Doppler Effect Made Compressible Using Mechatronics

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I. **Introduction**:

Our project aims to make it easier for our middle school and high school students to comprehend how Doppler Effect works. Our project will help concretize the concept of Doppler Effect to our students who are studying astronomy in earth science and sound and light in physics. This concept has been very obscure to most students to visualize without the aid of machines such as the one we have just finished built. It is our aim to be contagious to other teachers in our school to learn the concept of robotics and possibly become the beneficiary to this wonderful program in the summers to come. My partner, teachers from other school, and I had a secular sense of what robots are before the first three lectures. Our misconceptions were quickly vanished after Dr. Kapila and his logistic crew scholastically programmed our intellect to sense what a robot was. We have experienced a wave of emotions about this program from feeling scared which Dr. Noel warned us not to be to being over zealous about robotics. We are forever indoctrinated that science can be much more fun if robots are in use in the classroom. Let the non-initiated be envious of our good fortune of being illuminated in the discipline of mechatronics.

II. Background:

Doppler effect phenomenon is named after an Austrian mathematician and physicist Johann Christian Andreas Doppler (1803-1853), he observed that a frequency of a wave such as of sound changes when the source and the observer are in motion relative to each other, with an increasing frequency if the source and the observer approach each other and decreasing when they move apart. The motion of the source causes a real shift in frequency of the wave, while the motion of the observer produces only an apparent shift in frequency which can also be called as Doppler shift.

If the moving source is emitting waves through a medium with an actual frequency f_0, then an observer stationary relative to the medium detects waves with a frequency f given by:

$$f = f_0\left(\frac{v}{v + v_{s,r}}\right)$$ which can be written as:

$$f = f_0\left(1 - \frac{v_{s,r}}{v + v_{s,r}}\right)$$

where v is the speed of sound in this instance, r is the speed of the source with respect to the medium (positive if moving away from the observer, negative if moving towards the observer), radial to the observer. However, with a relatively slow moving source, $v_{s,r}$ is small in comparison to v and the equation approximated to:

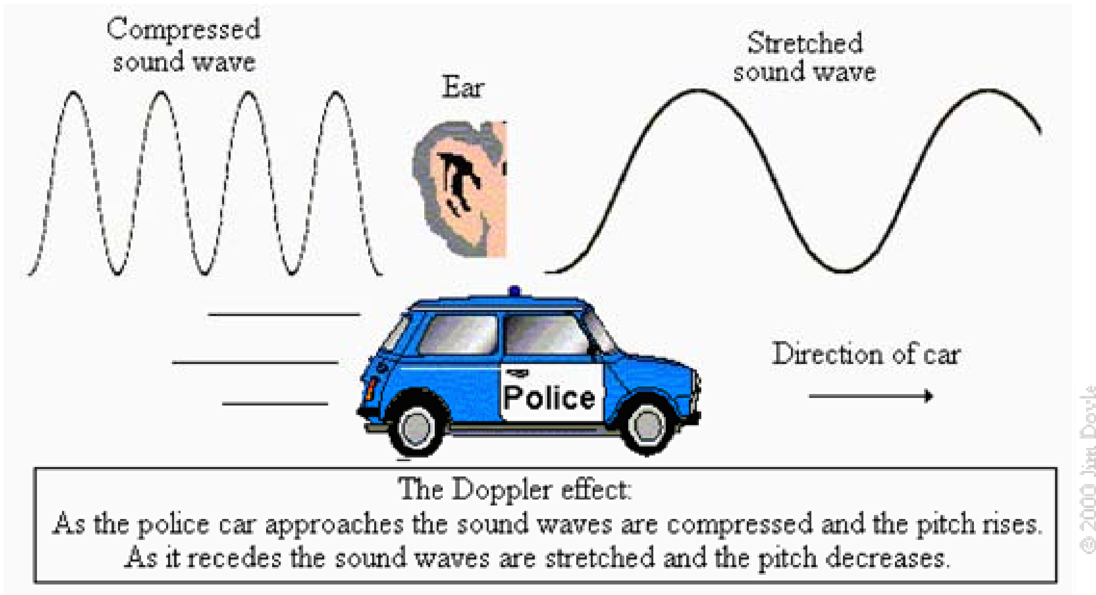
$$f = f_0\left(1 - \frac{v_{s,r}}{v}\right)$$

A similar analysis for a moving observer and a stationary source yields the observed frequency (the observer's velocity being represented as v_0):

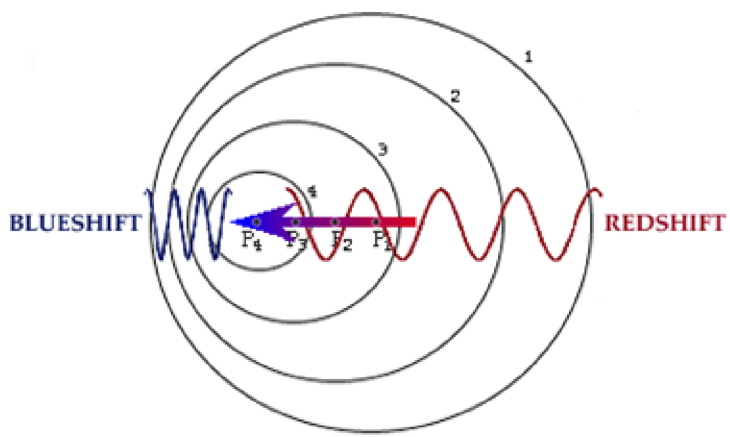
$$f = f_0\left(1 - \frac{v_0}{v}\right)$$

If v_0 is positive, the observer is moving away from the source, and negative if the observer is moving towards the source.

