



## Ph-28

### Pattern Recognition for Alternative Concentrations of NaCl and Glucose Doped Solutions using Optical Coherence Tomography

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#### Abstract

For the sake of developing the process of medical analysis of biological solutions (Blood, Urea) there should be more substitutions for the current methods using the chemical agents' addition to the samples. An important and fundamental development in medical research is the widening of the field of activity. The medical researcher is no longer content with the study only of the sick individuals; he is also concerned with the problem of keeping the healthy person fits. This shift in behavior needs "mass production" methods, since he will be often working with large group of communities and not only individual patients. Several experiments have been performed in using computers to process medical information. Light spectroscopy and imaging with computerized systems support this process with more accuracy and the storage ability. Optical coherence tomography (OCT) is an emerging technology that can generate high resolution images of tissues in real time. OCT is analogous to ultrasound imaging, except that it uses the echo delay of light instead of sound to generate images. Fourier transform aided with power spectrum density built the theoretical way to achieve the pattern recognition of different materials doped in one solution.

#### 1- Introduction:

Medical Analysis is an interesting, challenging, and paying career and one of the fastest growing fields in healthcare. Medical Analysts (MA) listen to dictated recordings made by physicians and other medical professionals and convert them into documents in a prescribed format. It can be anything like operating-room notes, autopsy reports, discharge summaries, and other documents. A practical knowledge of medical language, anatomy, physiology, disease processes, pharmacology, laboratory medicine, and the internal organization of medical reports is very much essential for doing Medical Analysis efficiently. It is different from Medical Transcription. A Medical Analyst must be more vigilant than the Medical Transcribers. It is not merely typing the dictation on to a Word document, but analyzing the voice files and documents and correcting the mistakes, if any, made by the physician [1].

OCT is attracting interest among the medical community, because it provides tissue morphology imagery at much higher resolution (better than 10  $\mu\text{m}$ ) than other imaging modalities such as MRI or ultrasound. OCT delivers high resolution because it is based on light, rather than sound or radio frequency. An optical beam is directed at the tissue, and a

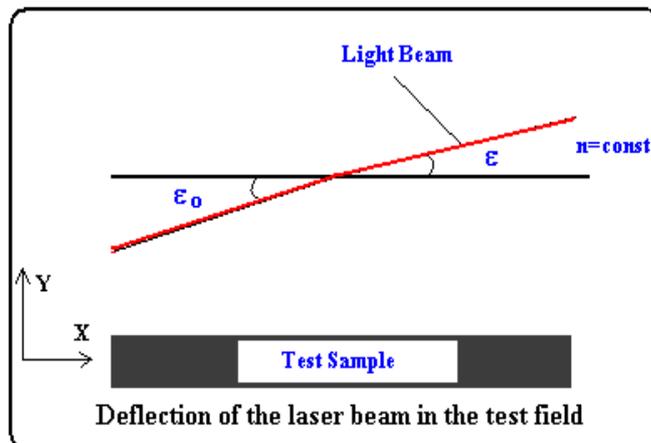
small portion of this light that reflects from sub-surface features is collected. Note that most light is not reflected but, rather, scatters [2-4].

The scattered light has lost its original direction and does not contribute to forming an image but rather contributes to glare. The glare of scattered light causes optically scattering materials (e.g., biological tissue, candle wax, or certain plastics) to appear opaque or translucent even while they do not strongly absorb light (as can be ascertained through a simple experiment — e.g., shining a red laser pointer through one's finger). Using the OCT technique, scattered light can be filtered out, completely removing the glare. Even the very tiny proportion of reflected light that is not scattered can then be detected and used to form the image in, e.g., a scanning OCT system employing a microscope [5].

Within the range of noninvasive three-dimensional imaging techniques that have been introduced to the medical research community, OCT as an echo technique is similar to ultrasound imaging. Other medical imaging techniques such as computerized axial tomography, magnetic resonance imaging, or positron emission tomography do not utilize the echo-location principle [6-9].

