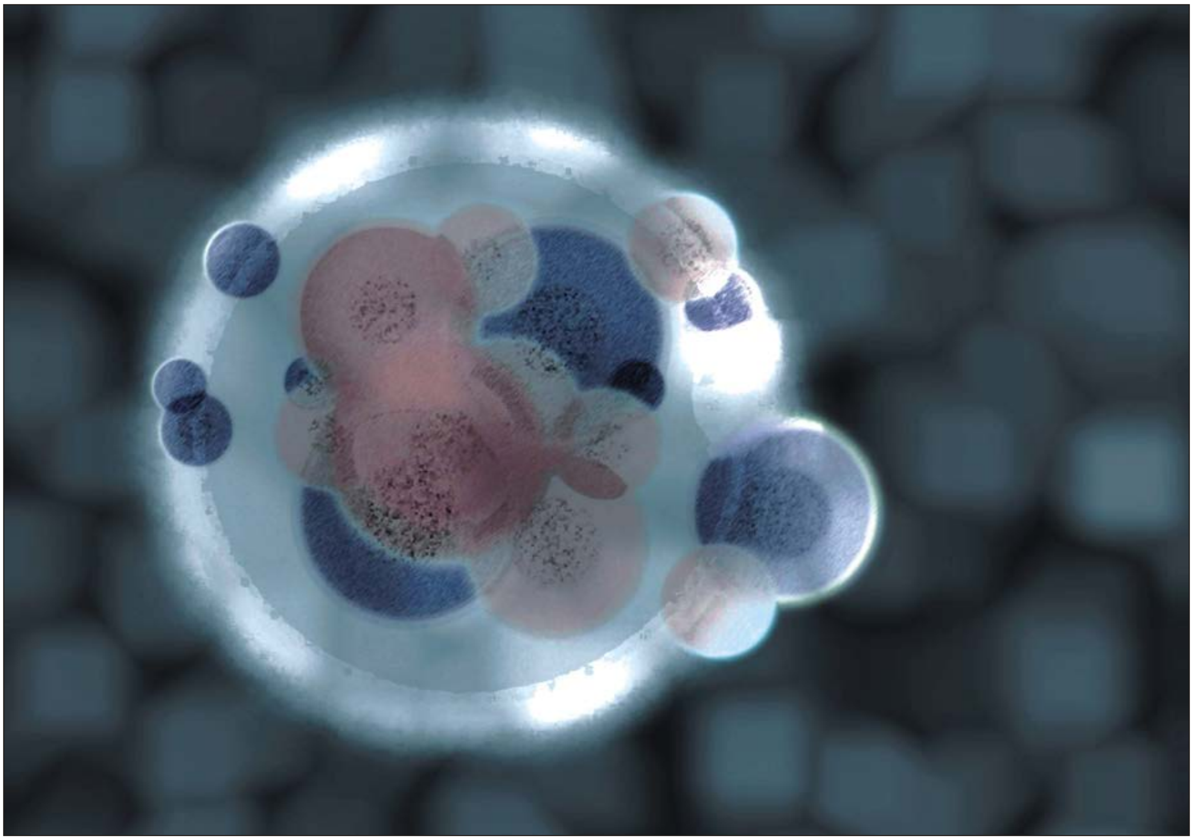

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Research Article
Investigation on Reflection of Signal Intensity for Laser Doppler Perfusion Instrumentation System Assisted Using Lab View

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Abstract

This study investigate on the reflection of signal intensity radiated from laser doppler perfusion via identified distances for signal optimisation before it is apply on human skin tissue for skin disease measurement for diagnose treatment. A calibration sample is applied in the investigation as distance calibrator. Results show that, higher distance measured results to losses of signal measurement. Thus, reflected signal intensity performance becomes less optimise and inappropriate for higher distance measurement. However, measurement at 10 cm of distance and lower, cause radiated light of reflected signal intensity results to significant measures with optimum due to above reference voltage.

Key words: LDP, MBF, channels, RSI

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Laser Doppler Perfusion (LDP) is use to investigate Human Skin Tissue (HST) assessment non-invasively via Microcirculatory Blood Flow (MBF). This method of measurement would minimize the level of discomfort and reduce the risk of diagnose treatment to patient under clinical observation such as Human Skin Disease (HSD). Clinical traditional methods such as patch test, scratch test and injection test are painful and cause discomfort to patient during the biopsy assessment and diagnose treatment[1,2].

