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THEORETICAL STUDY OF BLOOD FLOW AND PERFUSION PARAMETERS IN FOREHAND SKIN VASCULAR USING DATA OF LASER DOPPLER IMAGING APPLICATIONS ON MATLAB PROGRAM

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ABSTRACT

This study explains the work progressed in the research Project of the 2nd year of Medical physics and radiation science master's degree course at the University Sains Malaysia. This research, entitled "Theoretical Study Using MATLAB program for Blood Flow Parameters in Forehand Skin Vascular Applying Laser Doppler Imaging", has as initial target, the expansion of software and hardware settlement capable of being incorporated in tools for measuring blood flow or perfusion utilizing the Laser Doppler Imaging. In this study, the functional and theoretical rules are reviewed and explained. Two actions were done, one that utilizes and insert a specific mathematical equation on MATLAB program and another with an applying the values and check the validation of these equations for measuring and expect the blood flow or blood perfusion. Software (MATLAB program) routines to evaluate these achievements are also explained and discussed. This research study, in the scope of the 2nd year of Medical physics and radiation science master's degree course it is relating to forehand skin vascular hypertension, since that's too much significant region and where all the human and tool exchequer, currently obtained, let us to improve techniques and ways with a large possible of implementation. Thus, the project aims at developing mathematical equation to measure blood flow and perfusion in arterial microcirculation and to improve informatic applications that can be used as a graphic interface and as a results interpretation tool.

Key words: MATLAB Program, vascular hypertension, arterial microcirculation

INTRODUCTION

1.1 Blood

The fluid that circulates in the heart, arteries, capillaries, and veins of a vertebrate animal and that delivers necessary substances such as nutrients, antibodies and oxygen to the cells and transports metabolic waste products away from those same cells [1].

1.1.1 Blood flow in the body

Oxygenated blood is pumped to the left hand side of the heart in the pulmonary vein and enters the left atrium. From here it passes through the mitral valve, through the ventricle and taken all around the body by the aorta[2].

1.2 Blood composition

Blood is composed of plasma and formed elements. the formed elements contain are platelets, white blood cells (WBC) and red blood cells (RBC), While the plasma contains 91.5% water, 7% proteins and 1.5% other solutes (Figure. 1) [3].

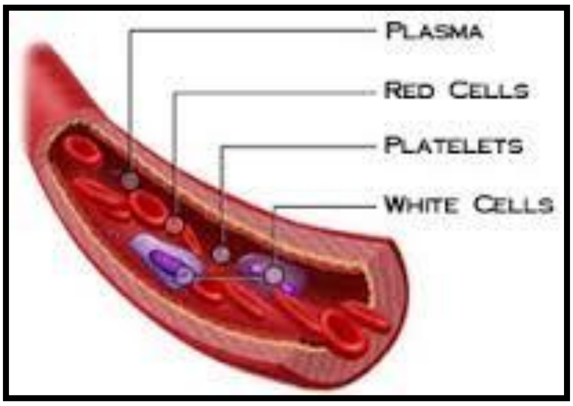

Figure1: Main component of blood plasma and formed element

1.2.1 Platelets

Called "Thrombocytes", mean the coagulation factors which it is to stop bleeding. Platelets are found only in mammals. Platelets no. between 150–450 x 10^9/ l. Platelets typically circulate for 10 days. And its main function is maintenance of vascular tone, inflammation, host defense and tumor biology (figure. 2) [4].

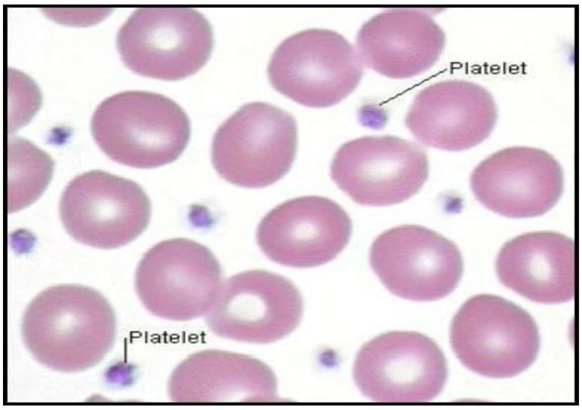

Figure 2: Blue dots it is the blood platelets.

1.2.2 White blood cell (WBC)

Called leukocytes, Immune system and protecting the body against both infectious disease and foreign invaders .also it found in bone marrow and passing through lymphatic system (figure. 3) [5].

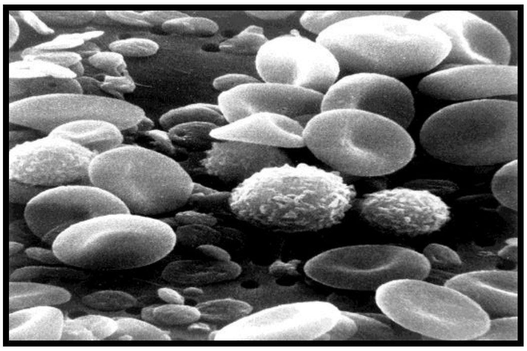

Figure 3: White blood cell (WBC).

1.2.3 White blood cells have five different types

White cells in human body approximately from 4-11 thousands cells and classified into two major line: the leukocytes and the lymphocytes .The leukocytes include neutrophils, monocytes, lymphocytes, eosinophils and basophils. While the lymphocytes include T cells, B cells and natural killer cells (figure. 4) [5].

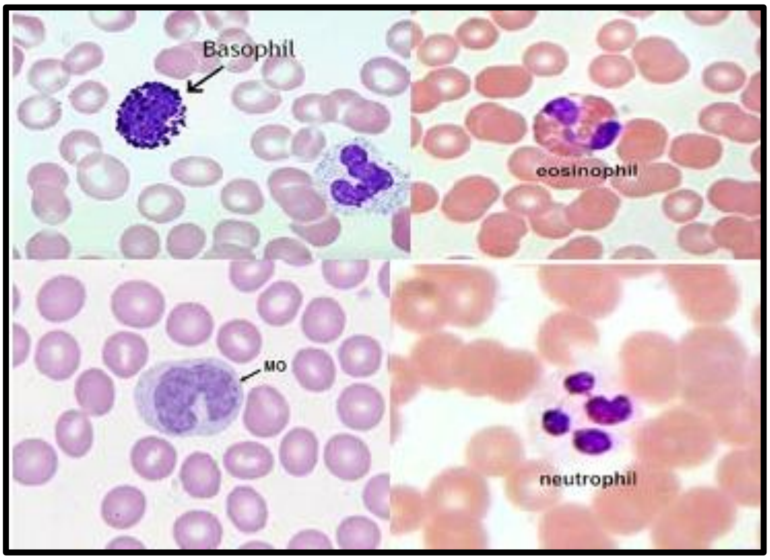

Figure 4: Types of leukocytes.

1.2.4 Red blood cells

Called erythrocytes, and are most common type of blood cell and it means transport of oxygen (O_2) to the body tissues through circulatory system by blood flow .also it is rich in hemoglobin and iron. So, 2.4 million new erythrocytes are produced per second in human. The cells develop in the bone marrow and circulate for about 100–120 days in the body. Each circulation takes about 20 seconds and produce from 4-5 million RBC in the human body. (blood cells).(Figure. 5)

Figure 5: Red blood cell (RBC).

