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Use a Laser Interferometer Technique to Detect Rabbit Eardrum Vibrations

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Abstract— This paper presents an experimental study of the rabbit eardrum spectral dynamic response by using the laser interferometric technique. Michelson laser interferometer was setup and used for this purpose.
The results showed that the vibration response of the rabbits eardrums in the presence of sound waves are changing mainly according to the frequencies of these sound waves stimulus. The spectral resulted curves revealed a similarity and linearity especially along the low frequency range (500 – 3500 Hz) for normal and healthy rabbits eardrums.
The results of the spectral vibration response for healthy rabbits eardrum represent a useful reference for the diagnosis of hearing problems related to the eardrum lesions.

***Index Terms*— Membrane vibration , laser interferometer , rabbit eardrum, hearing diagnosis problem.**

I. INTRODUCTION

The non – contact measuring method utilizing the laser interferometry have no such limitations represents an accurate sensor for measuring the vibrations of small mass objects in engineering and medical applications based on Doppler effect [1, 2].
In medicine the idea is to use the laser interferometer to measure the frequency shift of a coherent laser beam that is back scattered from a small area of the vibrating biological objects like the tympanic membrane without any mechanical contact or attachment which affects the accuracy of measurement and diagnosis to evaluate the membrane response to different frequencies of sound waves [6].
By using laser interferometer, the measurement of the eardrum vibration pattern was proved as a noninvasive and objective method for investigation of middle ear conduction properties.
In this study, a Michelson interferometer was setup and used as a measuring instrument to detect the healthy rabbit eardrum vibrations response to different in frequency and amplitude sound waves.

II. MATERIALS AND METHODS

Five rabbits were used in this study. Their ages ranged from 3.5 to 4 months. They were healthy and had no troubles or infections in their middle ears. Some of their features were summarized in table (1).

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Table 1: The biological features of the experimental rabbits.

Specimen	Gender	Age in Months	Selected Ear	Middle Ear Infection
Rabbit 1	Male	3.5	Right	None
Rabbit 2	Male	4	Right	None
Rabbit 3	Male	4	Right	None
Rabbit 4	Female	4	Right	None
Rabbit 5	Female	4	Right	None

All the measurements were made in the right ear of the five rabbits. The necessary medical examination of the rabbit's middle ear was carried out by the veterinarian to ensure that no pathological change was found which may affect the measured data. Fortunately the rabbits were conscious during the experiment so there was no need for anesthesia.

III. OPTICAL SYSTEM

The Michelson interferometer was setup as shown in figure (1). Solid state frequency – doubled Nd:YAG laser of 45mW power and 532nm wavelength was used. This laser beam was divided by a beam splitter positioned 10cm away from the laser source and inclined by 45º to the incident laser beam. The beam splitter transmitted and reflected 50% of the incoming laser beam into the test and reference beams. The reference beam length L1=20cm, and the test beam length L2=30cm from the beam splitter. The reference beam was directed vertically onto a stationary plane mirror. The test beam was directed to the right onto the rabbit eardrum membrane through a multimode fiber optic of 400µm fiber core. A couple of parallel fibers optics with the same properties were used in these experiments. The test beam from the beam splitter towards the membrane was delivered through the first fiber optic, while the second fiber was used to deliver the reflected beam from the membrane back towards the beam splitter. The head of the fiber facing the membrane was cut and polished at an angle of 45º to enhance the entrance of the back reflected beam from the surface of the membrane into the second fiber. The head of the fiber facing the beam splitter was also cut and polished at an angle of 45º to achieve the alignment of the reflected beam with the reference and the source beams on the beam splitter. The reflected beams from the plane mirror and the membrane, were recombined at the beam splitter to produce the interference pattern, which was detected by the photodiode. When the membrane vibrated in response to the acoustical stimuli, the frequency of the test beam is shifted, resulting in an optical frequency modulation of the mixed beam due to interference between the reference and test beams. The silicon PIN photodetector was positioned 45cm away from the beam splitter. The photodetctor wavelength sensitivity ranged from 300 to 1100nm. Its active area was 0.006mm^2. The detected interference modulated beams were displayed on a storage oscilloscope.