The technique of LDP depends on the Doppler principle known as Doppler Shift Estimation (DSE) where monochromatic of visible lights are scattered and shifted in angle by moving MBF. The frequency shift is depends on the movement of blood flow, the direction of incoming light and the direction of scatter light[3,4].

The LDP instrumentation system developed consists of two parts which are hardware development and software implementation. There are few component modules in the hardware development such as laser diode driver unit, laser Doppler perfusion sensor, signal conditioning unit and data acquisition (DAQ) unit. The functionality of laser diode driver unit is to generate and supply sufficient and consistent current to semiconductor laser diode of 3.5 Vdc (min) in order for it to operate effectively to the maximum of 4.95 Vdc. The visible light is then radiated on a calibration sample based on identified distances. The Reflected Signal Intensity (RSI) is detected via laser doppler perfusion sensor customized with photodiodes. It is then amplified and filtered via signal conditioning process unit. In order for the processed signal conditioning to be presented in the system, a Graphical User Interface (GUI) is programmed and implemented using Lab view via high speed 250 kS sec^{-1} of DAQ unit.

This paper is emphasis on the investigation of optimization reflected signal intensity based on identified distance measurement for LDP via calibration sample which later to be applied in diagnosing human skin tissue of skin disease.

LASER DOPPLER PERFUSION

Doppler shift estimation: Laser doppler technique is applied in this study and investigation because it is able to provide a unique and continuous measurement on HST. Thus, this technique is able to produce DSE when interact with moving MBF which would potentially provide alternative approach. Moreover, the time consuming in providing accurate clinical results of skin risk assessment can be minimized greatly[5,6].

This technique can also be used to measure velocity of blood flow non-invasively. The LDP is able to relate the MBF with the DSE. The light used in LDP monochromatic light consist of frequency shift caused by Doppler scattering which results to frequency broadening. The backs cattered light forms an interference pattern on the photodetector and that the fluctuations in this pattern carry information about the doppler shifts. In order for interference to occur, the coherence length of the laser must be much longer than the difference in path length for light waves that were emitted at the same moment. When visible light propagate to MBF, the visible light will scattered with a velocity and it will produce frequency shifted. The angular frequency shift (Φ) can be get between the incoming light and light scattered[3,4].

Flux perfusion: The term commonly used to describe blood flow measured by the laser doppler technique is called as 'Flux'. Flux is expressed as Perfusion Units (PU) and is calculate using the first moment of the Power Spectral Density (PSD). The LDP unit can be measured by achieving the Brownian motion of particles[3,5] as shown in the Eq. 1:

$$\text{Flux} = k_1 \int_{\omega 1}^{\omega 2} \omega \frac{p(\omega)}{l^n} d\omega - \text{noise} \qquad (1)$$

where, k1 is constants used to scale the raw output to a pre-determined calibration point, ω is the doppler shift in angular frequency units. Where, $\omega = 2\pi\Delta f$. Doppler shift frequency Δf is measured in frequency units Hz. Light intensity L used to normalise the signal to help eliminate the effects of gross variations in scattered light intensity. An index n, which normally takes the value 2 if normalisation is being used to compensate for laser power differences. The ω1 is the lower cut off angular frequency. The $\omega 1 = 2\pi f1$. Typically f1 is 20 Hz in laser doppler flowmetry instruments and 20-250 Hz in laser doppler imaging instruments depending on the speed of scanning pattern. The ω2 is the upper cut off angular frequency. It is limited to reduce overall noise. $\omega 2 = 2\pi f2$. Typically, f2 is 15 kHz for measurement of blood cell speeds up to approximately 6 mm sec^{-1}. For low blood cell speeds (approximately, 1 mm sec^{-1}) and for an optimum signal to noise ratio, 3 kHz can be used. For speeds up to 10 mm sec^{-1} a 22 kHz bandwidth is used[3,5].

MATERIALS AND METHODS

Experimental on reflected signal intensity: Three different distances of measurement are identified; 5, 10 and 30 cm measured from the calibration sample level. This is to investigate optimum range of reflected visible light signal detected from the calibration sample. In addition, this experiment is also conducted to ensure proportionality of RSI increases as the distance of detection measured from the calibration sample is increased.

Uncontrolled room conditions: Each of the collected raw data of 100100 sampled with default of 1 kHz speed of sampled data where channeled (Channel 1 = Ch1, Channel 2 = Ch2, Channel 3 = Ch3 and Channel 4 = Ch4) accordingly based on the position of LDP sensors customized with the photodiodes. The raw data of RSI is programmed, saved and subtracted to emit actual data from background interference. It is computed by subtracting both normal room condition and dark room condition. Both room conditions are uncontrolled. The actual data is then presented base on the statistical parameter such as arithmetic mean value, Root Mean Square (RMS) value and Standard Deviation (SD). Other statistical parameter such as variance and normalization provide less importance to identify the optimization of RSI range.