1.3 Blood flow parameters

1.3.1 Viscosity

Is a fluid is a measure of its resistance .and it is related to water .So ,if the viscosity high the fluid will appear to be a solid in the short term (figure. 6) [6].

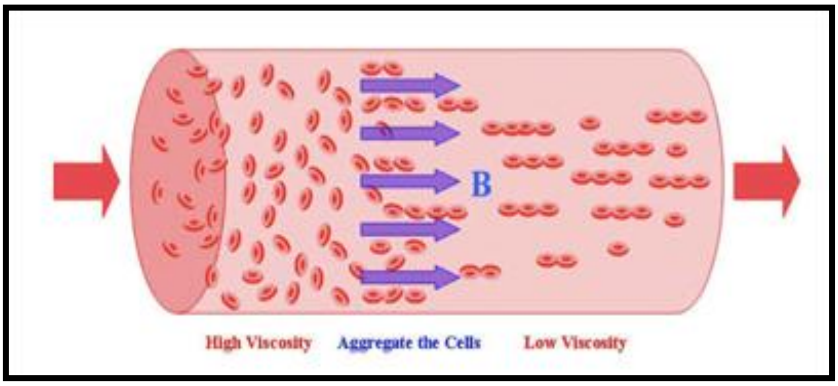

Figure 6: Viscosity of blood.

1.3.2 Blood Plasma

Is a fluid that is the blood's liquid medium, is pale-yellow in color, which comprises 55% of blood fluid, is mostly water (90% by volume) [7]. The normal pH of blood is in the range of 7.35–7.45 [8] .The various cells of blood are made in the bone marrow in a process called hematopoietic(figure. 7)[9].

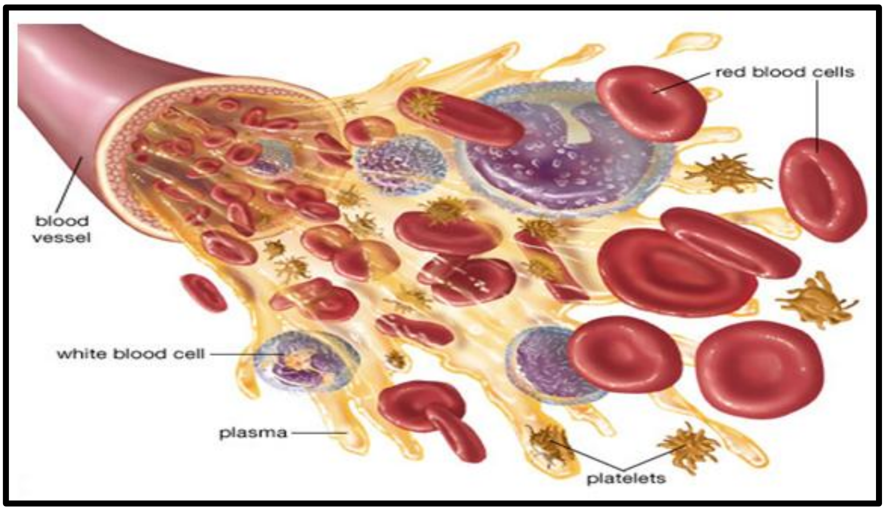

Figure 7: Pale-yellow color of blood plasma.

Human hand supply of blood by two arches. superficial palmer arch(SPA) and deep palmer arch(DPA) between radial and ulna arteries (main arteries of the hand) and their branches in the palm. SPA It is located just deep to palmer aponeurosis and superficial to digital branches of median nerve. About one third of the superficial palmer arch is formed by the ulna artery alone; a further two third is completed by the superficial palmer branch of the radial artery .Also all four medial fingers supply blood by three common palmer digital arteries .Which divides into two proper palmer digital arteries .So, the anastomosis between the radial and the ulna arteries through superficial and deep palmer arches in the palm play a significant role through collateral circulation in the diseases of the palm [10]. So, Radial artery pump blood to thump (lateral digit). While ulna artery pump blood to all medial digit (little, ring,medial and index fingers). (Figure. 8)

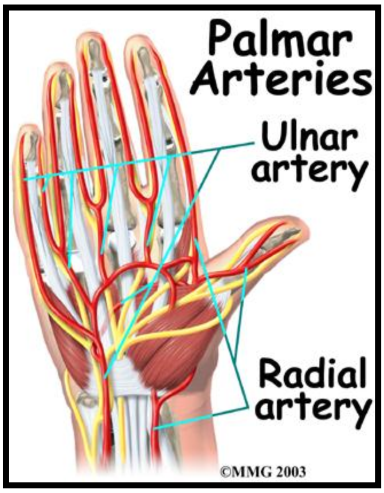

Figure 8: Forehand (Palm of Hand) skin vascular and how blood flow through it.

1.4 Literature review of Laser Doppler Imaging (LDI)

Laser Doppler Imaging (LDI) Is a non-invasive method of measuring microcirculatory blood flow in tissue. The technique is based on measuring the Doppler shift induced by moving red blood cells to the illuminating coherent light. Also distinguished by that is Contactless, Real time. Although of use classical medical instrumentation in (LDI), where discomfort and risk to patients is minimized. And the blood flow with a scanning LDI instrument typically takes minutes. Laser speckle contrast imaging (LSI) is closely related to LDI [11].The LDV is based on the measurement of the Doppler shift of the frequency of laser light scattered by a moving object. The magnitude of the Doppler shift is related to the optical geometry and the velocity of the scattering object. Application of the LDV to the field of vibration measurements in solids wasinitially in the context of rotating systems.The measurement of vibration mode shapes requires the sensing of structural response at a series of locations on the structure. When using an LDV system, the straightforward solution is to translate the test object or the complete LDV system so that various points of interest can be probed. There are two types of LDV, single beam and dual beam. A single-beam LDV measures velocities along the line of sight and introduction of scanning causes a response due to the varying distance between the surface and the sensor. and dual beam for measurements on opaque solid surfaces. The LDV beams must striking on the surface and this requires the optical axis of the system to be at an angle to the surface.The surface can be scanned only by moving the LDV probe transverse to the optical axis or in a combination of axial and transverse motion. A transverse scanning technique use to scanning motion derived from an oscillating mirror in the laser beam path [11].

A Vibrometer is generally a two beam laser interferometer that measures the frequency (or phase) difference between an internal reference beam and a test beam. The most common type of laser in an LDV is the helium–neon laser, although laser diodes, fiber lasers, and Nd :YAG lasers are also used. The test beam is directed to the target, and scattered light from the target is collected and interfered with the reference beam on a photo detector, typically a photodiode Most commercial Vibrometer work in a hydrodynamic by adding a known frequency shift (typically 30–40 MHz) to one of the beams. This frequency shift is usually generated by a Bragg cell, or acousto-optic modulator.In this chapter will offer some of literature review to simplify the basic, components and principle of Laser Doppler Imaging, and most common uses of LDI in measure of blood flow and in medicine. In addition to other names of Laser Doppler Imaging. Such as, Laser Doppler Vibrometer, Laser Doppler velocimetry and Laser Doppler Imaging.