The high pitch sound of a siren of an approaching ambulance which drops suddenly as the ambulance passes you is a great example of the application of Doppler Effect. This change of pitch results from a shift in the frequency of the sound waves, as illustrated in the picture below.

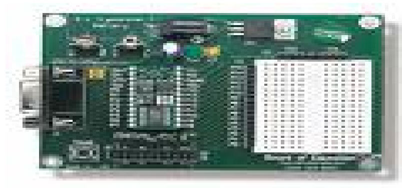


Another example is the phenomenon observed by astronomers who notice that galaxies that are receding from earth exhibit a red shift, since red light is the lowest frequency electromagnetic wave in the visible spectrum and violet the highest frequency electromagnetic wave which suggests that the light emitted by the galaxies would vary from violet to red signifying a decrease in frequency as illustrated below in the diagram.



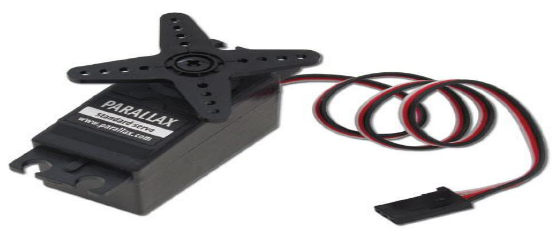
Equipment list:

1. Board of Education



2. Boe-bot

3. Servo – motors



4. Ultrasonic sensor

5. Parallax LCD

6. Resistors

7. LED’s

8. Jumping wires

9. Metal barrier

V. Experimental Procedure:

First, we assembled the Boe-bot's chassis and mounted the servos on it as shown below.

Secondly, we programmed the servo motors by following the circuit diagram below.

Thirdly, we calibrated the servo motors using the Pbasic and this program below

' Robotics with the Boe-Bot – CenterServoP12.bs2

' This program sends 1.5 ms pulses to the servo connected to

' P12 for manual centering.

Next, we added the ultrasonic sensor as shown below on the circuit that already has the electronic for the servomotors. Then we ran a program such as the one below to make sure that it is functioning.

Next the program is modified so the distance of the object to the ultra sonic sensor is measured.

Next we connected the Parallax LCD to board of education so that we disconnect the board from the computer, values can be read.   After the connection was carefully made, we ran the program below to make sure that the led is working properly.

VI. Results:
The results of our project prove to be in alignment with what we have expected, that is our hypothesis about the Doppler shift of frequencies. However, things were not going to well at first since it we had difficulty seeing a frequency shift which was hidden due to the fact that the Basic Stamp can not display non integer numbers. We had to use floatation of computation to instruct the computer to show the other digits of the frequency prime. After the necessary adjustments were made, we finally observed that the frequency emitted has shifted to a higher frequency as the robot with the ultrasonic sensor moving toward the stationary cart, which is the observer. On the other hand, when the ultrasonic sensor was moving away from the stationary observer, the frequency decreased. We programmed the Basic Stamp to measure the frequency observed by the stationary observer for two instances illustrated in the table below:

Table-1 this table shows the relationship between the shifted frequencies observed by a stationary observer while the source is moving toward the stationary observer.

Table-2 this table shows the relationship between the shifted frequencies observed by a stationary observer while the source is moving away from a stationary observer.

VII. Future Works:
Our project is ready to be used in the classroom. Its use will mostly be when we discuss sound and light waves in physics, and astronomy is taught. Presently, the machine is programmed to measure the shifted frequency when the source is moving toward and away from the stationary observer. We intend to upgrade the program so frequencies can be measured in the following instances: 1) both the source and the observer are moving away from each other. 2) Both the source and the observer are moving towards each other. 3) When a moving observer is moving toward a stationary source. 4) When both the observer and the source are standing still. In addition, we intend to demonstrate this project to the teachers during our departmental conference hoping that we can obtain funds to buy more expensive sensors which implies sensors with more accuracy. The design of this machine will be adjusted so that we can use it as a radar gun for track, football, and soccer field. The entire circuit will be inserted in a gun shaped plastic container with a switch on the outside. Since the concept of building such a machine is mastered, each one of us thinks that we can design the same machine on a higher scale by including a frequency sensor with great range such as 10 km so that the machine will be able to detect siren 5 to 10 blocks from the school. We are

also thinking a DC motors could be used instead of the servo motors which are considerable slower than the DC motors. Toy cars will be used instead the boo-bot .In addition, we will use various barriers such as cardboard, wood, foam, or rubber.

VII: References:

www.parallax.com
http://www.mechatronics.poly.edu/smart
http://www.google.com/search?hl=en&q=doppler+effect+definition
http://archive.ncsa.uiuc.edu/Cyberia/Bima/doppler.html
http://images.google.com/imgres?imgurl=http://www.physicsclassroom.com/

Acknowledgement

Thanks to Dr Kapila and Dr Noel for designing such a program which will certainly benefit our students. Our gratitudes are extended as well to Lady Padmini, and the following gentlemen that stood by us through the bad times and good times. Without them, none of the projects would have been a success. They are Nathan, Shing, Billy, Ashuman, Keith, Jared, and Valentine.