Effective Doppler experiments

In Bulletin 234, we published an article called *Higher Pitched* [1] about using the freeware sound handling package *Audacity* to demonstrate the Doppler Effect. It is a measure of the rapidity of change in the world of ICT that only two years later, we have a new method that is so much better it makes our previous efforts look almost embarrassing.

The latest method makes use of a piece of software called a frequency spectrum analyser. A screenshot from one is shown in Figure 1.

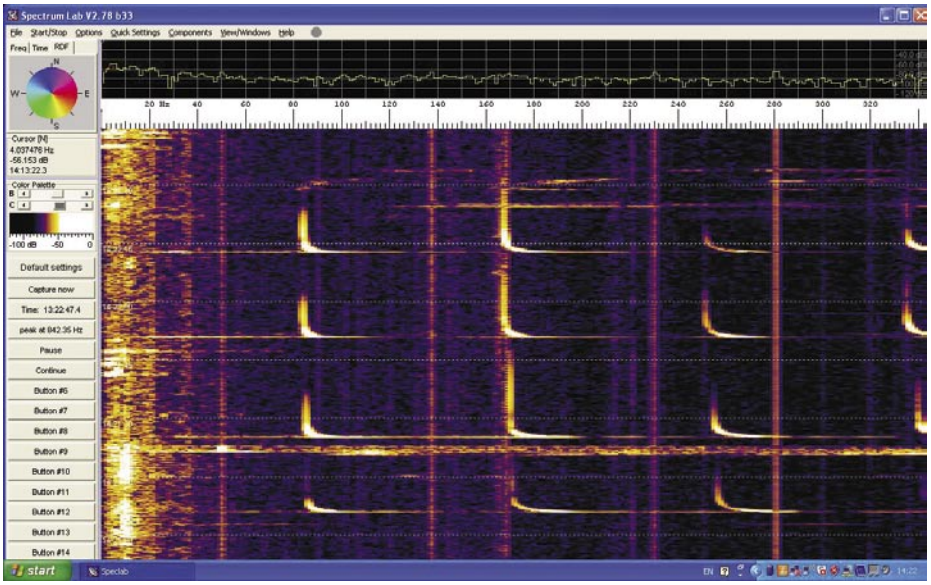

Figure 1 *- Frequency spectrum analyser.*

Referring to the main part of the screen, we see time on the vertical scale and frequency on the horizontal. The plot is of the sound from a sonometer wire that has been repeatedly plucked. We see a fundamental frequency of around 80 Hz and some harmonics at integer multiples of that value. The colour of the trace gives an indication of the amplitude of the sound though this can be determined more precisely by moving the cursor to the appropriate position.

Suitable free packages are Spectrumlab [2] for the PC and Baudline [3] for the Macintosh and Linux platforms. Apps are available for iOS and Android, but we found we had to pay a modest amount to get versions that allowed the user to zoom in on a narrow range of frequencies.

Figure 2 *- Smartphone signal generator app.*

We need a source of sound, preferably a reasonably pure tone. You could use a high frequency buzzer or Doppler Ball (see reference [1]) but we chose to install a free signal generator app on a smartphone. A number are available. We used one from Media Punk Studios (Figure 2).

This was our method:

- Set the spectrum analyser running, zoomed in to the frequency we had chosen to use.
- Move to a position some distance from the analyser.
- Switch on the signal generator. We chose a frequency of 5 kHz, because the larger the frequency, the greater the absolute frequency shift for a given speed.
- Check that the sound is being picked up by the analyser.
- Walk or run towards the analyser.

If we were doing this activity with a class, we would of course first demonstrate the frequency spectrum analyser, showing the effect on the display of varying the source frequency.

Figure 3 shows the results of one of our runs.

We see a steady vertical line towards the bottom of the picture. This represents the tone of 5 kHz being generated when stationary. As the person holding the signal generator walks briskly towards the analyser, the frequency is shifted upwards by around 30 Hz. Students can see this happening in real time. Should the sound source continue to move after reaching the analyser, the frequency will be shifted to a value lower than 5 kHz. Note that we do not yet know whether the ghostly purple lines to the right of the main trace are an artefact of the signal generator or analyser. However, we think that we do have a valid explanation for the faint apparent reflection of the main trace and we invite you to contact us with your own thoughts. You may also like to calculate the speed at which our tester walked through the SSERC lab.

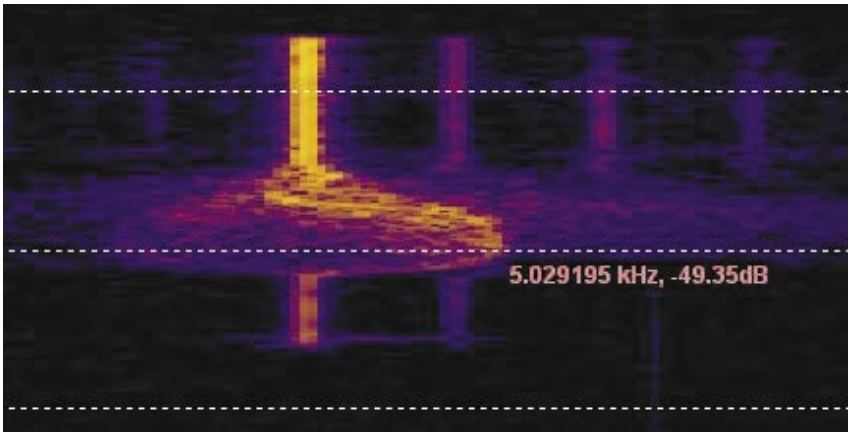

Figure 3 *- Doppler shift from moving signal generator.*

Figure 4 shows an alternative version of the experiment, where delegates at the 2013 IoP / SSERC Physics Teacher Summer School monitor the frequency from a signal generator carried by a cyclist, on their netbook computers. As there are analysers that run on small, portable devices, "moving observer" experiments are easy to do. We found that it was possible to see small Doppler shifts when the smartphone was gently wobbled in the hand, making it possible to model one method of exoplanet detection.

Can you trust an app?

According to developers, your smartphone can be a light meter, Geiger counter, signal generator, seismometer or frequency spectrum analyser. We have come across some applications that only "sort of" work. They do what light meters do, for example, but not very well. In the case of the signal generator app and PC freeware mentioned above, if all they did was to show qualitatively the Doppler Effect in action, that would be good enough. However, at SSERC we have calibrated test equipment and we are satisfied that the software we have used for this experiment is accurate enough for quantitative work in a Higher or Advanced Higher class.

Now imagine a galaxy of pupils all with smartphones generating a spectrum of different tones. Get them to recede from your analyser, and watch the red shift happen before your eyes.

Figure 4 *- SSERC person on a daft wee bike.*

References

[1] http://www.sserc.org.uk/images/Bulletins/234/Higher_Pitched-Doppler_Ball.pdf

[2] http://www.qsl.net/dl4yhf/spectra1.html (accessed June 2013). Note that we accidentally installed this on a memory card rather than the C: drive of our computer, and then accidentally discovered that it could run from the card on different machines without having to be installed specifically on them. Two helpful accidents.

[3] http://www.baudline.com/ (accessed June 2013). Not the slickest interface in the world, but it does the job. Just don't, under any circumstances, right-click.