Laser Doppler imaging measurement number of vibration mode shape by techniques is described in which the measurement point of a Laser Doppler Vibrometer (LDV) is continuously scanned over the surface of a micro-circular structure. The LDV vibration output is a mode shapes and amplitude of sine wave, defined along the scan line, may therefore be established by demodulation (remove the voltage receive by laser to other form). So, in the frequency domain, the LDV output is a line spectrum, at center on the excitation frequency and spaced at the scan frequency. The amplitudes give many of coefficients for shape defined along the scan. Most of important measurements can also be made, directed at a single point on a structure: when diameter of circular scan is small it will give the angular vibration of the structure at the centre of the circle. also the translational vibration at the point of focus measure by conical scan.[12].

To produce highly accurate and non-contact vibration transduction in applications because it can't to amount a vibration transducer onto a vibrating object, so the Laser Doppler Vibrometry is the best choice. The applications of vibration use to measurements on: rotating of blood flow at surfaces, targets submerged in water, light weight structures, remote targets and targets behind layers of glass. Use of Laser Doppler Vibrometry in such applications requires attention to a number of practical issues that are of paramount importance for a successful result. This paper will discuss these issues in detail and show how to deal with them such that measurement accuracy, precision and reliability is maximized. Furthermore, practical single point Laser Doppler Vibrometry applications will be used to highlight the theoretical discussions [13].

By this research can produce frequency shift of Doppler Effect by use Laser Doppler velocimetry to measure velocity. It can be used to monitor the movement and mobility in the body of blood flow.

The grain appearance to objects results from interference effect of random work of Laser speckle illuminated by laser light. If the object consists of individual moving scattering (such as blood cells), the speckle pattern fluctuates. So, the information about the velocity distribution of the scattering provide by this fluctuation. Both the speckle and Doppler approaches are measure at a single point. If a map of the velocity distribution is required, some form of scanning must be introduced. However, velocities at the speckle technique it is also possible to mapping real time. The article concludes with a review of reported applications of these techniques to blood perfusion mapping and imaging [14].

This work, use Laser Doppler Flowmetry to evaluate of Hemodynamic parameters, has as final goal, the development of hard and soft solutions uses in instruments for measuring blood flow by using the laser Doppler imaging. Initially of this report, the theoretical and functional principles blood component and properties. So, it is important to set up the goal of using laser Doppler flowmetery to measure blood flow in micro-circular. Two arrangements were made, one that uses a loudspeaker and another with a moving strip arrangement. Software routines to assess these implementations are also discussed[15].

The most important a non-invasive method was first introduced over 30 years ago and has undergone a continuous development since which use to estimate the blood perfusion in the micro-circulation is. This work presents a thorough theoretical framework of the technique. so the Laser Doppler Flowmetry (LDF) determined laser light interacts with the tissue and moving red blood cells and determined how the light forms a speckle pattern on the detector and how the frequency content of the formed speckle pattern can be used to estimate the blood perfusion. Hopefully, this will increase the understanding of the technique, leading to better perfusion estimates and new areas of application [16].

Anew method for estimating the measurement depth and volume in blood flow by laser Doppler Flowmetry (LDF) is presented. Basic of this method depend on Monte Carlo simulations of light propagation in tissue. So, individual and multiple Doppler shifts recalculated. The diameter of laser probe based (0.0, 0.25, 0.5, and 1.2 mm source-detector separation) of different LDF setups for both probe and imaging systems (0.5 and 2.0 mm beam diameter) are considered, at the wavelengths of light 453 nm, 633 nm, and 780 nm. The effect of speckle pattern use to setup imaging system. And how the laser Doppler Flowmetry (LDF) is deal with concentration of blood, saturation of blood oxygen, and other tissue properties. The results show that the effect on the measurement depth of changing tissue properties is comparable to the effect of changing the system setup [17].

Common causes to use Laser Doppler Flowmetry are an inexpensive, noninvasive method of measuring the continuous circulation of blood flow on a microscopic level. This method of measuring the most common property of red blood cells the flux and is growing in practical application. The frequency produces of the oscillation which it produced by the Doppler frequency shift of the red blood cells in a peripheral tissue and translates the frequency to an intensity oscillation it read by a Laser Doppler Flowmetery (LDF) works. Takes readings and sends results to an analyzer by the apparatus are composed of a low-powered laser and probe. The apparatus can penetrate 1-4 mm of tissue. The light emitted and reflected is fed through optical fibers to the analyzer-recorder. so the flux of red blood cells by Laser Doppler Flowmetery (LDF) , is the number of red blood cells times their velocity, which determines circulation [18].

This research, use Laser Doppler Flowmetry (LDF) as non-invasive technique, except for other laser speckle-based techniques that enables estimation of the micro-circulatory blood flow. This technique used more than one time and in more than field. So, it was introduced into the field of biomedical engineering in the 1970s, and a rapid evolvement followed during the 1980s with fiber-based systems and improved signal analysis. The first imaging systems of Laser Doppler Flowmetry (LDF) were presented in the beginning of the 1990s. Conventional LDF is accompanied by several limitations that may have reduced the clinical impact of the technique. This model analysis by Bonner and Nossal in 1981, which is the basis for conventional LDF, is limited to measurements given in arbitrary and relative units, unknown and non-constant measurement volume, non-linearity at increased blood tissue fractions, and a relative average velocity estimate [19].

The present work documents the development of a new measurement technique that allows measuring the velocity distribution of a flow field in an illuminated plane. The measurement principle is based on using the Doppler shift of light scattered from particles moving within the flow and optical heterodyning to demodulate the signals. This new technique can therefore be regarded as the planar extension of the well-known laser Doppler velocimetry (LDV).

Anovel flow measurement technique is laser Doppler velocimetry (ILDV), which it has ability to measurement of the velocity in an imaging plane. It is an evolution of heterodyne Doppler global velocimetry (HDGV) and use to planar extension of dual-beam laser Doppler velocimetry (LDV) by crossing light sheets in the flow instead of focused laser beams. So, the beam of the flow from two different directions and scattered from the moving particles produce a frequency shift due to the Doppler Effect. The direction of the illumination and the velocity of the particle determined the frequency shift. The superposition of the two different frequency-shifted signals on the detector creates interference and leads to an amplitude modulated signal wherein the modulation frequency depends on the velocity of the particle.[20].

MATERIALS AND METHODS

In this project will clarify and discussion firstly the basic and fundamental of Doppler Effect which is the effect frequency between two things, first Doppler effect is probe or laser light and the second Doppler effect is target or red blood cells in our studying in this project secondly, how Laser Doppler effect methods or it is principles which result in total Doppler shift, finally, Laser Doppler for blood flow and Doppler Shift, reflecting, refracting, absorption and composed angle between two reflecting.

Doppler Effect as applied to sound wave. So, if both source and listener are stationary it gives by:

$$\frac{C}{\lambda} \tag{1}$$

Where c speed of sound and λ the wavelength.

