V.; Filić , M.; valter , Z.

Abstract: *The electronic circuits to which a detector is connected conditions the signal output further from the detector.Knowledge of the modification to this signal imposed by the measuring circuit is important for accurate use of the detector signal. An electrical output signal from a detector that is proportional to the flux incident upon a detector is of a little value if it is exceeded by the random electrical fluctuations , known collectively as noise, produced by a variety of sources. Some noise generated in the postdetector electronics , or in the detector itself , can be special techniques. Methods have been devised both to reduce noise levels and to avoid some of their limitations on detectability.*

Key words: noise, filter, lock-in, detection,PSD

1. INTRODUCTION

Radiant flux and detection system generally suffer from two different kinds of noise. Radiation noise results from the fact that sources of electromagnetic radiation themselves exhibit an inherent temporal variability by virtue of the statistical nature of the photon emission process. The second kind of noise experienced in radiation detection system is electrical noise produced in the detector and its associated electronics. In our reflection measuring instrument this low frequency noise has several sources including flicker noise associated with semiconductor devices , detector-generated noise , shot noise , 1/f noise and variations in ambient light leaking into the instrument and reaching the detector. At higher frequencies the spectrum flattens out to give a resonably constant shot noise background which is associated with the quantum nature of light. The small peaks of 50Hz and 100 Hz are due to electrical interference from the power system. The larger peak at 100Hz is due to light from room lighting leaking into the instrument and reaching the detector. One method of modulating the flux reaching the detector is shown in Figure 1.

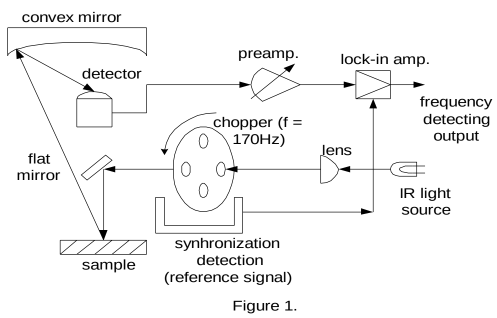

Figure 1.

Figure1. Schematic diagram of a reflectometer with signal detection system

The diagram shows the detector output spectrum in this new situation with the chopper running at 170Hz. The radiation coming from it can be chopped at the source with a rotating sectored wheel , called chopping – wheel. As the wheel rotates , it alternatively blocks completely and passes completely the radiation emanating from the source of the sample area to the detector. This produces a modulation of the light , the rate or frequency of modulation depending upon the number of open segments and the rate of rotation. The waveform will depend on the shape and size of the beam passing through the chopping wheel in relation to the blades or segments of the wheel. The advantage of this system is that it does not only exclude noise at frequencies other than the chopping frequency (170Hz) but it also excludes any unchopped stray light that might find its way to the detector from the room or other sources. This stray light rejection capability is an important attribute of chopped radiation source/detector system. Chopping wheel is commonly used in systems to minimize noise and stray light effects or to detect signals at the chopping frequency that are much smaller than the accumulated noise over all other frequencies. The light source and detector combination at the chopping wheel is provided to sense when the wheel is blocking and letting through the beam passing through it.

1. MEASUREMENT AND ANALISYS

In some cases , a much greater improvement can be achieved by the use of synchronous detection. An amplifier based on this detection principle will detect and "lock onto" the phase of a signal. It is therefore called a "LOCK-IN" amplifier. The block diagram of a typical lock-in amplifier is shown in Figure 2. Lock-in amplifier for noise reduction consists of: a preamplifier , a band pass filter , a phase-shifter , a mixer (demodulator) and a low pass filter.

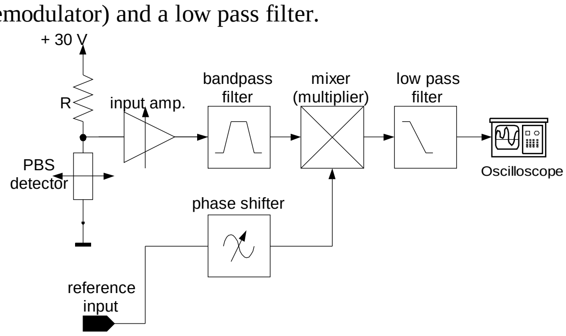

Figure 2. Scheme of lock-in amplifier

The input signal , including noise (white noise) is amplified by an adjustable gain , AC coupled amplifier , in order to match it more closely to the optimum input signal range of the PSD (phase-sensitive detection). Figure 3a shows the input signal consisting of information signal sine wave form at the chopping frequency of 170Hz (about 1V amplitude) with additional high frequency noise , plus harmonic component (1V peak) in the output preamplifier. A section of the amplifier can be placed behind the filter to avoid saturation of the filter caused by noise and distortion. Electronic band pass filter rejects the noise at higher and lower frequency and hence significantly improves the signal to noise ratio. Band pass filter is centered at 170Hz (fFigure 3c.).