## 2- Theoretical Studies:

Refraction occurs when [light waves](#) travel from a medium with a given [refractive index](#) to a medium with another at an angle. At the boundary between the media, the wave's phase velocity is altered, usually causing a change in direction. Its wavelength increases or decreases but its frequency remains constant. For example, a [light ray](#) will refract as it enters and leaves [glass](#), assuming there is a change in refractive index as shown in Figure (1). A ray traveling along the normal (perpendicular to the boundary) will change speed, but not direction. Refraction still occurs in this case. Understanding of this concept led to the invention of lenses

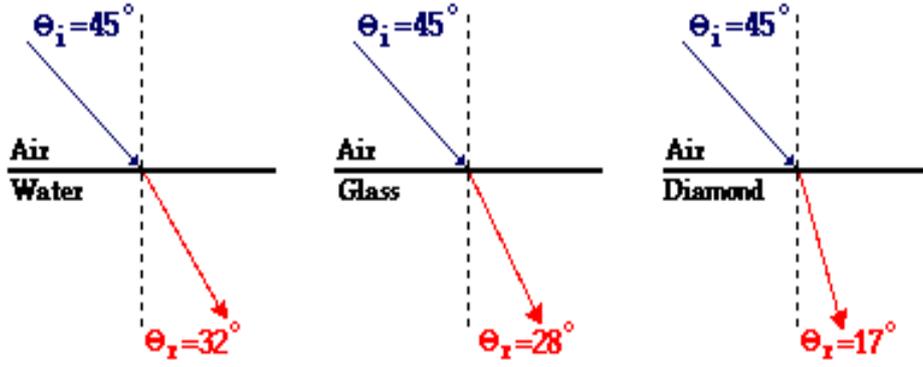


and the refracting telescope.

**Fig.1 light refraction between two different mediums**

The amount of bending which a light ray experiences can be expressed in terms of the angle of refraction (more accurately, by the difference between the angle of refraction and the angle of incidence). A ray of light may approach the boundary at an angle of incidence of 45-degrees and bend towards the normal. If the medium into which it enters causes a small

**Fig.2 Various bending angle due to various refraction indices**



amount of refraction, then the angle of refraction might be a value of about 42-degrees. On the other hand if the medium into which the light enters causes a large amount of refraction, the angle of refraction might be 22-degrees, (these values are merely arbitrarily chosen values to illustrate a point). The diagram shown in Figure (2), depicts a ray of light approaching three different boundaries at an angle of incidence of 45-degrees.

The refractive medium is different in each case, causing different amounts of refraction. The angles of refraction are shown on the diagram. The deflection angle ( $\epsilon$ ) of the deviated division depends on the refractive index of the sample medium which depends also on the concentration level of glucose in solution. There is no simple expression for ( $\epsilon$ ) that can be inverted to give the refractive index as a function of position. However, under the assumption of small numerical aperture, the deflection function can be related to the optical path length difference [10-12].

Here there is a derivation to set a relationship between the bending angle ( $\epsilon$ ) and the refraction index ( $n$ ) using Bouguer's formula. Since the impact parameter ( $a$ ) is constant in the straight line, it is possible to compute the bending angle (which is the departure of the true ray from the ideal assumption of the true line), as illustrated and shown in Figure 3. The straight line (laser source) is given by [10-12]:

$$r \sin \theta_s = a_s \quad (1)$$

True ray (laser source after sample interaction)

$$n r \sin \theta = a \quad (2)$$

Differentiating both expressions, multiplying the straight line one by the refraction index and subtracting both equations it is obtained the following [10-12]:

$$dn r \sin \theta + n dr (\sin \theta - \sin \theta_s) + nr (\cos \theta d\theta - \cos \theta_s d\theta_s) = 0 \quad (3)$$

Since the bending angle is very small in degrees it is possible to approximate the previous expression to:

$$dn r \sin \theta + n r \cos \theta (d\theta - d\theta_s) = 0 \quad (4)$$

The differential of the bending angle ( $d\epsilon$ ) is, in fact, the quantity ( $d\theta - d\theta_s$ ), therefore recalling the Bouguer's formula, the previous expression yields to:

$$d\epsilon = \left( -\frac{\sin \theta}{\cos \theta} \frac{dn}{n} \right) \quad (5)$$

The main hypothesis is that the test section may be regarded as a phase object, so that the actual ray trajectory can be approximated by a straight line between the launching and observation planes. This assumption does not introduce any significant error provided one uses a very small index difference between the glucose solution and the single material refractive index of the capillary.