But, when the listener move toward stationary source will add new velocity V_L given by:

$$\frac{VL}{\lambda} \tag{2}$$

So, frequency of listener fo given by:

$$\boldsymbol{f}_{\mathbf{O}}= \frac{\frac{CT}{\lambda}+VL\frac{T}{\lambda}}{T} = \frac{(C+VL)}{\lambda}. \tag{3}$$

When the listener stationary and hear the source its frequency

$$f_{\mathrm{S}}= \frac{c}{\lambda} \tag{4}$$

The difference between tow frequency defined as Doppler shift frequency. Express as:

$$f_{\mathrm{d}}= f_{\mathrm{o}}-f_{\mathrm{s}}= V_{\mathrm{L}}.f_{\mathrm{s}}/\mathrm{C} \tag{5}$$

There are three basic measurements related to light propagation of laser to target. Which are velocity of light (V), distance between light and target (ΔS)and elapsed time (Δt).So the velocity direct measurement by definition

$$V = \frac{\Delta S}{\Delta t} \quad (6)$$

When light strike at target it causes pulse frequency which it is proportional to velocity by this equation:

$$V_x = \frac{\Delta x}{T} = f\,\Delta x \quad (7)$$

Where T is the period between pulses and Δx is the line space.

The laser Doppler technique uses a mono-chromatic laser light as light source. The interference of two beams or tow scattering cross on detector. The laser Doppler technique indirect measuring technique since it measure the velocity of in homogeneity flow[16].

The laser Doppler imaging depend on two beam lights, the first is incident beam light of transmitted system characterize by wavelength λb and frequency fb (b mean beam), and the second is when light with frequency scattering from moving target particle and receive by detector. So, the speed of light

$$(c) = \lambda b \,.\, fb \quad (8)$$

Because the particle shift by movement or flow the laser Doppler can assesses the particle moving and can evaluated different type of movement. The laser Doppler technique also use to register the vibration (vibrometer).

Doppler shift of scattered laser light determined by speed of particle V. So, when incident light exits from laser device and propagation throw blood flow of hand palm it will face movement of blood as a vibration which it makes reflect for beam light.

Volume of blood flow in normal tissue (1mm^3) or small. While when tissue it have problems or disease for example vasoconstriction, vasodilatation and healing processing result in increase of blood flow this will increase volume of blood flow represent to larger volume [21].

Light intensity of laser Doppler blood flow measure at surface of tissue by moving mirror. And single point measurement gives (40 Hz) temporal resolution. So, this enabling rapid blood flow changes to record.

By contrast, there is some of difference of Doppler Effect of light. The speed of light it is constant in all cases and light need no material medium for its propagation. The Doppler shift frequency of light determined by relative motion between observer and source.

$$f_o = [f_s\left(1 - \frac{Vos}{C}\right)\sqrt{1 - (\frac{Vos}{C})\text{^}2]} - f_s \quad (9)$$

Where(c) velocity of light and Vos velocity of source with respect to observe (Target). This equation can applied to light inter tissue [22].

The light will have the same frequency as the emitted light if it strikes stationary object and reflect directly to receive object. But if returning light is strike in motion object or target as red blood cells the light returning under Doppler shift twice that predict by equation. So, the transmitted frequency is Doppler shift because motion of red blood cell and shift again of reflect light leave red blood cells.

Doppler shift frequency determined the velocity vector direct toward or away from receiver. If the backscattering direct, the frequency shift scale by cosine of angle between red blood cell velocity vector and line connect of object to receiver.

The basic principle of laser Doppler flowmetery relating to intensity of light undergoing molecular structure. Very small light incident on tissue surface will penetrate deeply and return to that surface, the depth measure in millimeter and wavelength use in therapeutic range (600-1200 nm). In this region the absorption weak [15].

Doppler shift determined by size of frequency Doppler shift (fD) in case of light scatter by moving object, for example Red Blood Cell , it given by following expression [19].

$$f_D = -v.q = -2\frac{v}{\lambda} sin\frac{\theta}{2} cos\varphi \quad (10)$$

Where v is velocity vector of moving object, q is the scattering vector (difference between wave vector ki and ks as shown in figure 3.3 of incident and scattering light), θ is the scattering angle, and φ angle between v and q.

Incident light have frequency fi and wavelength $\lambda_i = \frac{1}{ki} = \frac{c}{fi}$, where c=c/n, n index.

When incident light travel distance from λi it travels during specific time Δt. Thus,

$$\lambda i = \Delta t v cos\psi = \Delta t c \quad (11)$$

Where ψ angle between ki and v

During same time, light wave that is scatter with angle θ with wavelength λ_s, which can be expressed as:

$$\lambda s = c\Delta t - \Delta t v cos(\psi + \theta) \quad (12)$$

Combining equation 3.11 and 3.12 gives:

$$\lambda s = \frac{\lambda i - \lambda i \frac{v}{c} \cos(\psi + \theta)}{1 - \frac{v}{c} cos\psi} \quad (13)$$

The frequency shift f_D is difference between incident light and scattering light wave

$$f_D = fi - fs$$

$$= c\left(\frac{1}{\lambda i} - \frac{1}{\lambda s}\right)$$

$$= \frac{c}{\lambda i}\left(\frac{1 - \frac{v}{c} cos\psi}{1 - \frac{v}{c}\cos(\psi + \theta)} - 1\right)$$

$$= \frac{c}{\lambda i}\left(\frac{1 - \frac{v}{c} cos\psi - 1 + \frac{v}{c}\cos(\psi + \theta)}{1 - \frac{v}{c}\cos(\psi + \theta)}\right)$$

$$= \frac{v}{\lambda i}(\cos(\psi + \theta) - cos\psi \quad (14)$$

The angleψ can thus calculated:

$$\psi = \frac{\pi}{2} - \frac{\theta}{2} - \varphi \quad (15)$$

Combining equation 14 and 15 result (Figure. 9)

:

$$fD = \frac{v}{\lambda i}(\cos\left(\frac{\pi}{2} - \frac{\theta}{2} - \varphi + \theta\right) - \cos\frac{\pi}{2} - \frac{\theta}{2} - \varphi \quad .$$

$$= -2\frac{v}{\lambda i}\sin\frac{\theta}{2}\cos\varphi$$

$$f_D = -q.v \quad (16)$$

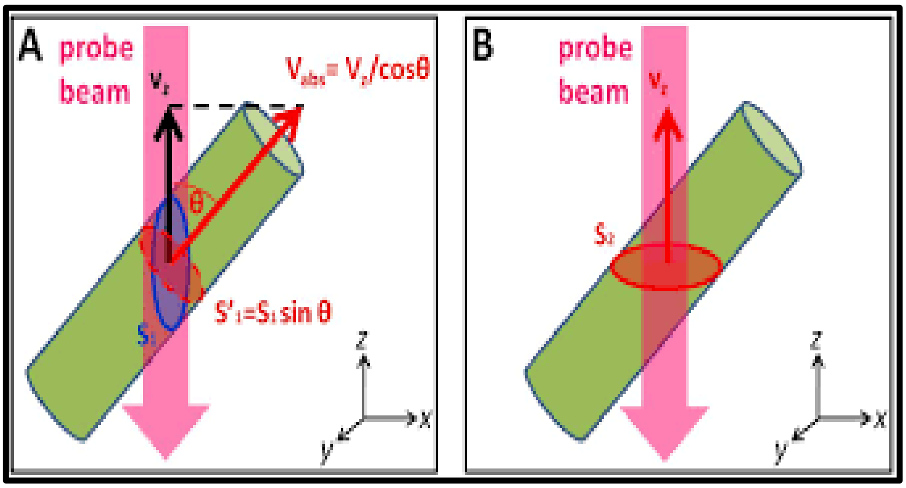

Figure 9: Light of laser Doppler imaging inside target and principle of produce Doppler shift.