RESULTS AND DISCUSSION

The results of investigation at three different distances measurement: 5, 10 and 30 cm as shown in Fig. 1 are resulted and discussed base on its statistical parameter of RSI such as arithmetic mean value, RMS value and SD.

Arithmetic mean value: Figure 1 shows that lower distance measured below 10 cm would stimulates less amplitude of RSI. It is clearly indicate that the average amplitude of Ch1 = 0.058 V±0.26 SD, Ch2 = 0.041 V±0.20 SD, Ch3 = -0.539 V±0.158 SD and Ch4 = -0.557 V±0.121 SD would results to an average of -0.249 V±0.185 SD. This value is below the references value of 0 V. Therefore, investigation of RSI at 5 cm distance is less optimize and less appropriate for HST measurement of MBF.

High distance measured at 10 cm as shown in Fig. 2, would stimulates substantial amplitude of RSI. It is clearly indicate that the average amplitude of Ch1 = 0.494 V±0.244 SD, Ch2 = 0.333 V±0.286 SD,

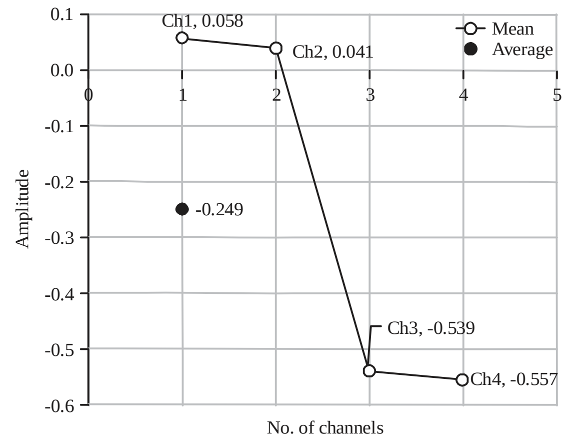

Fig. 1: Arithmetic mean value of 5 cm RSI

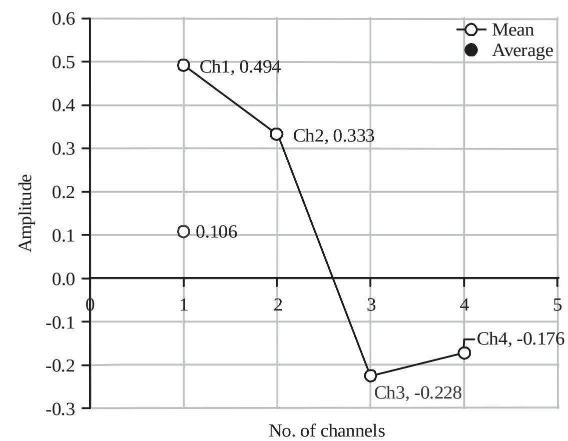

Fig. 2: Arithmetic mean value of 10 cm RSI

Ch3 = -0.228 V±0.167 SD and Ch4 = -0.176 V±0.156 SD would results to an average of 0.106 V±0.213 SD. This value is above the references value of 0 V. Therefore, investigation of RSI at 10 cm distance is relatively optimize and appropriate for HST measurement of MBF.

Higher distance measured at 30 cm would not only can use inaccuracy stimulation of RSI amplitude, it also leads toward losses of data by suppressing useful information to 0 V. It is clearly indicate as in Fig. 3 that the average amplitude of Ch1 = -0.024 V±0.011 SD, Ch2 = 0.008 V±0.013 SD, Ch3 = -0.033 V±0.018 SD and Ch4 = -0.023 V±0.037 SD would results to an average of -0.018 V±0.020 SD. This value is irrelevant and below the references value of 0 V. Thus, the value is almost insignificant. Therefore, investigation of RSI at 30 cm distance is relatively non-optimize, inappropriate and irrelevant for HST measurement of MBF.