In the Cartesian coordinate system, if the optical path differences are known for all  $\theta$  between zero and  $\pi$ , the normalized index profile can be reconstructed by the discrete integral, this is the form of Abel's transform whose inverse is [10-12]:

$$\Delta n(r) = \frac{n(r) - n_f}{n_f} = \frac{1}{\pi} \int_i^f \frac{\varepsilon dy}{\sqrt{y^2 - r^2}} \quad (6)$$

Where,  $\Delta n(r)$  is the refraction index difference,  $i = r$  and  $f = \infty$  are the limits of the phase object and is the index of refraction at  $f$ , which is in our case,  $\pi = 3.14$ ,  $(\varepsilon)$  is the deflection angle,  $r^2 = (y^2 + z^2)^{1/2}$  position along capillary tube cross sections.

### 3- Experimental set-up:

The configuration shown schematically in figure 3 represents the current state of our OCT system. The reference light from laser source (He-Ne laser) center frequency 633.8 nm is injected into objective microscope lens to have a fan beam magnified output ray, directed to a 20 cm focal length lens to have as a result parallel beam as it is illustrated as shown in Figure (3), a tunable open hole piece used to deliver the heart of the laser beam to meet the sample which is present at the way of the laser beam, where part of the beam is subjected to the sample and the other part pass normally in its way not affected by the sample cause there is no intersection, both beams interact with each other after the sample position to have an interference pattern.

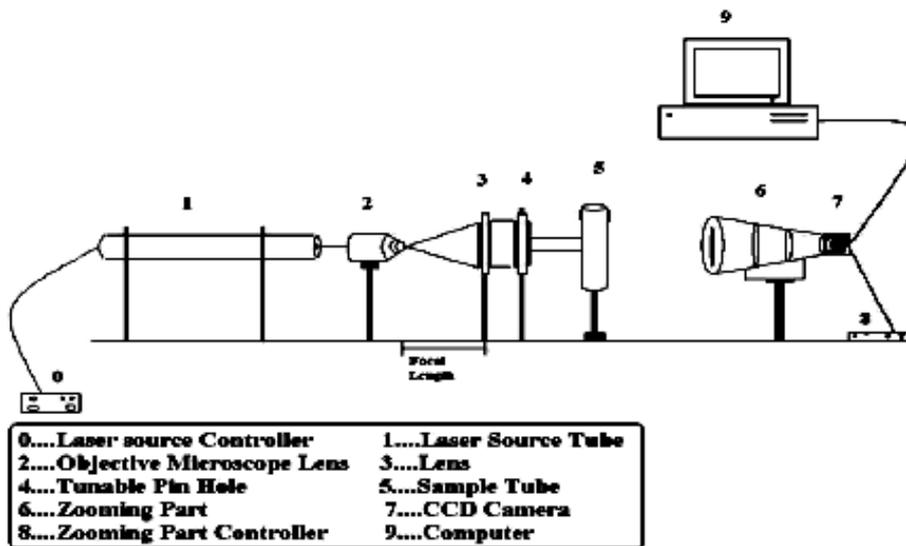


Fig.3 The laser OCT used system.

Before we go through the sample preparation for this experiment, it should be illustrated what is the goal from executing this experiment, it should be known that any biological solution such as blood has many ingredients, where each has its own effect on the characteristics of the sample, especially on the physical shape beside the chemical composition. For dealing with such biological solutions and to measure a specific concentration of one of the ingredients, the other ingredients effect should be avoided. The most cases the physicians add some kind of material to diminish the others effects. From the main ingredients in biological solutions are the salt with its different types and the primary forms of sugar. So this experiment is a step on the way of having a pattern recognition for the main ingredients of biological solutions, which are sugar (representing the presence of glucose in human body), and salt ((NaCl) representing

the different salts in the human body) in the same solution without adding any external materials. The samples for this experiment were simply different concentration levels of both ingredients sugar and salts separately as a first stage, and as second stage mixtures of both ingredients with different concentration levels relative ratios to each other are prepared [13]. In this experiment, the sample preparation takes in consideration the accuracy of maintaining the same raw materials used every sample preparation and every repeat of the experiment to verify the results, finally the usage of a very high sensitive weighing scale where its resolution reaches 0.01 gm. In this experiment there are 13 samples were prepared, 4 ones for the sugar solutions, 4 ones for the salt solutions, and 5 ones for the mixture of both salt and sugar ingredients solutions. We used a standard test tubes for calibration the amounts of solution where we assigned all these concentration on a fixed amount of distilled water which is 300 milliliter. The following tables will illustrate the prepared samples. Table1) provides a list of the first type of samples where each ingredient is doped in the specified quantity of water alone, by shaking the solution and being sure that it is completely doped in the water and there are no deposits at the bottom of the test tube.