The photo detector measures the time dependent intensity I(t) at the point where the measurement and reference beams interfere by this equation:

$$I(t) = \text{IM IR R} + 2\text{K}\sqrt{\text{IM IR R}}\; COS\left[2\pi f\ t + 4\pi\ \frac{\Delta L\ (t)}{\lambda}\right] \tag{17}$$

Where I(t) it's the light intensity which varies in periodic manner (t).

IR and IM are the intensities of the reference and measurement beams and measure by W/cm$^{\wedge 2}$.

K is a mixing efficiency coefficient of IR and IM = 2*pi / lambda.

Note: number (2) use because of double intensities (measurement and reference), (pi) its fixed mathematical factor.

(Lambda) is the wavelength of light = 633nm =633*10$^{\wedge -9}$.

And R is the effective reflectivity when the beam strike of the surface and its consider energy and measure by Voltage (v).

(S_{qr}) of IM IR R use to give the half valueofbeam intensity when it returns to detector.

Cos it is used to measure the angle between laser beam and velocity vector (theta).

Ft is the optical frequency of the laser which measure by MHz *10$^{\wedge 6}$.

Note: No. because of 2 incidents and 2 reflect.

(t)It is a period and measure in second.

(DL) is the difference of length of light and measure by half of wavelength or lambda.

RESULTS AND DISCUSSION

CASE 1

Study of blood flow and perfusion in the hand of one patient measure by LDI. And we found that intensity reference and measurement are 8,7 W/cm$^{\wedge 2}$ respectively. The effective reflectivity when the beam strikeof the surface was 10v.And optical frequency 12 MHz. Measure and Plot of light intensity when the period (t) from 0 to 1second done by Using MATLAB.

```
t=0:0.01:1; %time
IM=7; %Intensity measurement
IR=8; %Intensity reference
R=10; %Reflectivity
Lambda=633e-9; %Wave length
```

K=2*pi/lambda; %Wave Number
DL=316; %Half wavelength
Ft=12e6; %Transmission Frequency
X=IM*IR*R; %for briefing
G=Sqrt(X); %for briefing
Theta=2*pi*Ft*t+4*pi*(DL/lambda); %the angle
H=cos(theta); %for briefing
Y=2+K*G*H; %intensity
Plot (t, Y);
Holdon;

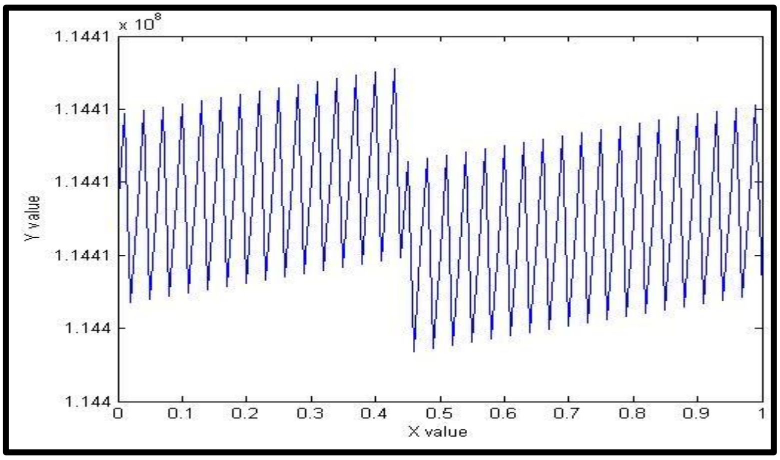

Figure 10: An amplitude of laser Doppler light in blood

Discussion of case 1

Y axis represent the amplitude (intensity) of light in power andx axis represent the period (t). the diagram shows the vibration amplitude measuring at difference point. Which give stability of Doppler amplitude from the start of measurement (0 sec-0.43 sec) then suddenly reduced with time of (0.45 sec) then dramatically increase. So, no static of amplitude because the effect of blood mobility.

CASE 2

Using the same parameters in case 1 studies to plot the time (t) with relationship to reference measurement, intensity measurement and reflectivity(X).

t=0:0.01:1; %time
IM=7; %Intensity measurement
IR=8; %Intensity reference
R=10; %Reflectivity
Lambda=633e-9; %Wave length
K=2*pi/lambda; %Wave Number
DL=316; %Half wavelength
Ft=12e6; %Transmission Frequency
X=IM*IR*R; %for briefing
G=sqrt(X); %for briefing
Theta=2*pi*Ft*t+4*pi*(DL/lambda); %the angle
H=cos (theta); %for briefing

Y=2+K*G*H; %intensity
Plot (t, X);
Holdon;

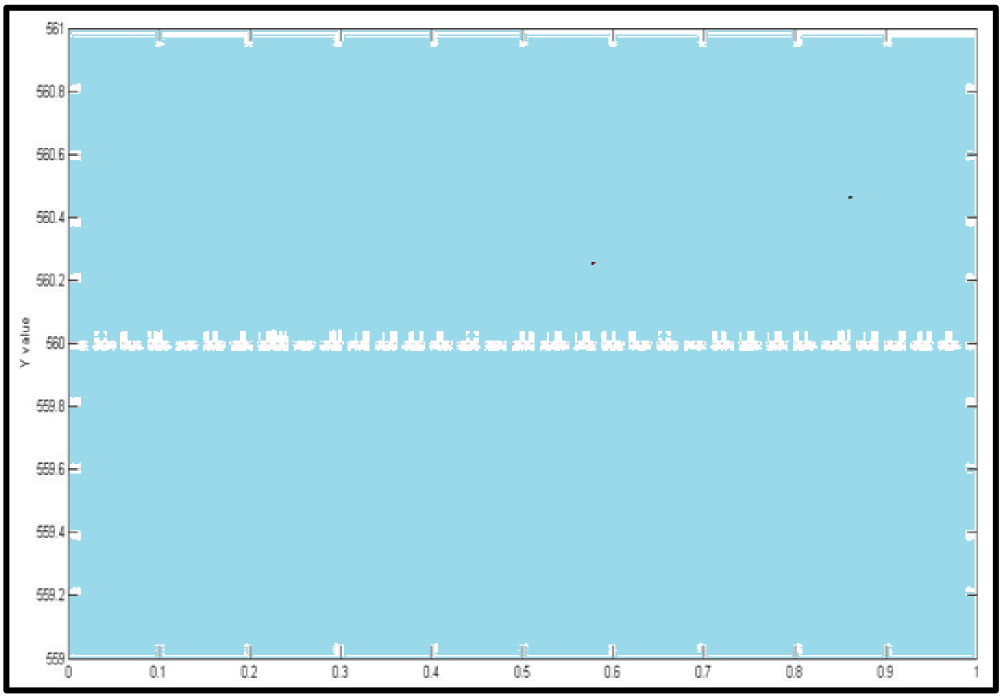

Figure 11: Relationship between intensity measurements, reference measurement and reflectivity.