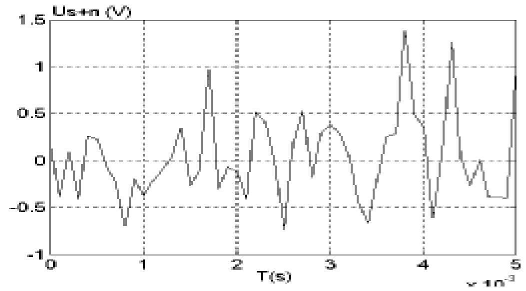

Figure 3a. Input signal with signal noise

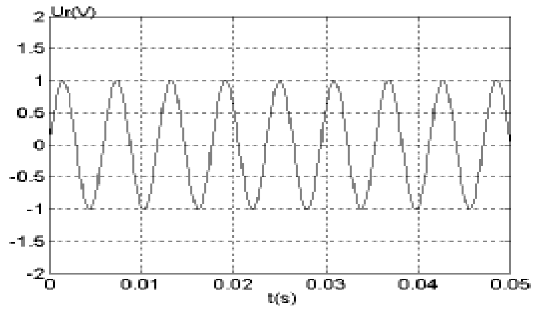

Figure 3b. Reference signal

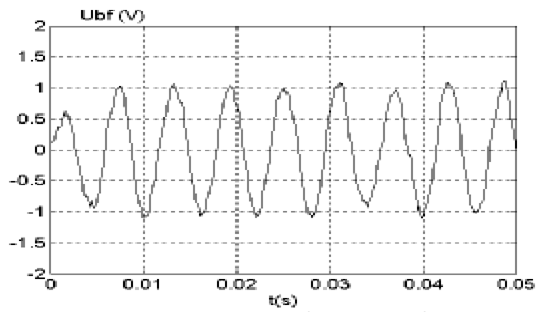

Figure 3c. Output signal of band pass filter

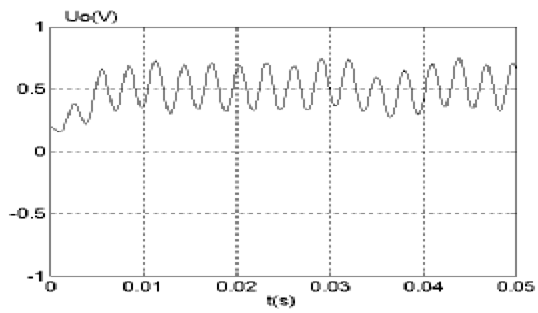

Figure 3d. Output signal of lock-in amp.

The width of the passband (B=10Hz) of the synchronous amplifier is a parameter. This parameter is Q and defined as the bandwidih of a filter divided by its centre frequency. The narrower it is , the greater is its exclusion of noise and the better is the resulting SNR. Lock-in measurement requires a frequency reference. In the diagram (Figure 3b.) , the reference signal is a sine wave at frequency of 170Hz , amplitude 1V. The lock-in amplifier uses this reference signal to select a small range of signal frequencies centered on the reference frequency to amplify and deliver to the signal measuring circuit. Synchronous amplifier includes comprehensive and flexibile phase shifting circuitry. The phase control on the lock-in usually takes the form of a continuous variable of 0-95 degree and 3 fixed increments of 90 degree giving 365 degree in total. After the amplification the signal is multiplied by the lock-in reference using a PSD or multiplier known as a demodulator or mixer. The detector operates by multiplying two signals together. If the sin is an output signal from band pass filter , the response might be the signal waveform shown in Figure 3c. Considering the case where U_{bf} is being detect , where $U_{bf} = V_1\cos(\omega t)$, the lock-in amplifier is supplied with a reference signal at frequency of 170Hz and uses this to generate an internal reference signal : $U_r = V_2 \cos(\omega t + \varphi)$, where φ is a user-adjustable phase shift introduced within the lock-in amplifier. The output of the PSD is simply the product of two cosine waves. $U_{psd} = V_1\cos(\omega t)$ x $V_2 \cos(\omega t + \varphi) = 1/2V_1V_2\cos\varphi + 1/2 V_1V_2(\cos2\omega t + \varphi)$. The output of the PSD then passes to a low pass filter which removes the 2ωt component , leaving the output of the lock-in amplifier as the required DC signal. If $f_1 = f_2$ and the magnitude , V_2 , of the reference frequency is kept constant , the filtered PSD output will be: the DC signal is proportional to the input signal amplitude V_1 and to the cosine of the angle , φ , betwen the signal and reference. Figure 3d. shows the situation in output low pass filter where $f_1 = f_2$ (170Hz) , phase shift betwen the signal and reference phase is 0 degres and amplitude V_1 and V_2 about 1V. The output from a lock-in amplifier is DC signal 0.5V, ($1/2V_1V_2$, φ =0) Phase-shifting is required, first of all, to ensure φ = 0 (maximum signal) excatly as the predetection filter will cause a phase shift of the input signal. Secondly , phase shifting enables us to measure the phase difference between the input voltage and the reference (zero signal when $\varphi = 90^0$)

4. CONCLUSION

When optical radiation measurements are noise limited , steps can be taken , such as cooling the detector , to reduce the magnitude of the noise. One can also build electrical detection systems to filter out noise frequencies , leaving only fluctations due to the signal being detected. In a practical situation the signal will usually be accompanied by noise , but it can be shown that as long as there is no consistent phase relationship between the noise and the signal , the output of the multiplier due to the noise voltages will not be steady and can therefore be removed by the output filter. In order to have maximum value of S/N ratio the following activities have been performed: selection of optimal current supplying NIR detector , lowering operation temperature , optimised signal preamplifier and selection of optimal rotation frequency of a plate on which eight optical filters are fitted

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