**Table 1- The Prepared Salt and Sugar Solutions.**

<b>Sample No.</b>	<b>Quantity of Salt (NaCl)</b>	<b>Sample No</b>	<b>Quantity of Sugar</b>	<b>Quantity of water const. for all (Milliliter)</b>
1	10 gm (NaCl)	5	10 gm sugar	300 milliliter
2	20 gm (NaCl)	6	20 gm sugar	300 milliliter
3	30 gm (NaCl)	7	30 gm sugar	300 milliliter
4	40 gm (NaCl)	8	40 gm sugar	300 milliliter

Table 2) provides the quantities for the ingredients of the mixture (salt& sugar) solutions. For unification of the same physical and chemical conditions the samples have been made in the same standard conditions of humidity and temperature and pressure of the laboratory room, with weighted quantities of all listed materials measured by highly standard and calibrated tools and devices to maintain the optimum quality and accuracy.

Especially in this stage the sample preparation needs a lot of interest for not having any deposits as a result of saturation of the solution from the doped materials. After each sample preparation, the tubes are cleaned very well and dried carefully to not have an over-carry effect (effect due to former prepared samples in the test tube) from the former preparation processes.

**Table 2- Prepared Salt and Sugar mixture solutions.**

<b>No.</b>	<b>Salt solution concentration</b>	<b>Sugar solution concentration</b>	<b>Amount of water</b>
1	10 gm (NaCl)	10 gm sugar	300 milliliter
2	10 gm (NaCl)	40 gm sugar	300 milliliter
3	20 gm (NaCl)	40 gm sugar	300 milliliter
4	40 gm (NaCl)	10 gm sugar	300 milliliter
5	40 gm (NaCl)	20 gm sugar	300 milliliter

All the samples preparation was made at the same conditions and at the same time of preparation before the experiment with 5 minutes. This allows the chance to have the highest accuracy of preparation in the laboratory. The prepared samples are put in standard tubes to preserve its status before transferring the samples to test tubes of the experiment. In this section it will be shown the results of the imaged prepared samples consequently to illustrate the difference between each of them according to its ingredients as follows:

#### 4 Results and Data Reduction

The first step accomplished is to see whether the implemented system could distinguish the difference between the concentration of the solution due the increase of the concentration of the salt and sugar in the solution, so the first step we check the histogram and the Fourier transform for each sample image.