Discussion of case 2

Base on the diagram which shows the intensity of reference and measurement beam with energy reflectivity at period. That the value of light amplitude it's fixed along of the time of 560 W/cm^2.So, the relationship between intensity, reference measurement with reflectivity is fixed.

CASE 3

Using the same parameters in case 1 studies to plot the time (t) with relationship to (Theta) which it composed between incident and reflective light.

t=0:0.01:1; %time
IM=7; %Intensity measurement
IR=8; %Intensity reference
R=10; %Reflectivity
Lambda=633e-9; %Wave length
K=2*pi/lambda; %Wave Number
DL=316; %Half wavelength
Ft=12e6; %Transmission Frequency
X=IM*IR*R; %for briefing
G=sqrt(X); %for briefing
Theta=2*pi*Ft*t+4*pi*(DL/lambda); %the angle
H=cos (theta); %for briefing
Y=2+K*G*H; %intensity
Plot (t, theta);

```
Holdon;
Ylabel 'Y value';
```

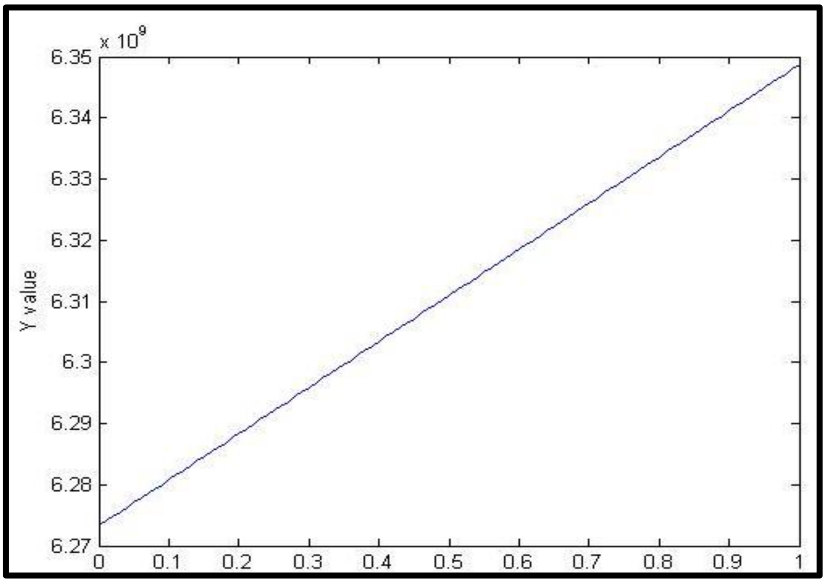

Figure 12: Angle (theta) between incident and reflected light.

Discussion of case 3

The result base of diagram shows the angle between laser beam (incident light) and velocity vector (reflective of surface target) during period of time. The angle was increased dramatically with over time. So, when increase the time of scanning the angle will increase.

CASE 4

Using the same parameters in case 1 studies to plot the time (t) with relationship to (Cosine Theta) which it composed between incident and reflective light.

```
t=0:0.01:1; %time
IM=7; %Intensity measurement
IR=8; %Intensity reference
R=10; %Reflectivity
Lambda=633e-9; %Wave length
K=2*pi/lambda; %Wave Number
DL=316; %Half wavelength
Ft=12e6; %Transmission Frequency
X=IM*IR*R; %for briefing
G=sqrt(X); %for briefing
Theta=2*pi*Ft*t+4*pi*(DL/lambda); %the angle
H=cos (theta); %for briefing
Y=2+K*G*H; %intensity
Plot (t, H);
Holdon;
Ylabel 'Y value';
```

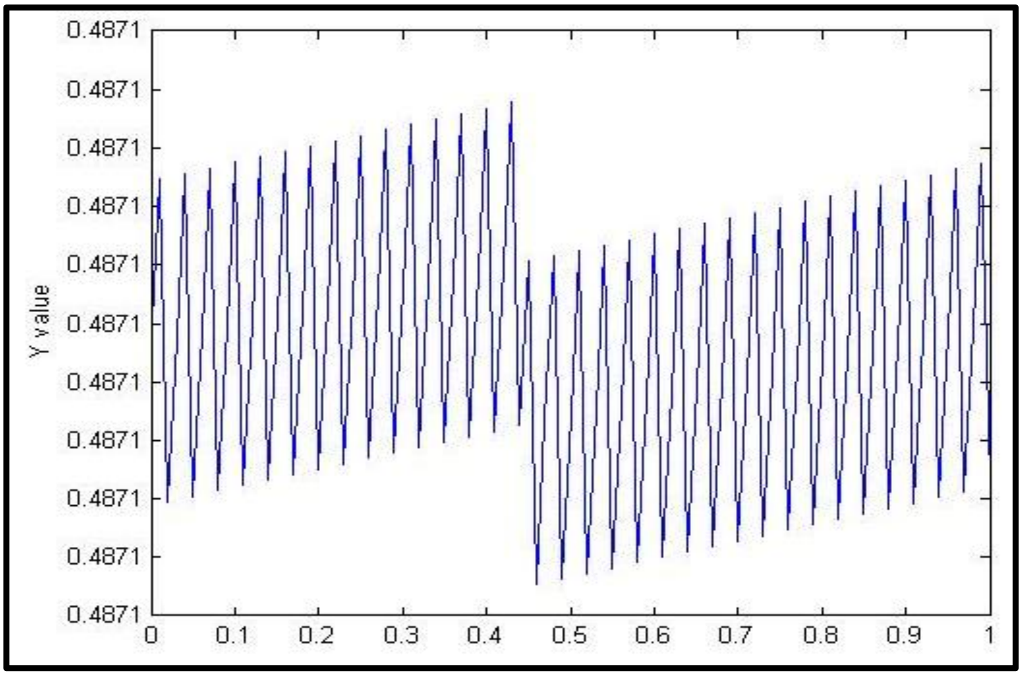

Figure 13: An amplitude of blood at cos theta.

Discussion of case 4

As a result of plot, that the diagram shows the cos of angle with relation of time of the vibration amplitude measuring at difference point. Which give stability of Doppler amplitude from the start of measurement (0 sec-0.43 sec) then suddenly reduced with time of (0.45 sec) then dramatically increase. So, no static of amplitude because the effect of blood mobility and it is give the same values and curve of amplitude (intensity) of light.