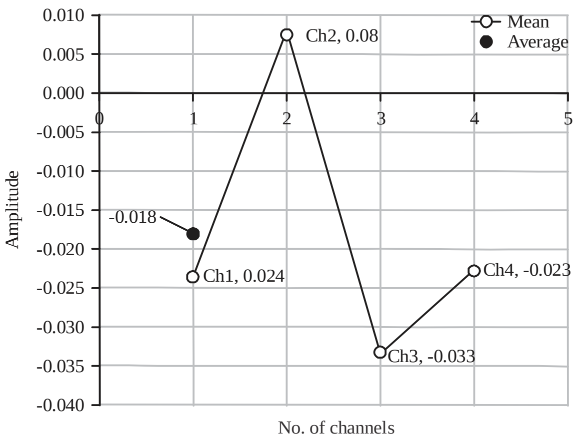

Fig. 3: Arithmetic mean value of 30 cm RSI

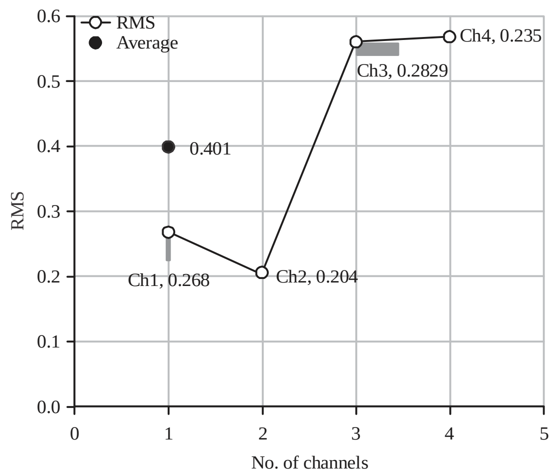

Fig. 4: RMS value of 5 cm RSI

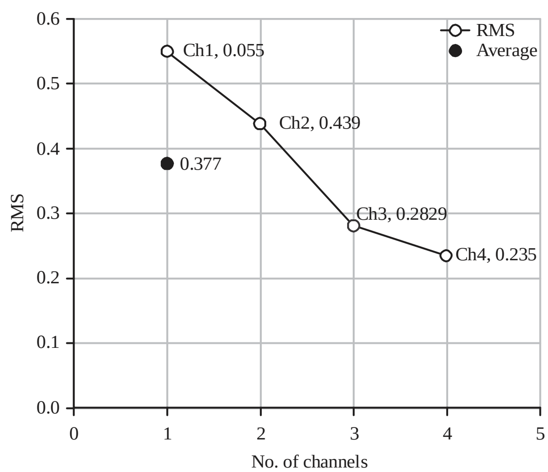

Fig. 5: RMS value of 10 cm RSI

RMS value: Figure 4 shows that lower distance measured at 5 cm would stimulates adequate RMS value of RSI. It is clearly

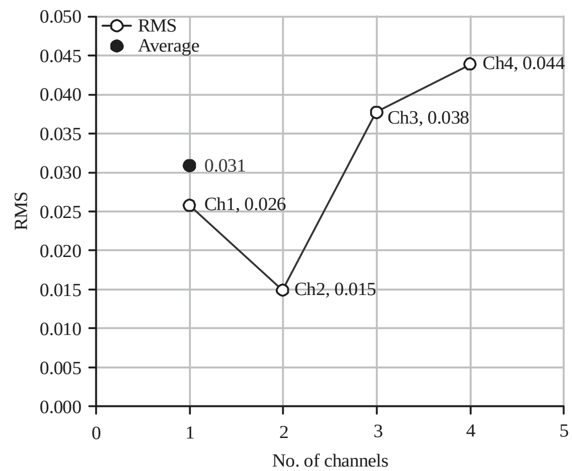

Fig. 6: RMS value of 30 cm RSI

indicated that the average RMS value for Ch1 = 0.268 Vrms, Ch2 = 0.204 Vrms, Ch3 = 0.562 Vrms and Ch4 = 0.570 Vrms would results to an average of 0.401 Vrms. This value is above the references value of 0 Vrms. Therefore, investigation of RSI at 5 cm distance for RMS is significant and appropriate for HST measurement of MBF.

High distance measured at 10cm as shown in Fig. 5, would stimulates substantial RMS of RSI. It is clearly indicate that the average RMS of Ch1 = 0.551 V, Ch2 = 0.439 V, Ch3 = 0.282 V and Ch4 = 0.235 V would results to an average of 0.377 V. This value is above the references value of 0 V. Therefore, investigation of RSI at 10 cm distance for RMS value is relatively optimize and significant for HST measurement of MBF. Higher distance measured at 30 cm as shown in Fig. 6, leads toward losses of data. It is clearly indicate that the average RMS of Ch1 = 0.026 V, Ch2 = 0.015 V, Ch3 = 0.038 V and Ch4 = 0.044 V would results to an average of 0.031 V. This value is inadequate and inappropriate because it is approximately equal 0 V. Thus, the value is almost insignificant. Therefore, investigation of RSI at 30 cm distance of RMS value is relatively inappropriate and results to approximate zero optimization of RSI for HST measurement of MBF.