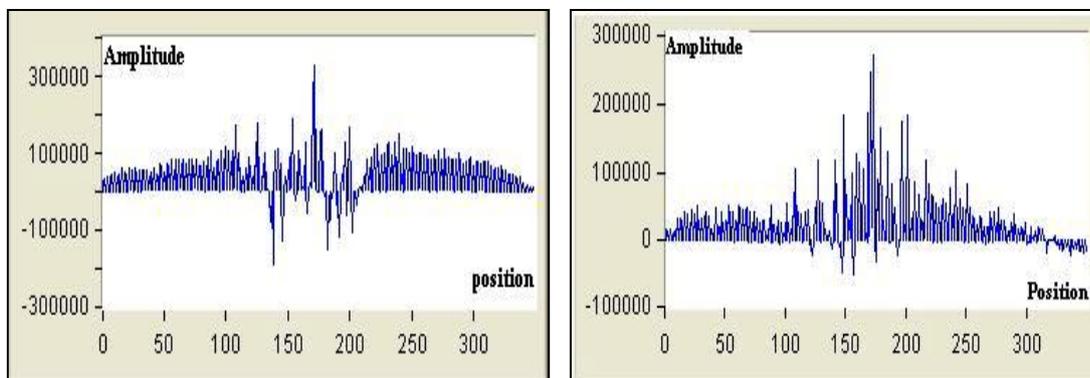


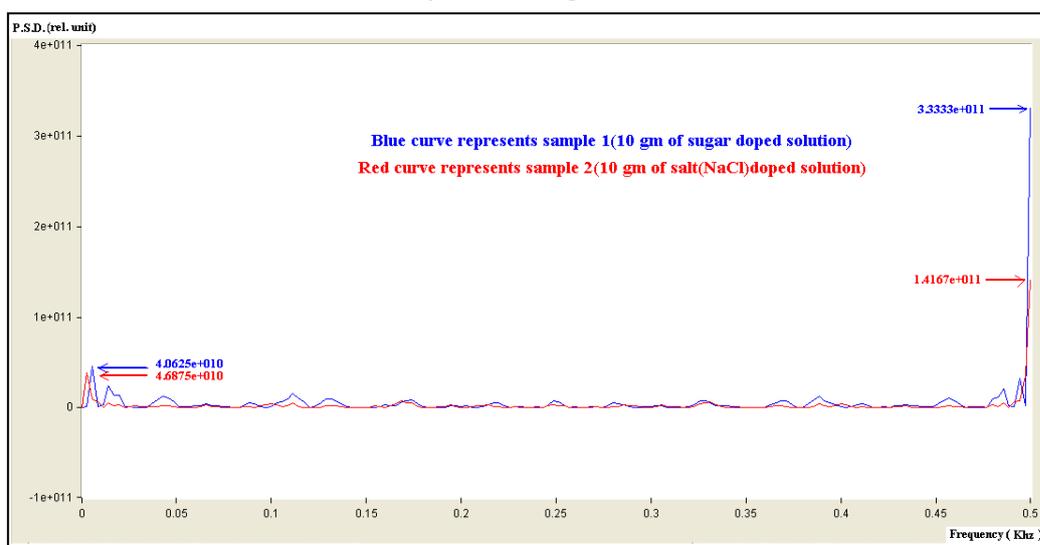
Fig. 5

Spectrum of (a) 10 gm salt (NaCl) and (b) sugar, doped solutions.

It is noticed from the two previously shown curves of the power spectrum density, that the chloride sodium (NaCl) has a signature characterized by negative peak values around the center as shown in Figure (5-a), on the other side it is clear that the negative peak values decreased so much in the curve of sugar and instead there are more positive peaks as shown in Figure (5-b). Then by summing the standard deviation of all image matrix columns and plot it for both samples, we get the following plot shown in Figure (6).

Fig. 6 Over-plot of sugar sample and chloride sodium sample of the same quantity

That difference directed the work to explore what will happen if the two components are mixed in one solution, will it easy to distinguish between them or not? That what will be

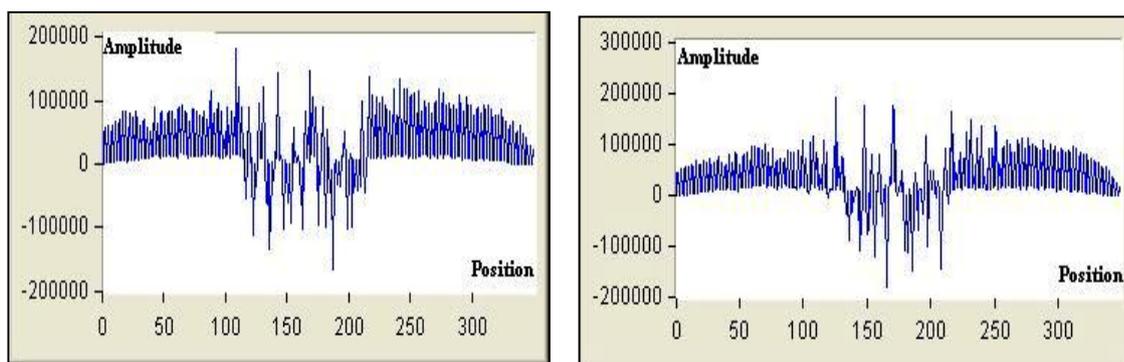


illustrated and shown in Figure 7(a,b). The experiment started by mixing same amounts then we increase one with respect to the other in the solution, where what want to sense the presence effect of each of them with a little concentration with respect to the other, so we have prepared 4 samples to compare between them as follows, Figure 7 illustrates the presence of the (NaCl) in the sugar doped solution with two different amounts, the first one is