CASE 5

Using the same parameters in 4.1 studies to plot the time (t) with relationship to square root the reference and measurement intensity with reflectivity.

```
t=0:0.01:1; %period
IM=7; %Intensity measurement
IR=8; %Intensity reference
R=10; %Reflectivity
Lambda=633e-9; %Wave length
K=2*pi/lambda; %Wave Number
DL=316; %Half wavelength
Ft=12e6; %Transmission Frequency
X=IM*IR*R; %for briefing
G=sqrt(X); %for briefing
Theta=2*pi*Ft*t+4*pi*(DL/lambda); %the angle
H=cos (theta); %for briefing
Y=2+K*G*H; %intensity
Plot (t, G);
Holdon;
Ylabel'Y value';
```

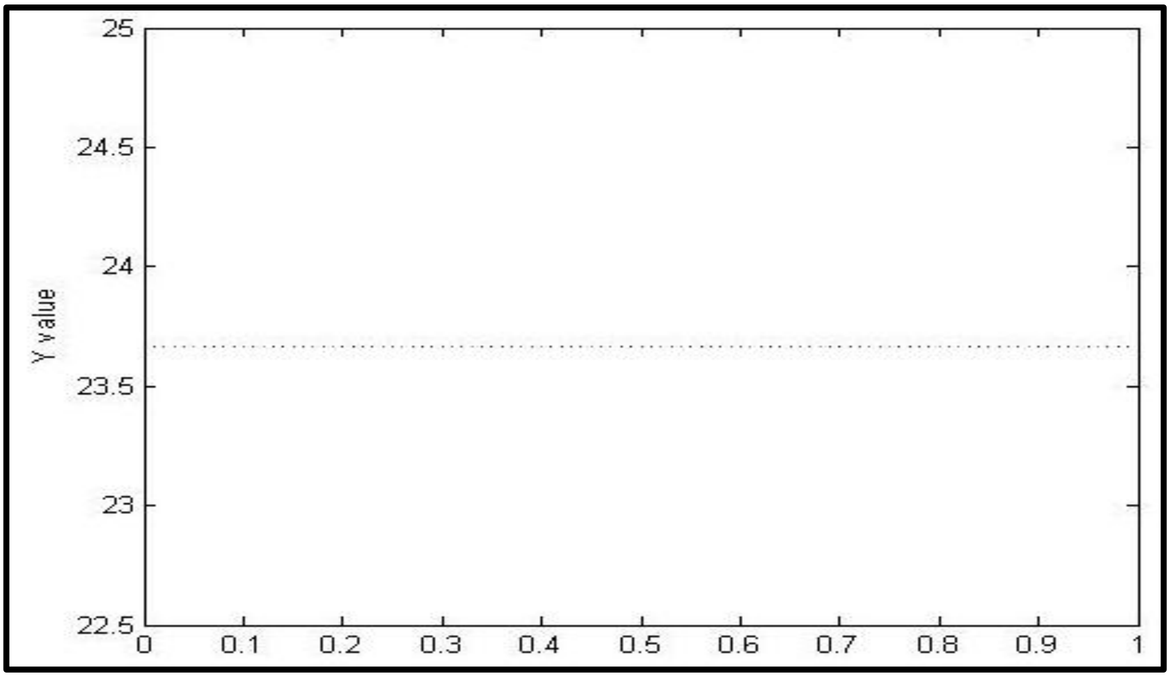

Figure 14: Square the intensity of incident and measurement.

Discussion of case 5

From this plot we noted that the measurement of go and returned beam intensity with period. Its appear fixed along of time of 23.7 W/cm^2 if use by square root. Note: At X the amplitude more than of S_{qr} root of x.

CASE 6

Study of blood flow in palm hand of one patient measurement by LDI. And we found that intensity reference and measurement are 3,5 W/cm$^{\wedge 2}$ respectively. The effective reflective when the beam strikeof the surface was 12 v. and optical frequency 8 MHz. Measure and Plot of light intensity when the period (t) from 0 to 6 secs done by using MATLB.

```
t=0:0.01:6; %time
IM=3; %Intensity measurement
IR=5; %Intensity reference
R=12; %Reflectivity
Lambda=633e-9; %Wave length
K=2*pi/lambda; %Wave Number
DL=316; %Half wavelength
Ft=8e6; %Transmission Frequency
X=IM*IR*R; %for briefing
G=sqrt(X); %for briefing
Theta=2*pi*Ft*t+4*pi*(DL/lambda); %the angle
H=cos (theta); %for briefing
Y=2+K*G*H; %intensity
Plot (t, Y);
Holdon;
```

Ylabel 'Y value';

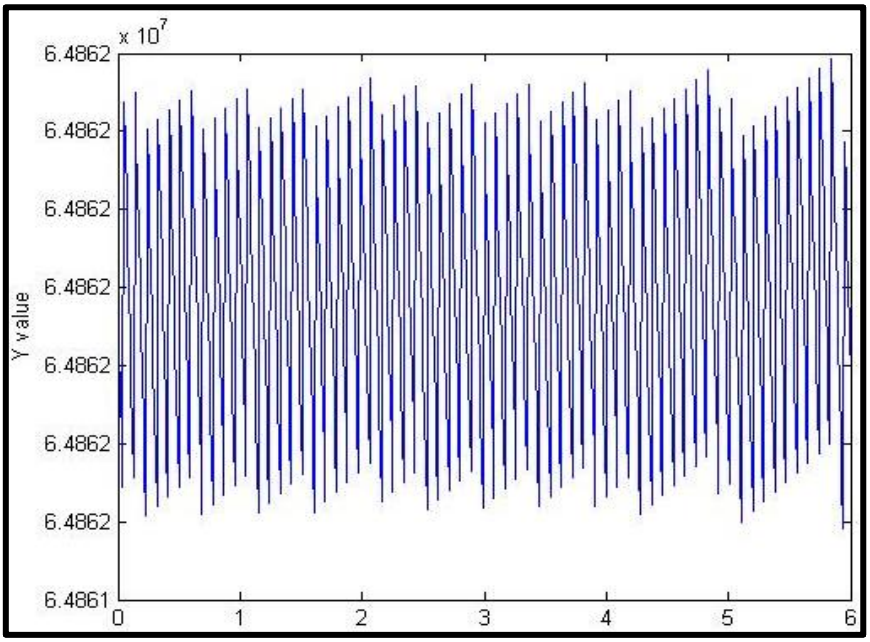

Figure 15: Mixing efficiency coefficient of IR and IM with cos theta.

Discussion of case 6

Base of plot, the diagram shows intensities during long period of time. Which it is not stable with over time. And this indicate that the efficiency coefficient of IR and IM with cos theta lead to discover of disease in blood flow which result of instability of plot.