SD: Figure 7 and 8 of SD statistical graphs show that measurement at 5 and 10 cm of RSI, respectively, would indicates a confident of statistical analysis conclusion in which both Fig. 7 and 8 SD data points are being expected as statistically significant. Since it is spread away from the reference value, 0 V. However, Fig. 9 indicates results approximate to reference of 0 V. This is considered as insignificant to the variation of measurement

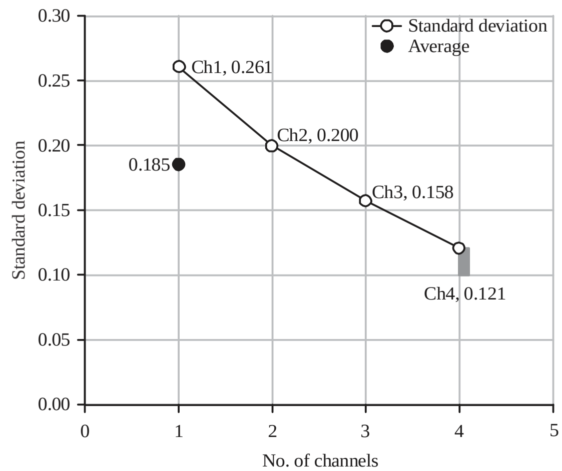

Fig. 7: SD of 5 cm RSI

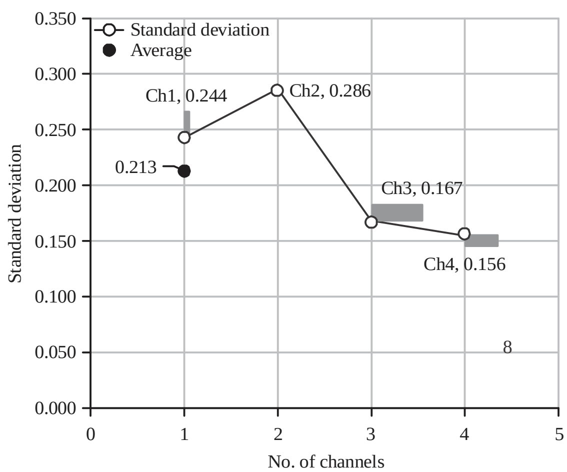

Fig. 8: SD of 10 cm RSI

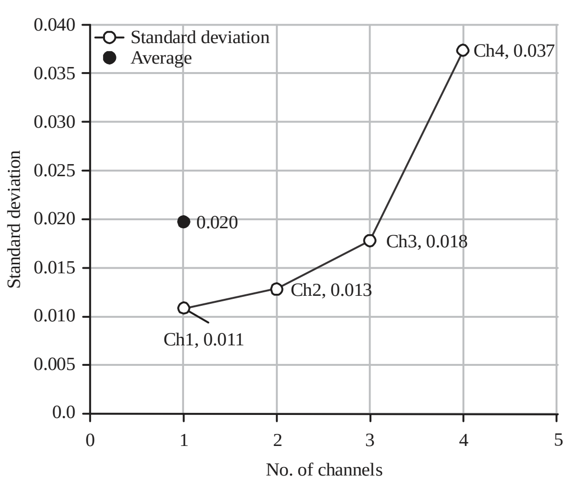

Fig. 9: SD of 30 cm RSI

due to its effect that would possibly cause losses of data during HST measurement of MBF.

CONCLUSION

This is a continuous investigation to investigate the optimum range of RSI for measuring MBF on HST. Measurement of RSI at 5 cm distance is consider as acceptable distance, however, it is less optimize as compare to 10 cm of detection range. It is clearly indicates based on the results that at 10 cm of distance, the RSI resulted an optimum signal with significant mean amplitude and RMS values. Nevertheless, at 30 cm of distance, the RSI would be less optimize and inappropriate for measurement due to small value of data and approximately to 0 V.

As for RMS value, all three graphs have different signal pattern. However, the RMS average value for both 5 and 10 cm are approximate to each other 0.401 and 0.377 Vrms, respectively. In conjunction, the RSI of RMS for 30 cm is too small (0.031) and can be predicted as 0 V. As a conclusion, results show that, higher distance measurement causes loss of signal measurement. Therefore, RSI becomes inaccurate and inappropriate to measure. On the other hand, measurement at 10 cm of distance and lower, would results to significant measure of radiated light RSI due to above reference voltage.

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