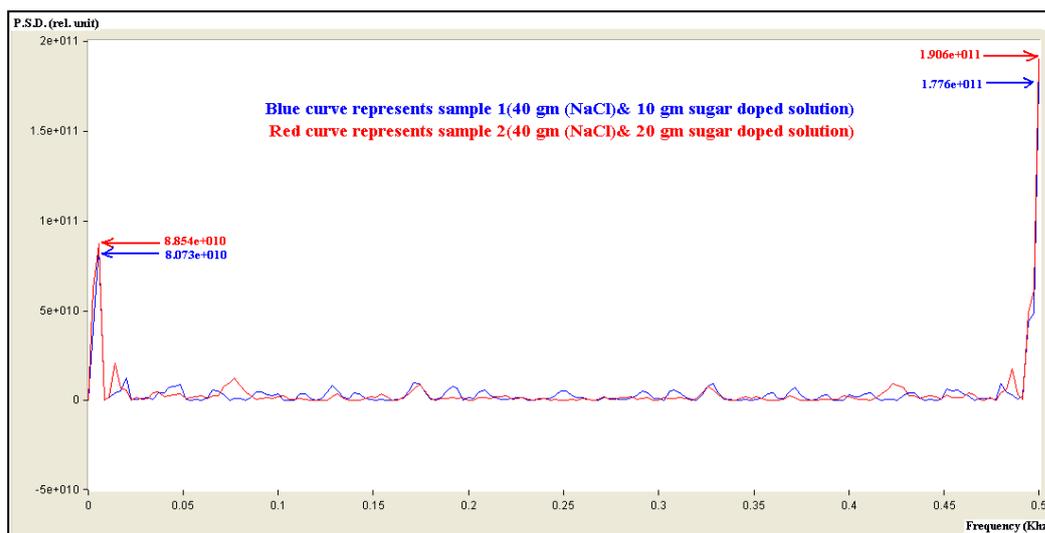
(40 gm of (NaCl) with 10 gm of sugar) as shown in Figure 7(a), while in the second mixture the concentration of the sugar increased to have the following (40 gm of (NaCl) with 20 gm of sugar) and shown in Figure 7(b), where we notice that the negative peak values, which is the dominating character of the (NaCl) solution has decreased in the second sample due to the effect of the presence of sugar which has a dominating character of high positive peak values around the center.

**Fig. 7 shows the effect of sugar concentration on the spectrum of mixtures for 40 mg of (NaCl) with both (a) 10 mg sugar and (b) 20 mg sugar.**

Then by applying the same steps of summing the standard deviation of the image matrix we have the following figure for the two prepared samples as will be illustrated in Figure (8). We see from Figure (8) that the two curves approximately identical at the start of the curve where this position is the dominating place of the (NaCl) solution, while at the end of the curve it appeared the effect of the increase of the sugar in the solution where that is the place of the presence of sugar effect on the curve. The same steps were repeated with the following



samples except that we replaced the two components, each of the NaCl and sugar take the role of the other with the same quantities to have the following results shown in Figure 9 (a,b).