CASE 7

Study of blood flow in patient with same parameters of study 5.6plot the amplitude of light with period time from 0-1 done by using MATLAB.

```
t=0:0.01:1; %time
IM=3; %Intensity measurement
IR=5; %Intensity reference
R=12; %Reflectivity
Lambda=633e-9; %Wave length
K=2*pi/lambda; %Wave Number
DL=316; %Half wavelength
Ft=8e6; %Transmission Frequency
X=IM*IR*R; %for briefing
G=sqrt(X); %for briefing
Theta=2*pi*Ft*t+4*pi*(DL/lambda); %the angle
H=cos (theta); %for briefing
Y=2+K*G*H; %intensity
Plot (t, Y);
Holdon;
Ylabel 'Y value';
```

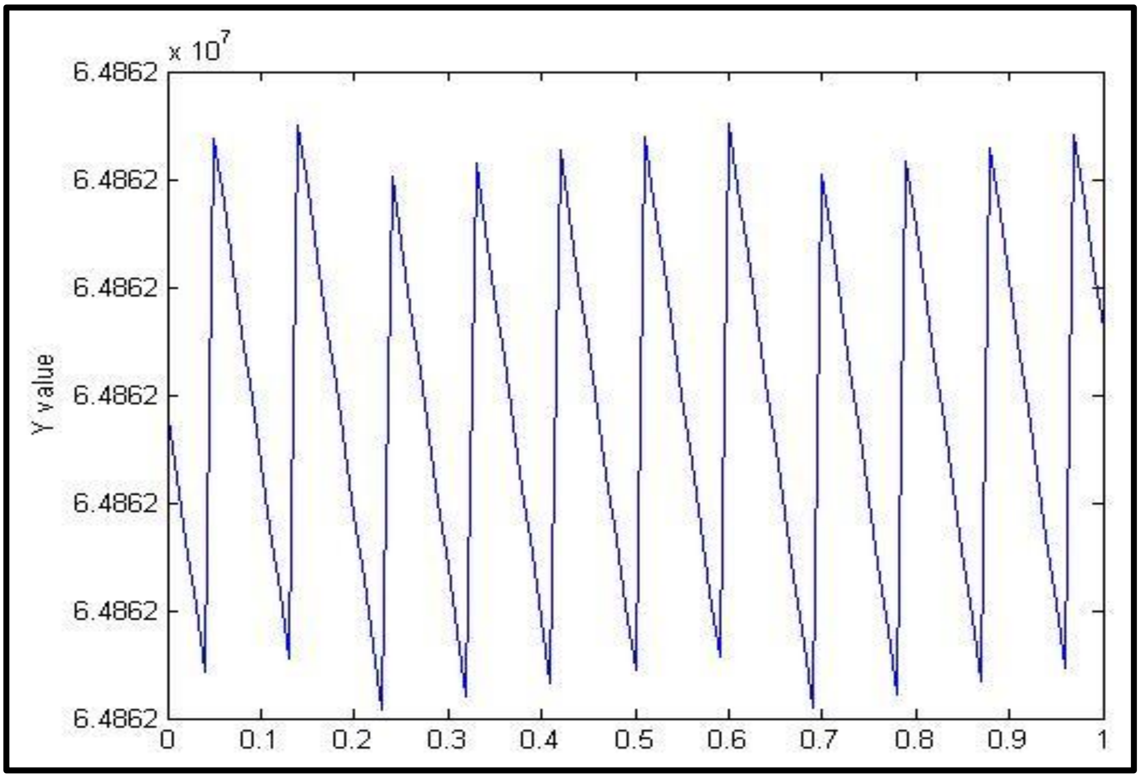

Figure 16: An amplitude over period of all parameters of basic equation (17).

Discussion of case 7

As a result ofplot. The diagram shows values of amplitude intensity with period. its show stable and regular amplitude from beginning to end of measurement. So, when period time of measurement increases this lead to more instability of amplitude.

CONCLUSION

When the light propagates through hand palm, some of the light penetrate the skin, then interact with different layer of tissue and other of light reflect and go back to photo detector to measure the values of incident, measurement intensity and angle between them. So, the light penetrates the skin.Therefore, Doppler Effect and its principle can apply on Laser Doppler Imaging. Because of movement or mobility of blood. When blood movement cause vibration and intensity which give values by using Laser Doppler Imaging(LDI).

Laser Doppler Imaging linear with velocity and require no pre-calibration, non-invasive to patient, less contact with him and short scanning time (during seconds). However, Laser Doppler Imaging not only measure the velocity of blood, is measure the velocity of fluid in general.Sometimes, the results of measuring velocity by Laser Doppler Imaging are error or wrong. Because of presence of some artifact during scanning. Such as movement of patient, increase blood pressure and malfunction in Laser Doppler device.

REFERENCES

1. Chobanian, A.V., et al., The seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. Jama, 2003. **289**(19): p. 2560-2571.
2. Grobelnik, B. Blood Flow. in Postgradute seminar, University in Ljubljana, Faculty of Mathematics and Physics. 2008.
3. Gerard J. Tortora, B.D., The Cardiovascular System: The Blood".Principles of Anatomy & Physiology. John Wiley & Sons, Inc. pp. 729–732., 2012.

4. Harrison, P., Platelet function analysis. Blood reviews, 2005. **19**(2): p. 111-123.
5. Stock, W. and R. Hoffman, White blood cells 1: non-malignant disorders. The Lancet, 2000. **355**(9212): p. 1351-1357.
6. Bourne, M., Food texture and viscosity: concept and measurement. 2002: Academic press.
7. NEW, W.S., Encyclopedia> Blood type.
8. Casiday, R. and R. Frey, Blood, Sweat, and Buffers: pH Regulation During Exercise. 2012.
9. Bianco, P., et al., Bone marrow stromal stem cells: nature, biology, and potential applications. Stem cells, 2001. **19**(3): p. 180-192.
10. Sawant, S.P., The anatomical study of variant superficial palmar arch.
11. Briers, J.D., Laser Doppler, speckle and related techniques for blood perfusion mapping and imaging. Physiological measurement, 2001. **22**(4): p. R35.
12. Grothusen, J.R. and R.J. Schwartzman, Laser Doppler imaging: usefulness in chronic pain medicine. Pain physician, 2011. **14**: p. 491-498.
13. Stanbridge, A. and D. Ewins, Modal testing using a scanning laser Doppler vibrometer. Mechanical Systems and Signal Processing, 1999. **13**(2): p. 255-270.
14. Gatzwiller, K.B., et al. Practical aspects of successful laser doppler vibrometry based measurements. in Proceedings of 21 st International Modal Analysis Conference (IMAC-XXI), Kissimmee, Florida. changes in physiological states. Biomedical Signal Processing and Control. 2002.
15. Ferreira, A.I.L., Laser Doppler flowmetry. 2007.
16. Fredriksson, I., C. Fors, and J. Johansson, Laser doppler flowmetry-a theoretical framework. Department of Biomedical Engineering, Linköping University, 2007.
17. Fredriksson, I., M. Larsson, and T. Strömberg, Measurement depth and volume in laser Doppler flowmetry. Microvascular research, 2009. **78**(1): p. 4-13.
18. Morf, S., et al., Microcirculation abnormalities in patients with fibromyalgia-measured by capillary microscopy and laser fluxmetry. Arthritis Res Ther, 2005. **7**(2): p. R209-R216.
19. Fredriksson, I., Quantitative laser Doppler flowmetry. 2009.
20. Meier, A.H. and T. Roesgen, Imaging laser Doppler velocimetry. Experiments in fluids, 2012. **52**(4): p. 1017-1026.
21. Kubli, S., et al., Reproducibility of laser Doppler imaging of skin blood flow as a tool to assess endothelial function. Journal of cardiovascular pharmacology, 2000. **36**(5): p. 640-648.
22. Shepherd, A.P. and P.Å. Öberg, Laser-Doppler blood flowmetry. Vol. 107. 1990: Springer.