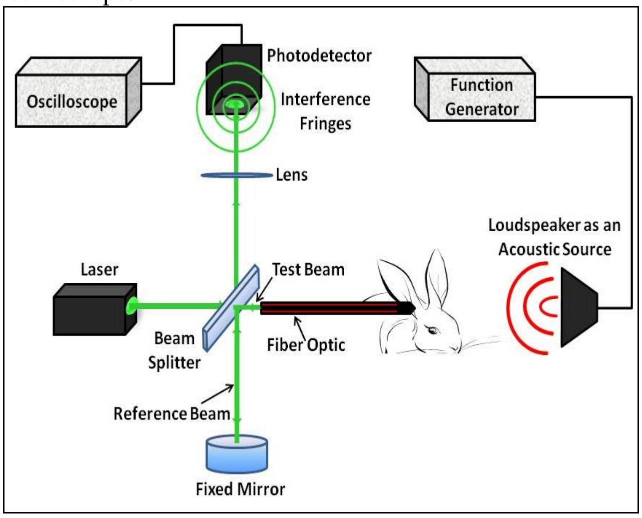


Fig. (1): Experimental setup, illustrating the interferometer and the attached peripherals required for its operation.

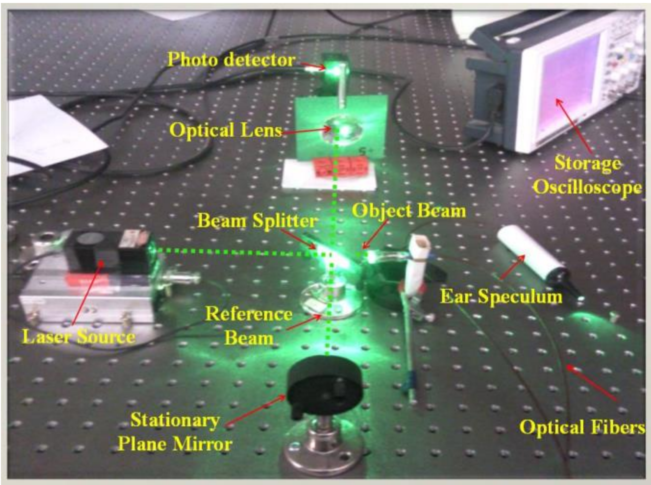


Fig. (2): A photograph illustrates the experimental setup.

Each experimental rabbit was placed in lateral recumbency on the table with the ear under study in up position. The ear speculum, which was holding the fibers optics as shown in figure (3) was positioned into the external ear and focusing on the eardrum to ensure the incident of the laser beam on the drum membrane as shown in figure (4). White powder was spread over the surface of the rabbit eardrum to increase the intensity of the reflected beam.

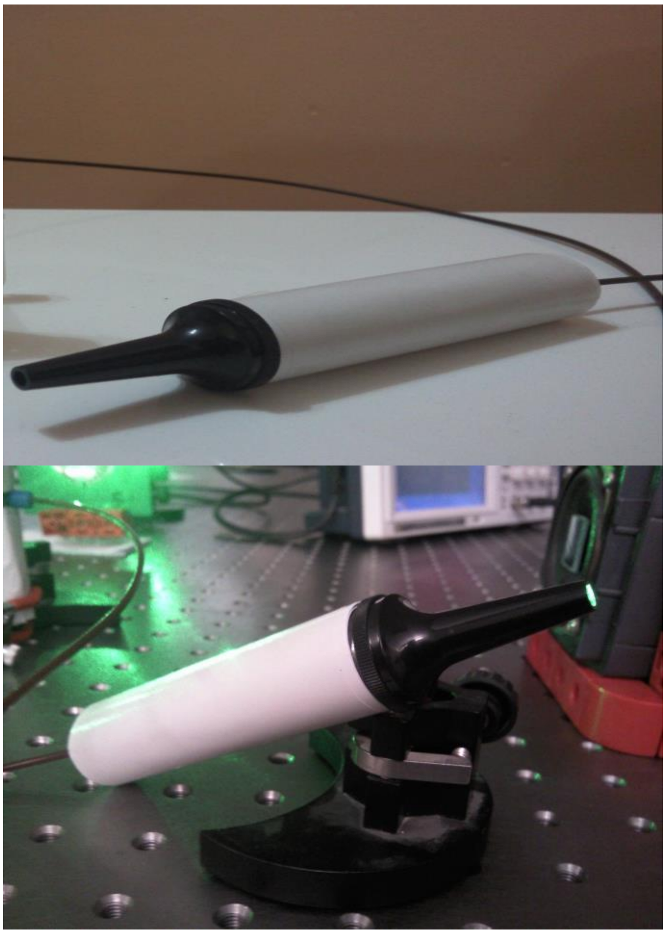


Fig. 3: A photographs illustrates the fiber optics positioned into the ear speculum used in this study.