**Fig. 8 Over-plot of samples 1&2 (same concentration of (NaCl) and different concentrations of sugar).**

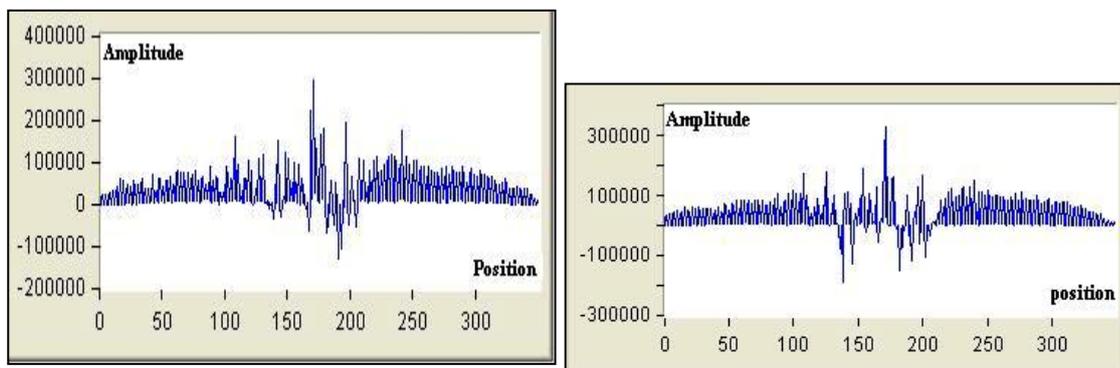
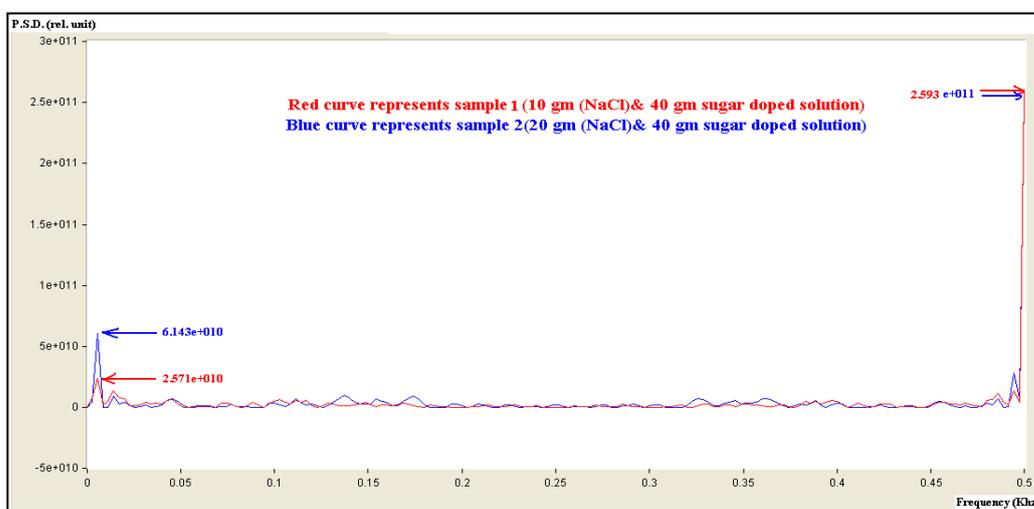


Figure 9 (a,b) illustrates the presence of the sugar in the (NaCl) doped solution with two different amounts, the first one is (10 gm of (NaCl) with 40 gm of sugar) as shown in Figure 9(a), while in the second mixture the concentration of the (NaCl) increased to have the following (20 gm of (NaCl) with 40 gm of sugar) as shown in Figure 9(b), where we notice that the positive peak values, which is the dominating character of the sugar solution has slightly decreased in the second sample due to the effect of the slightly increase of NaCl concentration, which has a dominating character of negative peak values around the center.

**Fig. 9 shows the mixture of sugar with (NaCl) spectrum with the increase of (NaCl) in the second one to illustrate the effect of its presence.**

Then we have the following result shown in Figure (10) by applying the same previous steps.



**Fig. 10 Over-plot of samples 1&2 (same concentration of sugar and different concentration of (NaCl)).**

From Figure (10) it is noticed that there is identical coincidence at the end of the figure where this is the place of the appearance of the sugar effect on the curve, while on the contrary there is a clear difference between the red and blue curve at the start of the figure which is the place of the appearance of the (NaCl) effect on the curve.

### 5- Conclusions and Discussions:

We have investigated experimentally the presence and distinguish of the sugar in the (NaCl) doped solution with two different concentration amounts, the first one is (40 gm of (NaCl) with 10 gm of sugar), while in the second mixture the concentration of the sugar increased to have the following (40 gm of (NaCl) with 20 gm of sugar) and from the measured results, we

have noticed that the negative peak values of the spectrum, which is the dominating character of the (NaCl) solution has decreased in the second sample due to the effect of the presence of sugar which has a dominating character of high positive peak values around the center. The presence of the (NaCl) in the sugar doped solution with two different concentration amounts, the first one is (10 gm of (NaCl) with 40 gm of sugar), while in the second mixture the concentration of the (NaCl) increased to be (20 gm of (NaCl) with 40 gm of sugar), in which we have investigated that the positive peak values, which is the dominating character of the sugar solution has slightly decreased in the second sample due to the effect of the slightly increase of (NaCl) concentration, which has a dominating character of negative peak values around the center. This experiment opens the way to start recording pattern recognition for the existence of any material in doped solution. The pattern recognition procedure can be achieved by a substitution other than utilizing chemical agents which will save a lot of cost and expenses and could solves situations if these agents are not available. Finally, we hope to give a step forward to assist in having a new benefit for saving human body health.

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