Fig. 4: The ear speculum was positioned into rabbit's external ear and focusing on the eardrum to ensure the incident of the laser beam on the drum membrane.

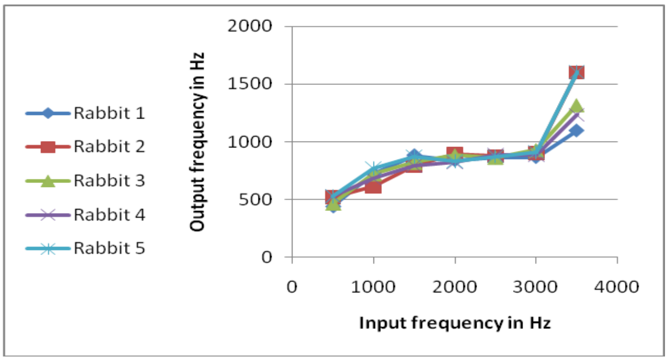
IV. Acoustic Waves Source

The acoustic stimulus source was 5cm loudspeaker drum diameter positioned at 15cm away from the rabbit. The loudspeaker as shown in figure (1) was connected to a variable voltages and frequencies function generator which was used to drive the loudspeaker by a sinusoidal voltage at frequencies ranged from 500 to 3500Hz, and amplitudes from 3 to 7V.

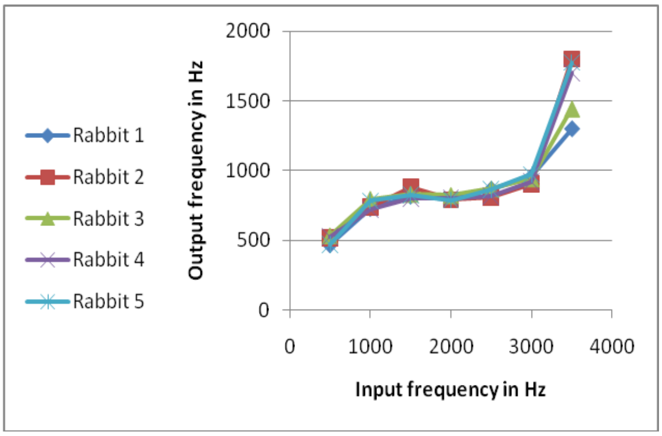
V. RESULTS

Each measurement of eardrum response in frequency and intensity was repeated three times then the average readings were considered for each rabbit. The data was gathered different input acoustic frequencies and amplitudes. The results was saved in a storage oscilloscope.

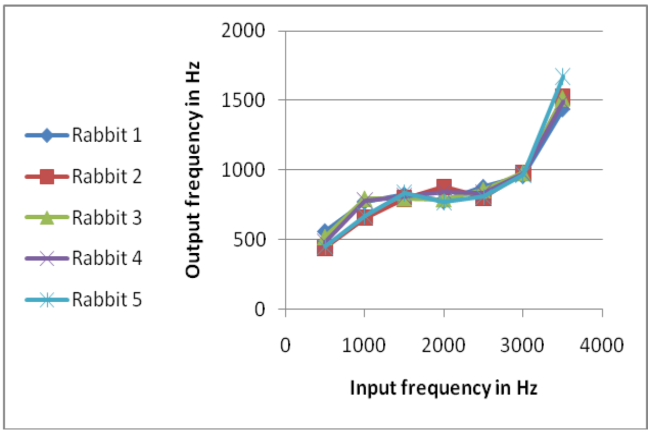
The vibration response characteristics of each rabbit'seardrum membrane in frequency and amplitude are shown in figures (5) and (6). The results seem to be very close to each other in general especially for frequencies up to 3 KHz.



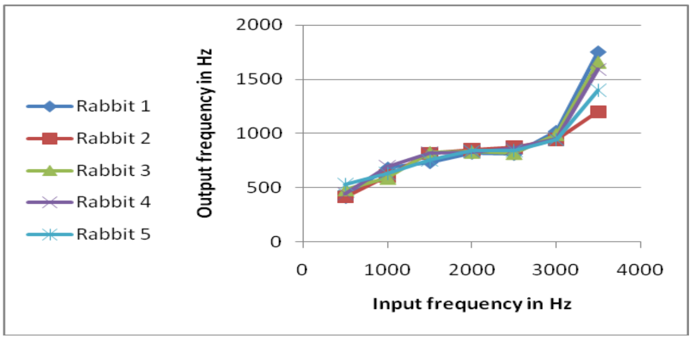
(a) Rabbits right eardrum measurements at 3V input amplitude.



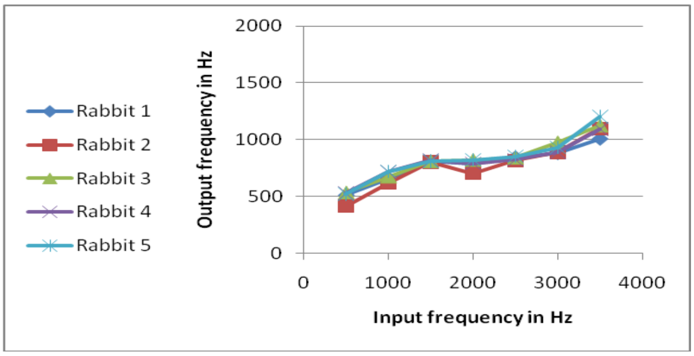
(b) Rabbits right eardrum measurements at 4V input amplitude.



(c) Rabbits right eardrum measurements at 5V input amplitude.



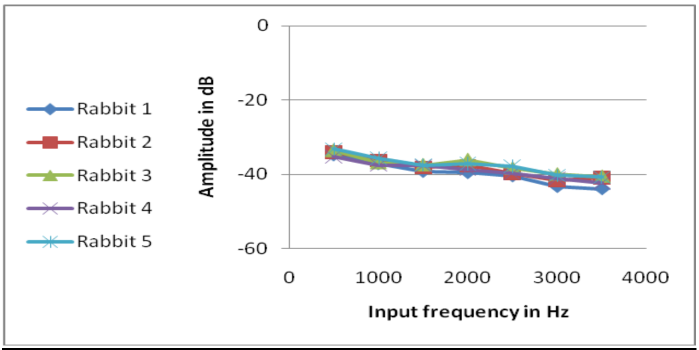
(d) Rabbits right eardrum measurements at 6V input amplitude.



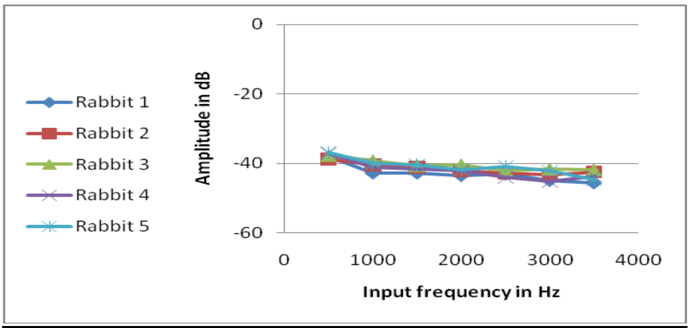
(e) Rabbits right eardrum measurements at 7V input amplitude.

Fig. 5: Frequency characteristics of the rabbits eardrums vibration response to acoustic stimuli. (a) at 3V input amplitude. (b) at 4V input amplitude. (c) at 5V input amplitude. (d) at 6V input amplitude. (e) at 7V input amplitude.

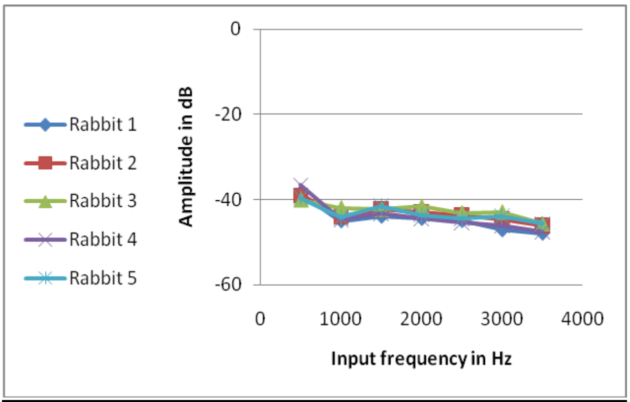
The amplitudes of these vibrations in dB for different input sound waves frequencies are seen in figure (6). Different input amplitudes of the sound waves were used.



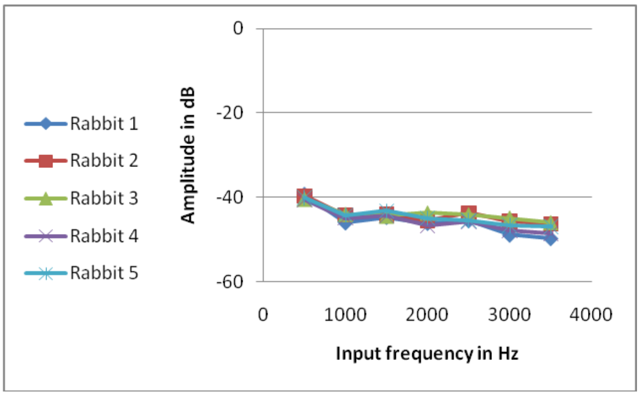
(a) Rabbits right eardrum measurements at 3V input amplitude.



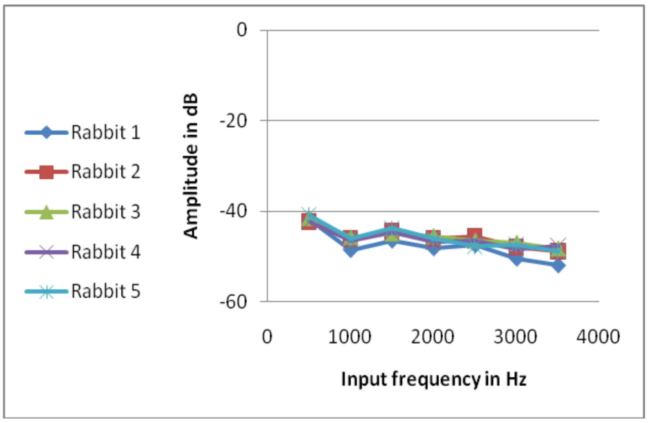
(b) Rabbits right eardrum measurements at 4V input amplitude.



(c) Rabbits right eardrum measurements at 5V input amplitude.



(d) Rabbits right eardrum measurements at 6V input amplitude.



(e) Rabbits right eardrum measurements at 7V input amplitude.

Fig. 6: Amplitude characteristics in (dB) of the rabbits eardrums vibration response to acoustic stimuli. (a) at 3V input amplitude. (b) at 4V input amplitude. (c) at 5V input amplitude. (d) at 6V input amplitude. (e) at 7V input amplitude.

DISCUSSION

Figures (5) and (6) showed how the rabbit eardrum vibrated in response to the acoustic stimuli. The vibration frequency patterns of their eardrums showed linear characteristics according to the frequencies of the input acoustic waves. Less changes in the frequency response appear within the range of 1500Hz input frequencies.

The displacement amplitudes or intensities of the vibrations decrease as the sound waves frequency increased, suggesting that the eardrum mass terms become less significant at these frequencies which will lead to decrease in the membrane displacement.

CONCLUSIONS

The spectral response of live rabbits eardrum vibrations in the presence of different sound waves was achieved by using the non – invasive laser interferometer measurements.

It is an effective method for correct measurement of the eardrum vibrations since it does not loading the eardrum mechanically.

The results showed the characteristics and the spectral response of live normal and healthy rabbits, which can be used as a tool to study the hearing problems and lesions diagnosis of the eardrums.

Middle – ear mechanism is remarkably similar among mammals [7]. The selection of the rabbits eardrum for experiments was based on its similarity to human middle ear anatomy [8]. This encourages us to suggest that the human eardrum response behavior will be also looks like the behavior of the rabbit eardrum.

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